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Institution Vision: To emerge as one of the finest technical institutions of higher learning to develop engineering professionals who are technically competent, ethical and environment friendly for betterment of society.

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Institution Mission: Accomplish stimulating learning environment through high quality academic instruction, innovation and industry institute interface

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Summary of Faculty Paper Publications for the Academic year 2018-2019

Journal/Conference	Scopus Indexed	Peer reviewed
No. of papers published in International Journal	05	6
No. of papers published in International Conference	08	01
Total	13	7
Total Publication Count		20

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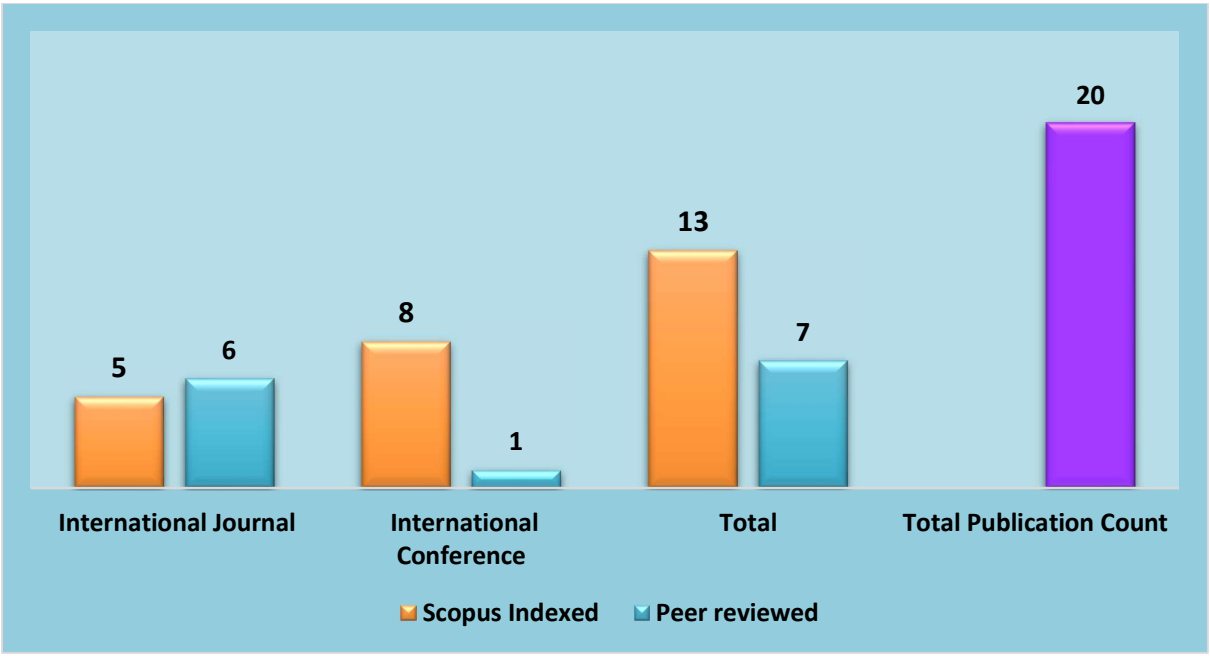

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3.	Design of Multiband Antenna for Wi-Max and WLAN Applications Using DGS"	Banuprakash.R, GSPN Amith , Gagana. N, Ravi AG, Pavanashree. C,	International Journal of Engineering &Technology, Vol 7 (3.12) (2018) pp140-143
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6.	A miniaturized dual band microstrip antenna for Worldwide interoperability microwave access and C band radio navigation"	Banuprakash R, Chetana C, Lekhya Sindhura, Madhushree M, Mahima Rajendra	IEEE International Conference on Advanced Information and Technology-ICAIT-2019, AIT Chikmagalur, from 25th-27th July 2019.
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INTERNATIONAL CONFERENCE

SL NO.	PAPER TITLE	AUTHOR'S NAME	Name of the Conference / Journal ,Number, Year of Publication
1	Multifunctional Robot	Thejaswini S, Soundarya V, Lavanya M, Chandana B, Sadam Hussain Kazimi	International Conference on applied Engineering Sciences and Management (ICAEM-2018) , K S School of Engineering and Management, Bengaluru, 12th and 13th October 2018
2	A survey on Bandwidth Allocation Schemes In WSNs Using Priority Based Mac Protocol	Sowmyashree.M.S, C S Mala	3rd IEEE International Conference on Electrical, Electronics, Communication, Computer and Optimization Techniques (ICEECCOT- 2018), in association with IEEE Bangalore section organized by GSSS Institute Engineering & Technology for Women, Mysuru on14th -15th December 2018
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Edited by

Dr. Thejaswini S
Assistant Professor
Dept. of ETE
BMSIT&M

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Analysis of EEG Based Emotion Detection of DEAP and SEED-IV Databases using SVM

Thejaswini S, K M Ravikumar, Jhenkar L, Aditya Natraj, Abhay K K

Abstract: ***The Affective computing is one of the fast-growing areas which has inspired research in the field of emotion detection for many applications. This paper briefs out the related work on EEG based emotion detection using publicly available data and a proposed method to detect inner emotion-states. A supervised machine learning algorithm is developed to recognize human inner emotion states in two-dimensional model. The electroencephalography signals from DEAP and SEED-IV database are considered for emotion detection. Discrete Wavelet Transforms are applied on preprocessed signals to extract the desired 5 frequency bands. Some features like Power, energy, differential entropy and time domain are extracted. Channel wise SVM classifier is developed and channel combiner is done to detect the appropriate emotion state. The classification rate for four classes are 74%, 86% ,72% & 84% for DEAP database and 79%, 76%,77% & 74% for SEED-IV database.***

Index Terms: BCI, DEAP, DWT, EEG, SEED-IV, SVM.

I. INTRODUCTION

Brain computer Interface is an emerging research field since past few years. BCI systems involves in analysis of Electro-Encephalogram signals from brain. The concept of BCI began as assisting individuals with physical and physiological disorders over a decade. [1][2] Now the research in BCI has extended in various fields including normal people. Some of such applications are classification of abnormal brain activity, epilepsy detection, emotion detection etc. Emotion detection is one among the growing areas in the field of affective-computing in which the interaction between machines and individuals can be improved through the change in individual's inner states. [3] This motivated many researchers to develop real time emotion detection for clinical, entertainment, marketing etc. [4]

Emotions have a major effect on the social skills of a person and their perception of the world. Human emotion can be detected by a plethora of factors like expressions, speech and physiological signals. In [5], emotion detection using EEG signals is advantageous than other methods.

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Mrs. Thejaswini S, Assistant Professor,Department of Telecommunication Engineering,B M S Institute of Technology and Management,engaluru, Karnataka, India.

Dr. K M Ravikumar, Principal and Professor Department of Electronics & Communication, Engineering, S J C Institute of Technology

Jhenkar L Student Department of Telecommunication Engineering,B M S Institute of Technology and Management, Bengaluru, Karnataka, India

Abhay K K, Student, Department of Telecommunication Engineering,B M S Institute of Technology and Management, Bengaluru,

EEG tracks and records electrical impulses of the neurons in the brain. EEG was primarily used for medical diagnosis but since the introduction of more portable and cost-effective BCI headsets, the possibility of application in the entertainment industry has increased. Emotion states are interpreted through dimensional model as shown in Fig-1 as well as discrete model. In dimensional model, the discrete basic emotion states are spatially represented across valance and arousal.

In this paper, a review on emotion detection using EEG-signals data sets available online is carried out and a method is proposed on two databases. In the proposed system, a machine learning algorithm is developed to identify emotion states based on dimensional model for the available database. Time domain features, wavelet features and entropy features are identified and classified using SVM classifier. This paper is organized as stated below: Introduction of BCI, emotion detection is described in section I. In section II, literature review of similar work is discussed. Methodology, results and discussion are elaborated in section III and IVand conclusion in section V.

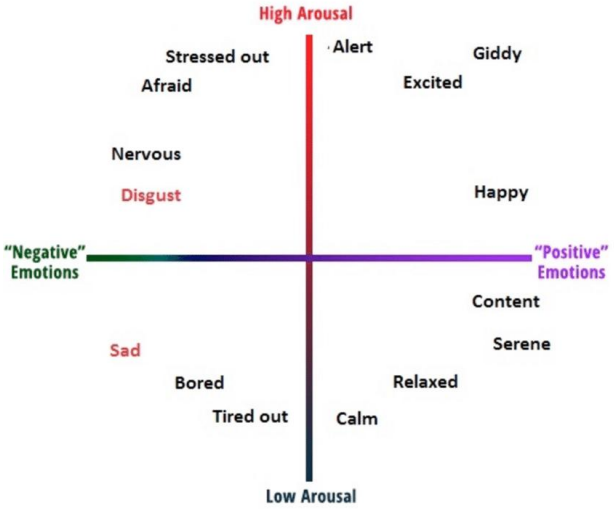

Fig 1: Dimensional model

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II. LITERATURE REVIEW

The following authors used DEAP Data-set for analyzing emotion states. Hongpei et al. [6], explains the effect of detecting emotion states accuracy of brain signal with different bands of frequencies and number of channels.

The classifier used is the K-nearest neighbor Classifier. Better accuracy of about 95% is obtained in gamma frequency bands and accuracy was increased when number of channels were increased from 10,18, 18 and 32. Zamanian et al. [7], extracted Gabor and IMF along with time-domain features and using multiclass SVM as classifier, they obtained an accuracy of 93% for 3 and 7 channels. Chao et al. [8] explored deep learning framework achieving a rate of 75.92% for arousal and 76.83% for valence states. Liu et al. [9], classified the data using time and frequency domain features and obtained 70.3% and 72.6%, using SVM. Mohammadi et al. [10], used Entropy and energy of each frequency band to classify using KNN and achieved an accuracy of 84.05 % for arousal and 86.75 % for valence. Xian et al. [11] used MCF with accuracy of 83.78 % and 80.72% for valence and arousal respectively with statistical, frequency and nonlinear dynamic features. Alhagry et al. [12] proposed a LSTM Recurrent Neural Network and the average accuracy for arousal, valence, and liking classes was 85.65%, 85.45%, and 87.99%. Maria et al. [13] investigated power features based on Russell's Circumplex Model and applied to SVM with performance of 88.4% for Valence and 74% for Arousal.

Singh et al. [14] used SVM classifier to classify emotions into four quadrants through ERP and latency features. The accuracy rate was 62.5% to 83.3% for single trail and for multi subject trails, they obtained 55% classification rate for 24 subjects. Ang et al. [15] proposed an algorithm using wavelet transform and time-frequency features with ANN classifier. A classification rate of 81.8% for mean and 72.7% standard deviation y for happy emotion was obtained. For sad emotions, performance of frequency domain features was 72.7%. Krishna et al. [16] used Tunable-Q wavelet transform to get sub-bands of EEG signals which is acquired from 24 electrodes by watching 30 video clips. They obtained higher classification accuracy of 84.79%.

From the survey it is seen that researchers have developed many ML algorithms using different features and have obtained an accuracy of 74 to 90 %. In this proposed method, a machine learning algorithm is developed to classify the emotion states in to 4 classes using channel fusion method for data available from DEAP and SEED-IV data base separately.

III. METHODOLOGY

It is observed from the survey that the models developed for detecting emotion states are preferably supervised algorithms. The preprocessed SEED-IV and DEAP data are analyzed using different features in frequency and time domain. A supervised machine learning model is developed to identify the emotion states into 4 classes. The proposed method is shown in Fig-2.

A. Data Acquisition

The first and one of the most important things to start is with data acquisition. The EEG signals are obtained by use of very high-performance systems at various sampling rate based on the capacity of the system used. The sampling rate of the device used must be more than 150hz as the EEG signals range from 5hz to 70hz. To analyze emotion states using EEG signals, the data from 2 different online available databases namely DEEP and SEED-IV are used.

In DEAP database [17], the brain signals for 32 subjects is acquired from a 32-channel EEG device at a sampling rate of 500hz, by showing 40 video trails of each 1 min duration to all subjects. Two different devices namely Twente and Geneva were used for data acquisition. The data which is available online is pre-labelled based on the emotion wheel. The protocol followed for the process of data acquisition is shown in Fig-3.

In SEED-IV database, EEG data is acquired from a 64-channel device by showing 2 mins videos for 15 subjects at a sampling rate of 1000hz.For each subject 3 sessions were performed on different days.So, it makes a total of 45 subjects.

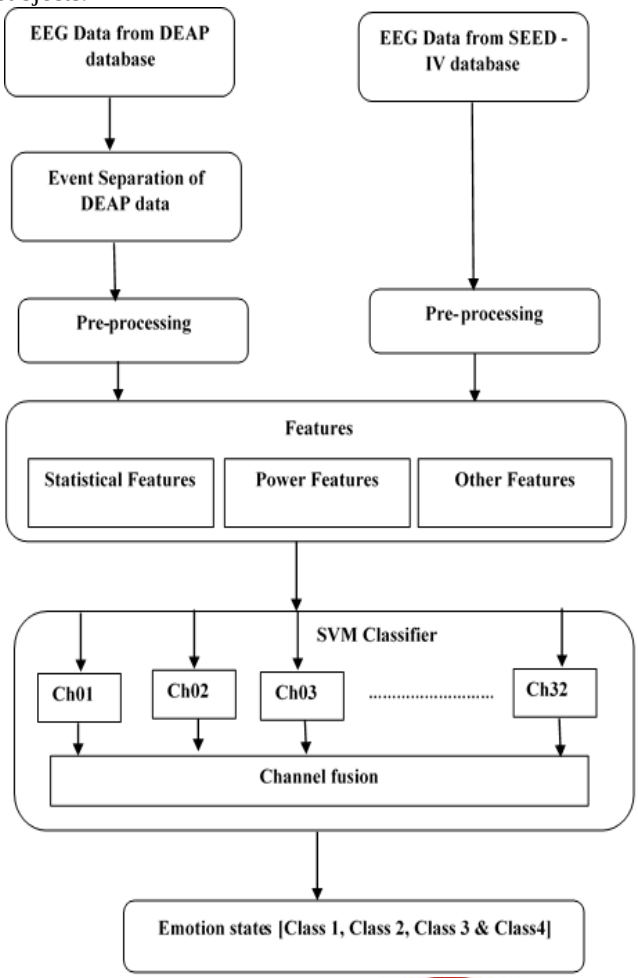

Fig 2: Proposed Methodology

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B. Event Separation

The duration of events varies based on the length of the video shown and the number of events in a trial depends on the number of videos shown in each trial during data acquisition. The duration of each event and number of events per trial could be different in different databases based on the protocol followed for data acquisition. The raw data obtained by DEAP database is converted to mat files after separating each event from the continuous data, based on the protocol followed during the data acquisition. The data obtained from SEED-IV are mat files which has events pre-separated based on the protocol followed. The same channels were considered for both the databases.

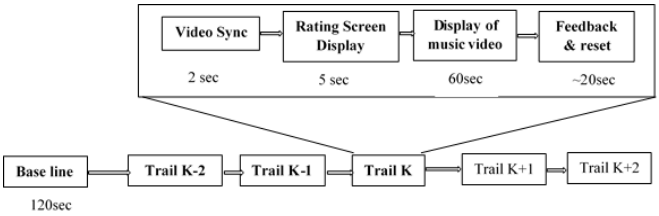

Fig 3: DEAP data protocol

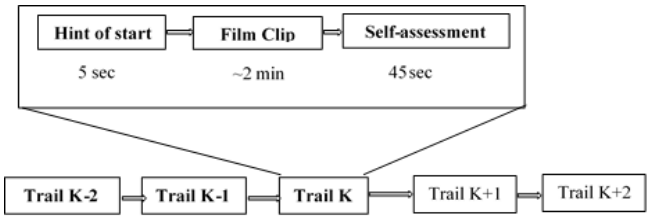

Fig 4: SEED-IV data protocol

C. Pre-Processing

For pre-processing the raw EEG signals, the signals are passed through 3 different filters removing different types of artifacts from the raw signals at each filter. First the signals are passed through 50hz/60hz notch filter to remove the line frequency artifacts added into the raw data during data acquisition. As we use 50hz, 230V AC power supply, we used a 50hz notch filter. Before analysis the data is converted from fixed or common reference to average reference since the electrodes are spread across the scalp, moving average re-referencing method is used to re-reference the data. The signals are then given to a 1-D 10^{th} order median filter. This removes the impulsive noises present in the data. Hence, a smooth signal is obtained without spikes or impulsive noises present in it. This filter is implemented using "medfilt" function in MATLAB. Finally, the signals are passed through a band pass filter. A bandpass filter of order 20, with lower and upper cut-off frequencies 0.1 and 60 respectively is implemented using "filtfilt" function in MATLAB. This filter band limits the acquired signal's frequencies in the EEG signal range.

D. Feature extraction

It is the process of extracting meaningful features out of the pre-processed data to implement robust classification. There are many features that can be extracted from an EEG signal. The two-main category of features that can be extracted are in time domain, frequency domain [18] [19],the features used in this paper for analyzing EEG signals are given below in Table-1. 8-level DWT decomposition "db8" is carried out on the pre-processed signal to obtain 5 frequency bands: delta (1-3Hz), theta (4-7Hz), alpha (8-13 Hz), beta (14-30Hz), gamma (31-60Hz) [20]. For both the databases, channel wise feature vector is computed for each channel and stored, in-order to feed them respectively to the 32 channel wise classifiers used.

E. Classification

Support Vector Machine (SVM) is used to classify the emotions into 4 classes based on the extracted features. SVM is a supervised machine learning algorithm. The features extracted are given to SVM classifier. In each database, 70% of the data is used for training, the remaining 30% is used for testing. Labelled training data is given as the input to the algorithm, the output obtained is an optimized hyperplane which is used to categorize new examples. The SVM algorithm used has various parameters like regularization, gamma and kernel etc., by choosing the correct parameters based on the nature of available data we have achieved considerable nonlinear classification. In this paper, 32 classifiers, one for each channel, is developed to classify the emotions into four states. To predict the final emotion state, a channel fusion method is employed. The SVM algorithm is implemented in python. Separate SVM classifier is developed for both databases.

Table 1: Extracted Features

Feature Type	Feature Name
Time domain (Statistical Features)	Mean, Root mean square, Std-deviation, First difference, Normalized first difference, Second difference, Normalized second difference, Kurtosis, Skewness, Variance, Mobility and Complexity (Hjorth Parameters)
Wavelet or Frequency Domain features of 5 band	Band energy, Power spectral density, Differential entropy, Average band power
Other features	Hurst exponential and Permutation entropy

DEAP database has signals acquired from 32 subjects. Out of 32, the data of 22 subjects are used for training while the remaining 10 subjects' data are used for testing the trained model. The feature vector used for training each channel wise classifier is

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880*34 in size, which comprises the data of 34 features extracted from 40 events present in all 22 subjects' data.

SEED-IV database has down sampled data of 45 subjects. Out of the data of 45 subjects, the data of 32 subjects are considered for training while the remaining 13 subjects' data is used for testing. A 742*34 feature vector is fed to each channel wise classifier. The feature vector comprises the dataof 34 features extracted from 24 events present in all 32 subjects' data.

IV. RESULTS

In DEEP database, 22 subject's data are used for training. Each subject has 40 events and 34 extracted features, so 880*34 feature vector is fed to each of the 32-channel based SVM classifiers. In SEED-IV database, 32 subject's data are used for training. A feature vector of 742*34 is applied for each of the 32-channel based SVM classifiers. The trained network is tested on remaining 30% data for both the models. The training model is designed to predict 4 classes, class1: HAHV, class 2: HALV, class 3: LALV and Class 4: LAHV.

The classification accuracy for DEAP database is 74 %, 86%, 72% and 84% for class1, class 2, class 3 and Class 4 respectively.

The performance rate for SEED-IV database is 79%, 76%,77% and 74% for class 1, 2, 3, and 4 respectively. The overall performance of trained SVM model for both databases is shown in Table 2. The accuracy rate of the classifier is shown in Fig-5.

Table 2: Overall Performance

Class	SVM- Classifier performance	
	DEAP data	SEED-IV data
1. HAHV	74%	79%
2. HALV	86%	76%
3. LALV	72%	77%
4. LAHV	84%	74%

It was observed that among 34 features extracted, Hurst exponential, differential entropy and average power of all bands, and a few time domain features like kurtosis, RMS, skewness, second and first normalized difference were predominant for all the classes.

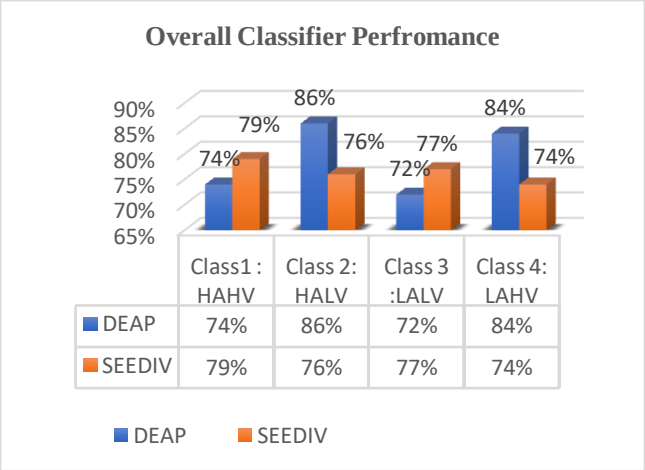

Figure 5: SVM Classifier performance for two databases

IV. CONCLUSION

In this paper, highlight on the work done for available databases like SEED-IV and DEAP were discussed. The Statistical features, frequency domain features, Hurst exponential and Permutation entropy were extracted for both the databases: SEED-IV and DEAP separately. Power features, Hurst exponential and a few time domain features played an important role in distinguishing the emotion states. The average performance of the SVM classifier is 79% and 76.5% for DEAP and SEED-IV database respectively. The overall classification rate for 4 emotion classes of DEAP database is 74%, 86%, 72%, 84% respectively and for the SEED-IV database it is 79%, 76%,77% and 74% respectively.

The channel fusion method employed with channel wise SVM classifier seems to perform better for DEAP data than for SEED-IV data. A model is developed to obtain the performance of the signals acquired.The same model developed can be used in future to compare performance of real time signals acquired [18] [20]. Further some more features can be added to increase the classifier rate. A robust model can be developed to classify inner emotions for different databases.

REFERENCES

1. Gary Garcia Molina, TsvetomiraTsoneva and Anton Nichol, "Emotional Brain- Computer Interfaces", IEEE, 2009.
2. MandeepKaur, Computer Sc. &Engg. Sharda University, Greater Noida, U.P., India "Technology Development for Unblessed People using BCI: A Survey", International Journal of Computer Applications (0975 – 8887) Volume 40, February 2012.
3. Al-Nafjan, Abeer, ManarHosny, Yousef Al-Ohali, and Areej Al-Wabil. "Review and Classification of Emotion Recognition Based on EEG Brain-Computer Interface System Research: A Systematic Review." Applied Sciences 7, no. 12 (2017): 1239.
4. Y. Liu, O. Sourina, and M. K. Nguyen, "Real-Time EEG-Based Human Emotion Recognition and Visualization," in International Conference on Cyberworlds (CW), 2010, pp. 262-269.Li M., Chai Q., Kaixiang T., Wahab A., Abut H. (2009) EEG Emotion Recognition System. In: Takeda K., Erdogan H., Hansen J.H.L., Abut H. (eds) In-Vehicle Corpus and Signal Processing for Driver Behavior. Springer, Boston, MA
5. Gary Garcia Molina, TsvetomiraTsoneva and Anton

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& Sciences Publication

Nichol, "Emotional Brain Computer Interfaces", in 3rd International Conference on Affective Computing and Intelligent Interaction and Workshops, 2009, pp.1-9
6. Li, Mi, HongpeiXu, Xingwang Liu, and Shengfu Lu. "Emotion recognition from multichannel EEG signals using K-nearest neighbor classification." Technology and Health Care Preprint (2018): 1-11.
7. Zamanian, Hanieh, and Hassan Farsi. "A New feature extraction method to Improve Emotion Detection Using EEG Signals." ELCVIA Electronic Letters on Computer Vision and Image Analysis 17, no. 1 (2018): 29-44.
8. Chao, Hao, HuilaiZhi, Liang Dong, and Yongli Liu. "Recognition of emotions using multichannel EEG data and DBN-GC-based ensemble deep learning framework." Computational intelligence and neuroscience 2018 (2018).
9. Liu, Jingxin, HongyingMeng, Maozhen Li, Fan Zhang, Rui Qin, and Asoke K. Nandi. "Emotion detection from EEG recordings based on supervised and unsupervised dimension reduction." Concurrency and Computation: Practice and Experience 30, no. 23 (2018)
10. Mohammadi, Zeynab, JavadFrounchi, and MahmoodAmiri. "Wavelet-based emotion recognition system using EEG signal." Neural Computing and Applications 28, no. 8 (2017): 1985-1990.
11. Li, Xian, Jian-Zhuo Yan, and Jian-Hui Chen. "Channel Division Based Multiple Classifiers Fusion for Emotion Recognition Using EEG signals." In ITM Web of Conferences, vol. 11, p. 07006. EDP Sciences, 2017.
12. Alhagry, Salma, AlyAlyFahmy, and Reda A. El-Khoribi "Emotion Recognition based on EEG using LSTM Recurrent Neural Network ", (IJACSA) International Journal of Advanced Computer Science and Applications, Vol. 8, No. 10, 2017, PP 355 – 358
13. Menezes, Maria LuizaRecena, A. Samara, L. Galway, A. Sant'Anna, AntanasVerikas, Fernando Alonso-Fernandez, H. Wang, and R. Bond. "Towards emotion recognition for virtual environments: an evaluation of eeg features on benchmark dataset." Personal and Ubiquitous Computing 21, no. 6 (2017): 1003-1013
14. Singh, Moon Inder, and Mandeep Singh. "Development of a real time emotion classifier based on evoked EEG." Biocybernetics and Biomedical Engineering 37, no. 3 (2017): 498-509.
15. Ang, Adrian Qi-Xiang, Yi Qi Yeong, and Wee Wee. "Emotion Classification from EEG Signals Using Time-Frequency-DWT Features and ANN." Journal of Computer and Communications 5, no. 03 (2017): 75.
16. Krishna, AnalaHari, AravapalliBhavya Sri, KurakulaYuvaVenkataSaiPriyanka, SachinTaran, and Varun Bajaj. "Emotion classification using EEG signals based on tunable-Q wavelet transform." IET Science, Measurement & Technology (2018).
17. Koelstra, Sander, Christian Muhl, Mohammad Soleymani, Jong-Seok Lee, AshkanYazdani, TouradjEbrahimi, Thierry Pun, Anton Nijholt, and IoannisPatras. "Deap: A database for emotion analysis; using physiological signals." IEEE transactions on affective computing 3, no. 1 (2012): 18-31.
18. ThejaswiniS , Dr. K M Ravi Kumar " Detection of human emotions using features based on discrete wavelet transforms of EEG signals" , International Journal of Engineering & Technology, 7(1.9) (2018) , PP : 119-122.
19. Thejaswini S., Ravi Kumar K.M., Rupali S., Abijith V. (2018) "EEG Based Emotion Recognition Using Wavelets and Neural Networks Classifier", In: Cognitive Science and Artificial Intelligence. Springer Briefs in Applied Sciences and Technology. Springer, Singapore, 23 December 2017. PP 101 -112.
20. Thejaswini S, Dr. K M Ravi Kumar, "A Novel Approach to Detect Inner Emotion States Using EEG Signals and Wavelet Transforms", 5th International Conference on communication and computer engineering ICOCOE 2018, 17th to 19th July 2018, SWISS GARDEN HOTEL, T2-4, The Shore @ Melaka River, JalanPersisiranBunga Raya, 75300 Malacca, Malaysia.

AUTHORS PROFILE

Mrs. ThejaswiniS, isworking as**Assistant Professor**,Department of Telecommunication Engineering,B M S Institute of Technology and Management,Bengaluru, Karnataka, India. She has completed her BE in E&CE and M.Tech in digital Communication and Networking. she is pursuing her Ph.D. in the area of Brain computer interface. She has more than 10 paperPublication in international Journals and Conferences. Her area of interest is BCI, Machine Learning and Signal Processing. She has a teaching experience of 15 years and research of 5 years.

Dr. K M Ravikumar, is working as **Principal** and ProfessorDepartment of Electronics & Communication, Engineering, S J C Institute of Technology, Chickballapur, Karnataka, India. He has obtained his Ph.D in the area of Digital signal processing. He a has around 22 years of teaching experience and more Than 10 years of research experience in the fields of speech processing, Brain Computer Interface, Image processing domains. He has more than 20 publications in peer reviewed Journals and more than 15 papers in International Conferences. Some of his achievements AreSpecial Officer, VTU-Regional, Expert Committee Member for National Board of Accreditation (NBA), New Delhi, Reviewer: Elsevier Editorial Systems, Member LIC (Local Inquiry Committee), VTU, Belgaum. He has received various awards and few are Bharat VidyaShiromani Award, Best Engineering College Principal of the year- 2016, RashtriyaVidyaGaurav Gold Medal Award etc

Jhenkar Lis Student in Department of Telecommunication Engineering,B M S Institute of Technology and Management,Bengaluru, Karnataka, Indiajhenkar2109@gmail.com

Aditya NatarajisStudentDepartment of Telecommunication Engineering,B M S Institute of Technology and Management,Bengaluru, Karnataka, Indiaaditya.n2011@gmail.com

Abhay K Kis StudentDepartment of Telecommunication Engineering,B M S Institute of Technology and Management,Bengaluru, Karnataka, Indiaabhay.karanam@gmail.com

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Research paper

A Compact Multi-band Rectangular Slot Microstrip Antenna for Wi-MAX, WLAN and X-band Applications

Banuprakash.R[1*], Hariprasad.S.A[2]

[1]Assistant professor, Department of TE, BMSIT&M, Bengaluru, India
[2]Director, School of Engineering and Technology, Jain University, Bengaluru, India
**Corresponding Author E-mail: [1]r.bhanuprakash@bmsit.in*

Abstract

In this paper a rectangular slotted rectangular patch tripple band antenna for wireless applications is presented. The antenna has dimension of about 25 x 20 x 1.6mm^3. The antenna operates at the frequencies 3.6 GHz, 5.8 GHz and 7.5 GHz with bandwidth of about 3.61%, 1.03% and 1.07% respectively. This antenna can be used for WIMAX (3.6GHz), WLAN (5.8GHz) and X-band(7.5GHz) applications. The stable radiation pattern, acceptable gain and good impedance matching are observed at obtained frequencies using HFSS tool.

Keywords: *Ttrippleband, slot. HFSS, WLAN, WiMAX*

1. Introduction

In recent years, multiband antenna has received significant attention in antenna design due to its operational characteristics[. The arrival of various wireless standards and protocols lead to the need to develop compact, lightweight antennas operating with multiple frequency bands [3]. Multiband antennas can operate at different frequencies for various wireless applications. A size reduction is needed to meet the specific requirement [1].Compared with conventional antennas, patch antennas are with small size, ease of integration in mobile and wireless communication [2]. miniaturization can be obtained using metamaterial loading, shorting walls [4-5]. To achieve multiple frequencies various techniques can be employed like slots on the patch, slots on the ground plane, a defective ground structure, etc. Although the radiation patterns are stable, however the antenna structures need careful optimization [6].

A. Contribution

In this research we have proposed a multiband slotted antenna for WIMAX, WLAN and X-band applications. The main contributions are as follows: The antenna consists of rectangular shaped slot on radiating patch. The designed antenna is compact with total volume of 800mm^3 (25 x 20 x 1.6mm^3) and patch are of 324mm^2 (18 x 18mm^2).

2. Antenna Design

The proposed antenna is designed using the following equations [7].

The length (L) is given by (1),

$$L = \frac{C}{2f_0\sqrt{\epsilon_{eff}}} - 0.824h\left[\frac{(\epsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\epsilon_{eff}-0.258)(\frac{W}{h}+0.8)}\right] \quad (1)$$

The width (W) is calculated by (2),

$$W = \frac{C}{2f_0\sqrt{\frac{\epsilon_r+1}{2}}} \quad (2)$$

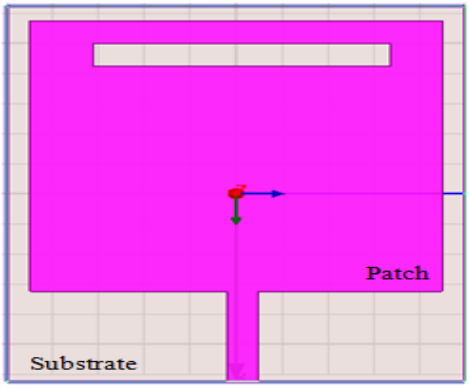


Fig. 1: Front View of the proposed antenna

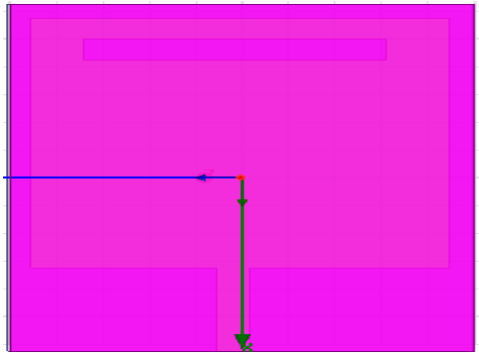


Fig. 2: Back View of the proposed antenna

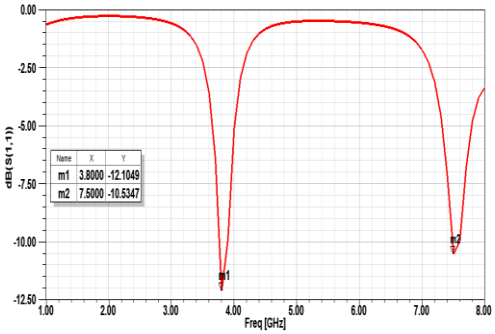


Fig. 2: Antenna and its return loss without slot

Micro strip feeding technique is employed to achieve less return loss and better impedance matching. The current distribution due to slot makes the antenna to operate at different frequencies like 3.6GHz (WIMAX), 5.8GHz (WLAN), 7.5GHz (X-band applications).

Table 1: Dimensions of the Antenna

Sl no.	Parameter	Value
1.	Dielectric constant	4.4
2.	Thickness	1.6mm
3.	Length of the ground(L_g)	25mm
4.	Width of the ground(W_g)	20mm
5.	Length of the patch(L)	18mm
6.	Width of the patch(W)	18mm
7.	Length of the feed(L_1)	6mm
8.	Width of the slot(W_1)	13mm
9.	Width of the feed (W_2)	1.25mm

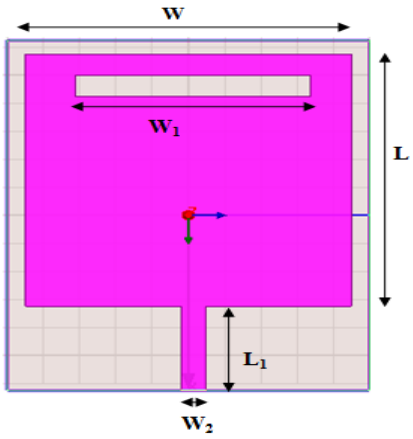


Fig. 4: a) Antenna with detailed dimensions layout

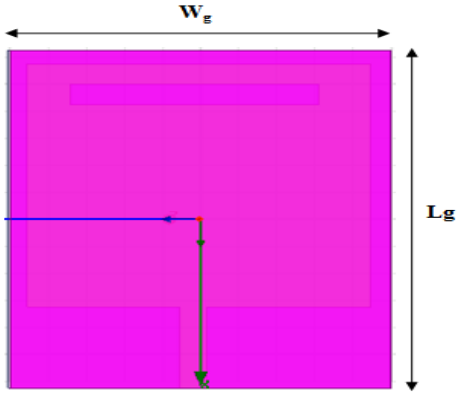


Fig. 4: b) Antenna with detailed dimensions layout

3. Analysis of the Antenna

To analyse the performance of the antenna, parametric studies are carried out. The analysis is carried out at those dimensions which have effect on antenna performance i.e, the analysis is done by varying a parameter while keeping the other constant.

A. Effect of Feed Width (W_2)

Analysis is carried out to analyse the effect of the feed width on the return loss of the antenna. The feed width (W_2) is varied in terms of 0.5 mm as shown in the figure (4 a).

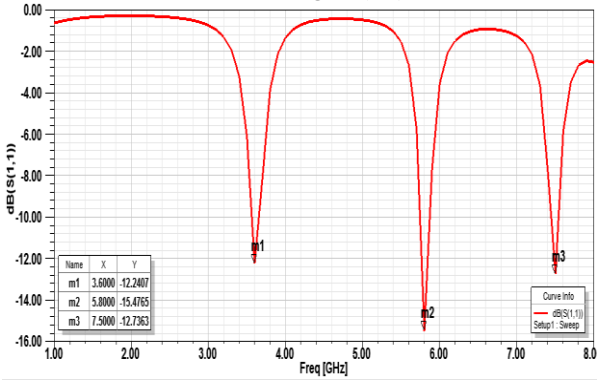


Fig. 5: a) Feed width (W_2)=1.5mm.

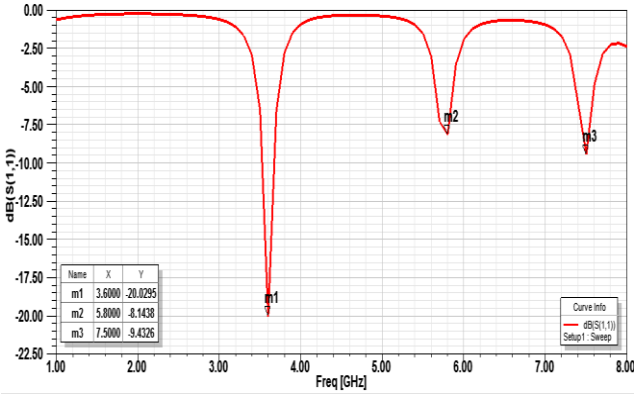


Fig. 5: b) Feed width (W_2)=1mm.

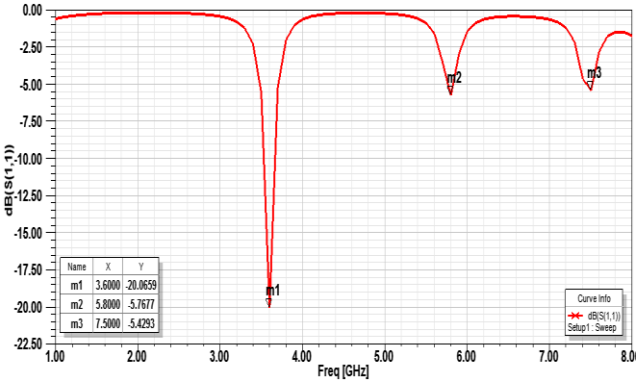


Fig. 5: c) Feed width (W_2)=0.5mm.

Further, to study the operation of the antenna the current distribution is analysed and depicted in the figure (6). At 3.6GHZ current is distributed near the sides of the square slot and on the feed. At 5.8GHz maximum current is distributed near the length of the slot and on the lower half of the feed. At 7.5GHz the current is distributed parallelly on the surface of the patch.

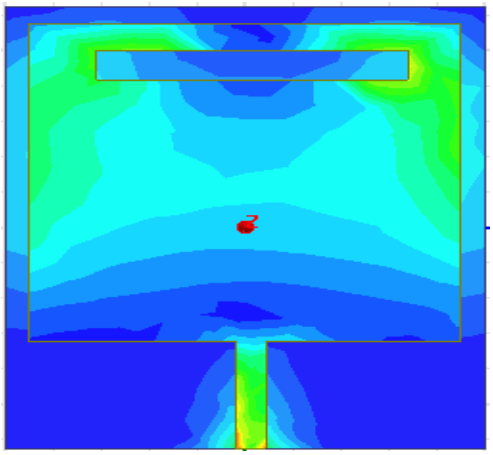


Fig. 6: a). Current distribution at 3.6GHz

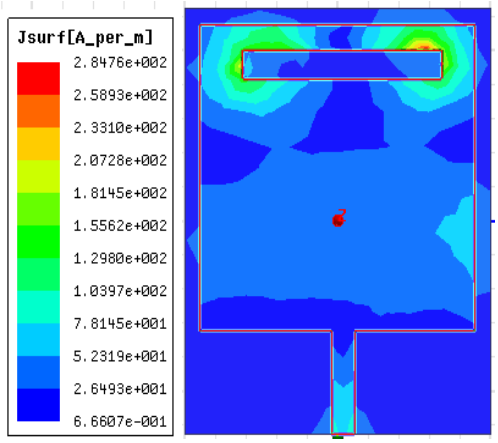


Fig. 6: b). Current distribution at 5.8GHz

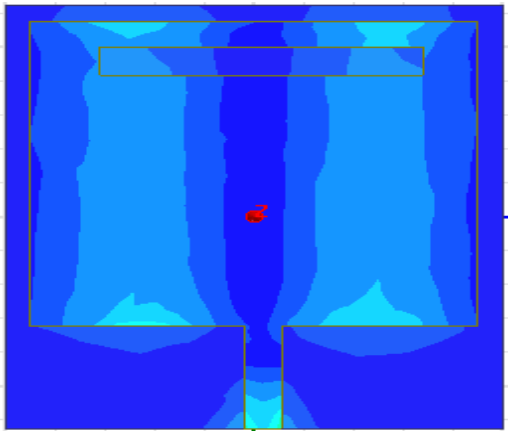


Fig. 6: c). Current distribution at 7.5GHz

4. Results

The antenna is built on a volume of 25 x 20 x 1.6 mm^3 ($800mm^3$). The substrate used is FR4 with the height 1.6mm and dielectric constant of 4.4. The simulated result of the return loss (S_{11}) is illustrated in the figure (7). The antenna shows the triple resonance at 3.6GHz (WIMAX), 5.8GHz (WLAN), 7.5GHz (X-band). The antenna shows good S_{11} which is less than -10dB.

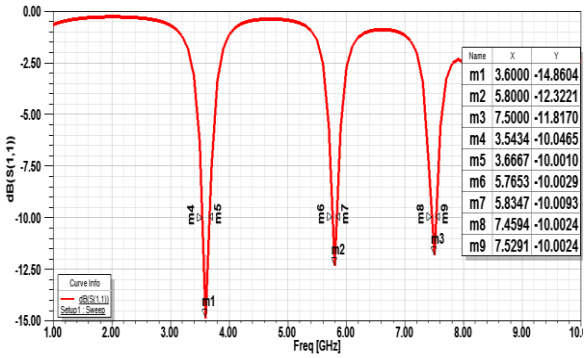


Fig. 7: S_{11} of the antenna.

Table 2: Final results of the antenna

F Frequency (GHz)	Return loss (S_{11})	Bandwidth (GHz)	Bandwidth (%)
3.6	-14.86	0.13	3.61
5.8	-12.32	0.06	1.03
7.5	-11.82	0.08	1.07

The VSWR of the antenna is given in the figure (8). For better performance of the antenna VSWR should lie between 1-2. The designed antenna obtains VSWR of 1.4, 16, 1.7 at resonance frequencies 3.6GHz, 5.8GHz, 7.5 GHz respectively.

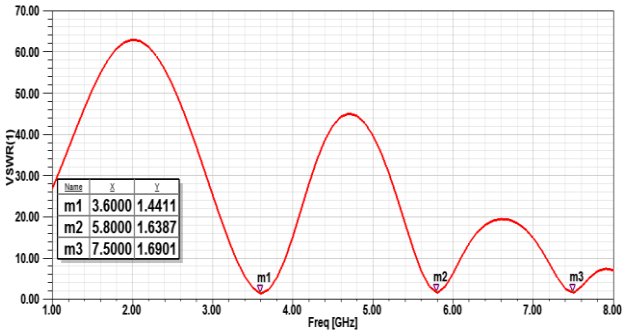


Fig. 8: VSWR plot of the antenna

The radiation pattern is further interpreted in the figure (8). It shows the antenna has omni-directional path in the H-plane and bi-directional path in the E-plane at operating frequencies 3.6GHz, 5.8GHz, 7.5GHz.

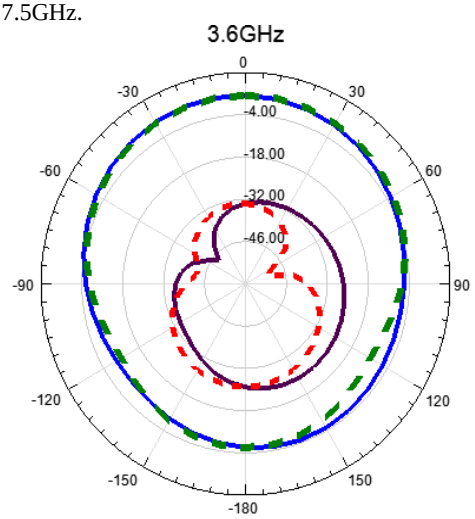


Fig. 9: a). Radiation pattern of the antenna at 3.6GHz

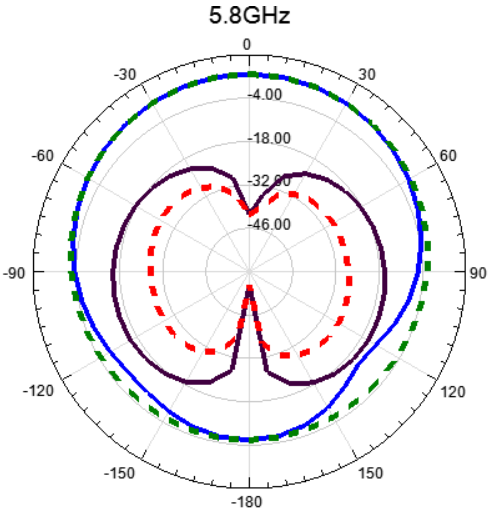


Fig. 9: b). Radiation pattern of the antenna at 5.8GHz

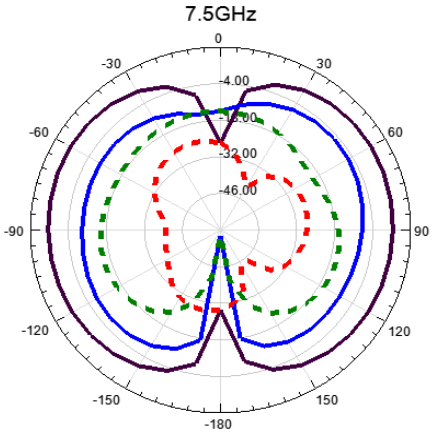
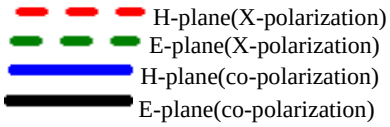


Fig. 9: c). Radiation pattern of the antenna at 7.5GHz



The 3-D gain plot of the antenna is specified in the figure (9). The gain of about -1.28dB, 1.09dB and 1.53dB are obtained for 3.6GHz, 5.8GHz and 7.5GHz respectively. The gain at 3.6GHz is low because of slot.

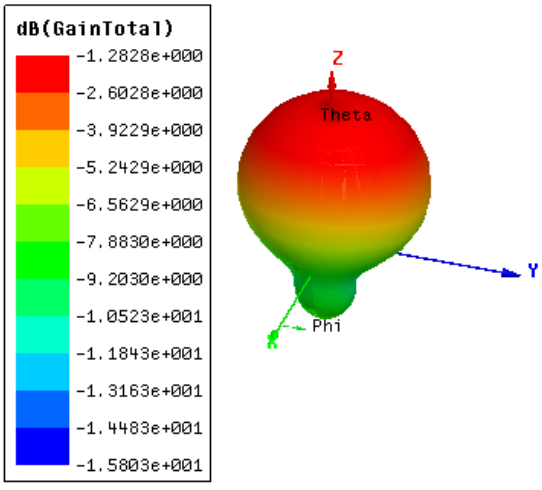


Fig. 10: a). 3-D plot of gain at 7.5GHz

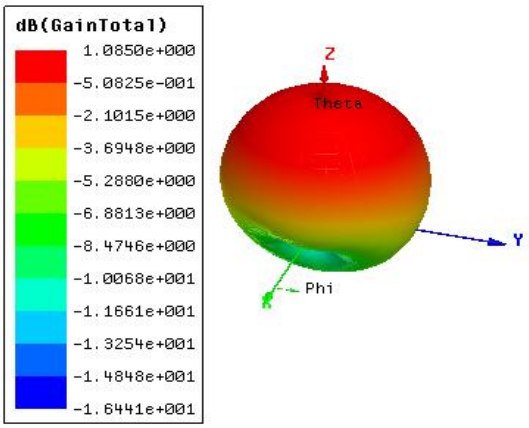


Fig. 10: b). 3-D plot of gain at 5.8GHz

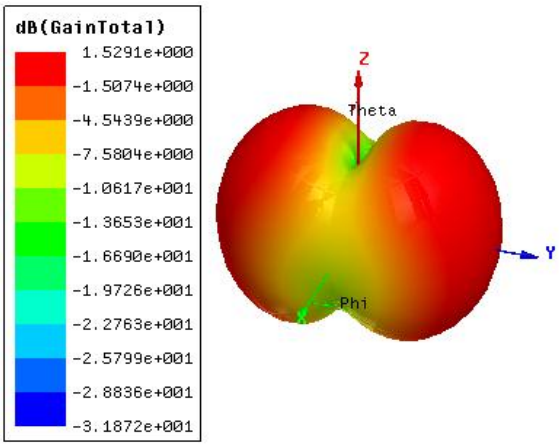


Fig. 10: c). 3-D plot of gain at 7.5GHz

5. Conclusion

A rectangular slotted rectangular patch antenna for WIMAX, WLAN and X-band applications is presented. The antenna shows low return loss at resonance frequencies 3.6GHz, 5.8GHz and 7.5GHz. From the parametric analysis it is observed that trivial change in the dimensions of the antenna changes the performance of the antenna. The antenna has acceptable gain which is useful in the above mentioned applications. The gain can be improved by using superstrate.

References

[1] Abdelheq Boukarkar, Xian Qi Lin, Yaun Jiang, and Yi Qiang Yu, Miniaturized single-feed multiband patch antennas, IEEE, 2017.
[2] Muhammad Salim Garba and Hong-Xing Zheng, Analysis and design of compact multiband patch antenna for wireless application, Institute of antenna and microwave techniques, Tianjin university of technology and education, IEEE, 2016.
[3] Indu Jiji Rajmohan and M. I. Hussein,A multiband planar antenna design using hexagonal patch and a resonator slot, UAE University, IEEE, 2016
[4] S. A. H. Saghanezhad and Z. Atlasbaf, Miniaturized dual-band CPW-fed antennas loaded with U-shaped metamaterials, IEEE, 2016.
[5] M. Li, X.Q. Li, J. Y. Chin, R. Liu and T. J. Cui, A novel miniaturized printed planar antenna using split-ring resonator, IEEE, 2008.
[6] S. M. Aguilar, M. A. Al-Joumayly, M. J. Burfeindt, N. Behdad, and S. C. Hagness, Multiband miniaturized patch antennas for a compact, shielded microwave imaging array, IEEE, 2014.
[7] C. A. Balanis, Antenna Theory: Analysis and design. Hoboken, NJ, USA: Wiley,2005, p.811.

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Research paper

Design of Multiband Antenna for Wimax and WLAN Applications Using DGS

Banuprakash.R[1], GSPN Amith[2], Gagana N[3], Ravi AG[4], Pavanashree C[5]

[1]Assistant Professor,
[1,2,3,4,5]Department of TE, BMSIT&M, Bengaluru,India
**Corresponding Author Email: r.bhanuprakash@bmsit.in[1], amithgspn23@gmail.com[2], raviag37@gmail.com[3], pavanashreec@gmail.com[4]*

Abstract

In this paper, a multiband antenna with a micro strip feed line is presented. This antenna is designed on FR4 substrate with dielectric constant 4.4 having overall size of 20 × 20 × 1.6mm^3. The proposed antenna comprises defected ground structure with T and L shape slots to achieve multiband frequencies. This multiband antenna covers three different frequencies as 3.3 GHz, 3.85 GHz and 5.25 GHz. All of these frequencies are applicable for WiMAX and WLAN applications respectively. Return loss (S11), Gain and Radiation patterns are simulated and observed on HFSS.

Keywords: *Defective ground structure, WiMAX,WLAN.*

1. Introduction

With the rapid development of wireless communication systems in recent years, miniaturized antenna acquired demand to include as an internal antenna. Therefore, microstrip antenna has become the main drift of development. Antenna is a type of transducer which is used to convert electrical energy into RF energy. Antenna is a basic device for any communication setup [1].
These microstrip antennas are being used for various applications like Wi-MAX and WLAN applications mainly due to their low profile, low cost, light weight and easy fabrication. For these applications, microstrip patch antennas can be designed by placing a Periodic or Non periodic slots on ground plane called as Defective Ground Structure (DGS) [2-3].
A micro strip feed line can be used to feed the antenna in the design of multiband antennas for wireless applications. Wireless bands are Wi-MAX (3500-4500 MHz), WLAN (5100-5800 MHz) [4].Defective Ground Structure is a dynamic neighborhood of seek in the field of receiver and wave propagation.

2. Antenna Structure Design

A. Defected Ground Structure

Etched slots or defects on the ground plane of microstrip circuits are referred to as Defected Ground structure. Single or multiple defects can be made on the ground plane.
The utilization of DGS is invincible by the properties of the defects such as the shape, dimension, repetition etc. It has been used in the field of micro strip antennas for enhancing the bandwidth and gain. It is also used to suppress the higher mode harmonics, mutual coupling between adjacent element, and cross-polarization for improving the radiation characteristics of the microstrip antenna.

B. Design of the Antenna

In this multiband antenna square shape FR4 substrate with length 20mm, width 20mm and height of 1.6mm is considered. A rectangular patch is placed on the substrate as shown in the figure1.

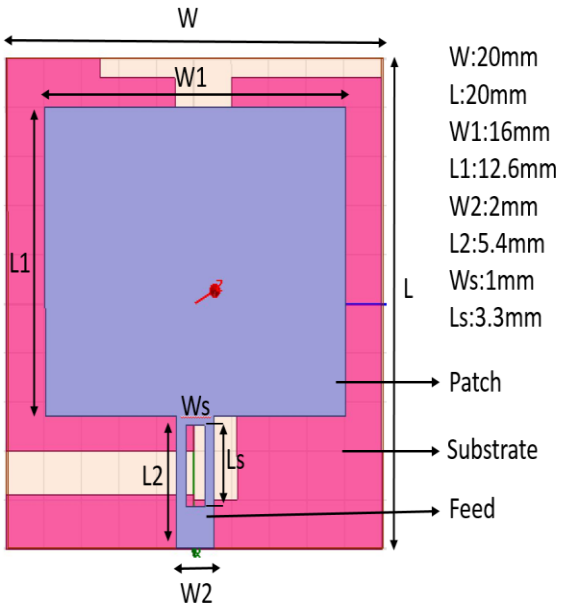


Fig. 1: Front view of an antenna

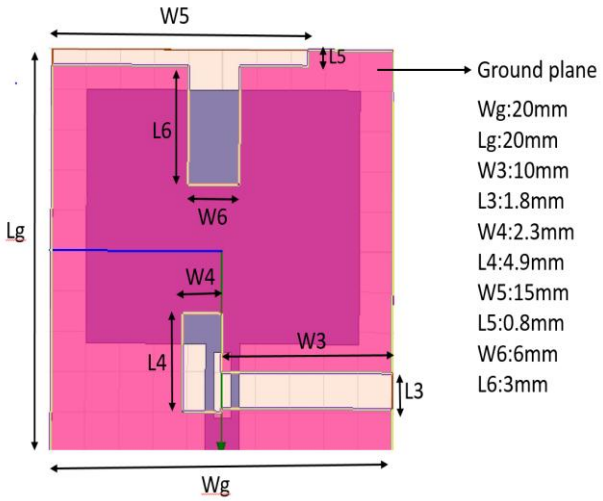


Fig. 2: Back view of an antenna

The L and T shape slots have been made in the ground plane to achieve multiple frequencies as depicted in the figure 2. All slot dimensions are balanced according to the length and width.

3. Simulation of Antenna and Result Discussions

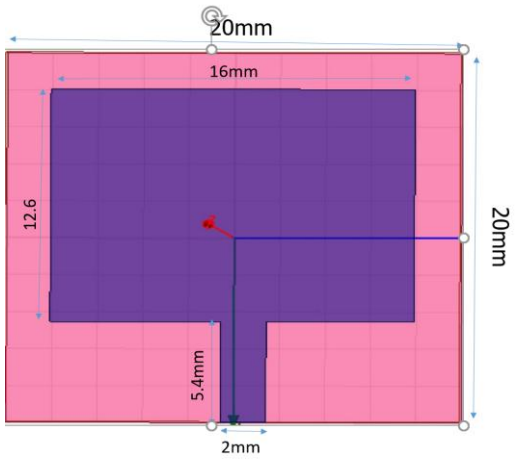


Fig.1: Front View of Antenna Without slots

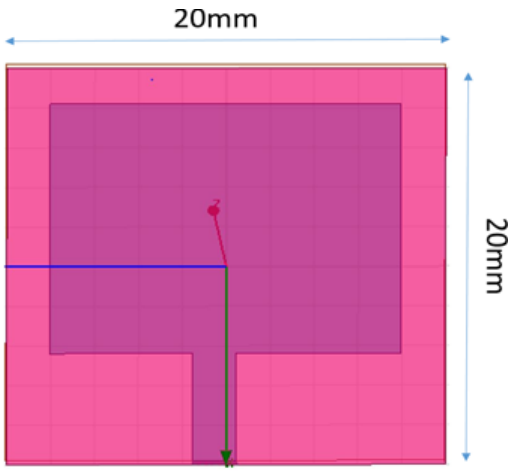


Fig. 2: Back View of the Antenna without slots

At the outset aerial deserted antenna is analyzed without DGS everywhere filler radiates at two bands 5.2GHz and 8.2GHz.

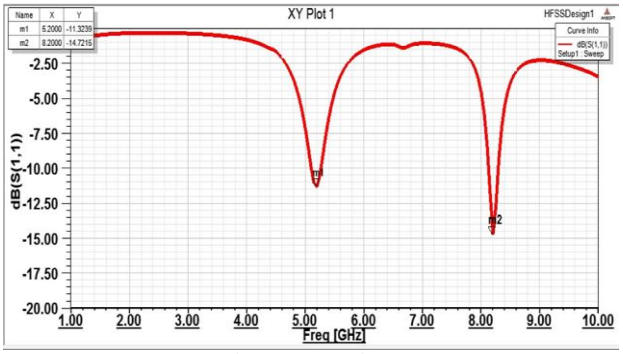


Fig. 3: Simulation of Return loss of Antenna Without DGS

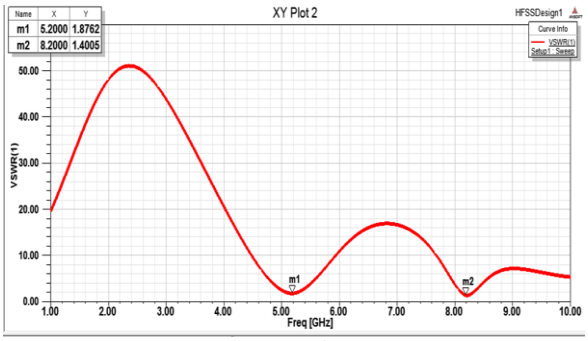


Fig.3: Simulation of VSWR of Antenna Without DGS

Since 5.2GHz is hold for WLAN application our aim is to keep grip of 5.2GHz and acquire other useful frequencies. This is completed according to the current distribution where slots are sliced in ground plane at less radiating part of 5.2GHz.

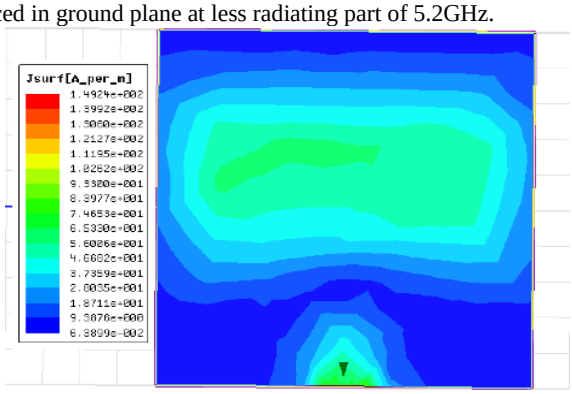


Fig.3: Current Distribution on ground plane at f:5.2 GHz.

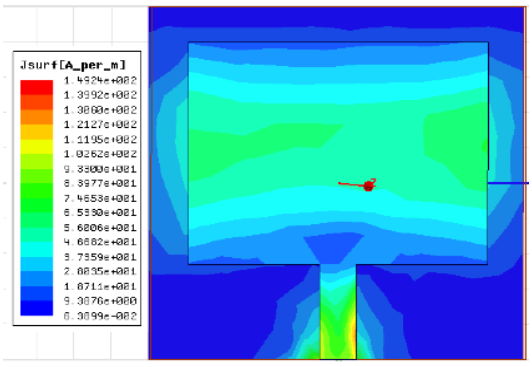


Fig. 4: Current Distribution on patch at f:5.2GHz.

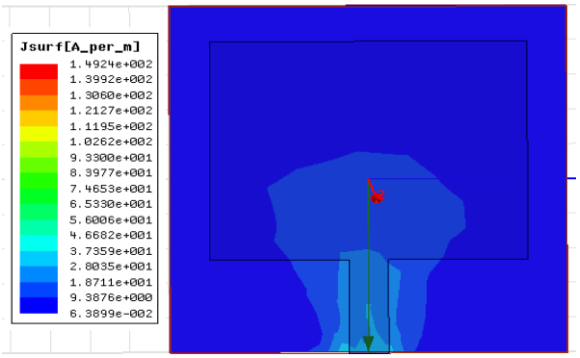


Fig. 5: Current Distribution on patch at f:3.3 GHz

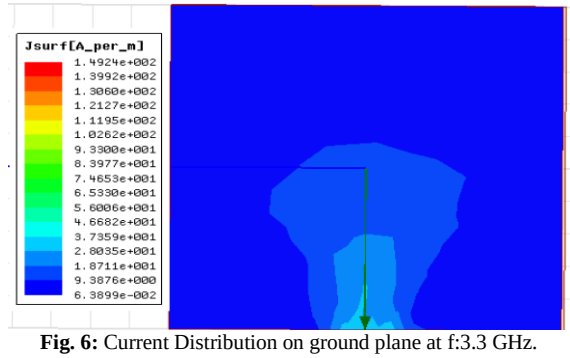


Fig. 6: Current Distribution on ground plane at f:3.3 GHz.

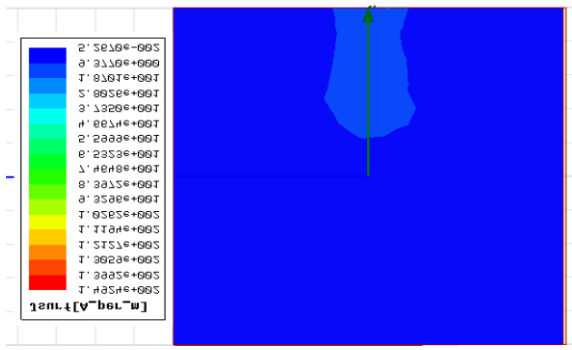


Fig. 7: Current Distribution on ground plane at f:3.8GHz.

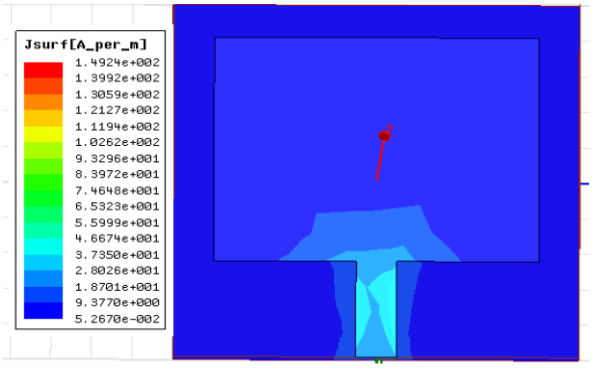


Fig. 8: Current distribution on patch at f:3.8GHz.

The length and width of the rectangular patch is (L1x W1) 12.6mm x 16mm. Each slot in ground plane is cut in order to obtain multiple frequency. Where L and T shape slots produce the frequencies that holds good for WIMAX applications and the slot on feed line (Ls x Ws) 3.3mm x 1mm is cut in order to obtain positive gain at 3.3GHz.

A. Return Loss

Here antenna is producing 5.25GHz where both L and T shape slots together produces 3.3 and 3.85GHz. For these frequencies the return loss is -20.25, -20.22, and -16.47 respectively .

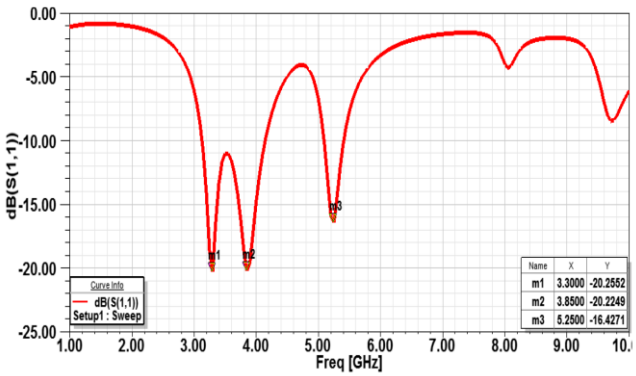


Fig. 11: Simulation of return loss of antenna with DGS

B. Radiation Pattern

Radiation pattern of an antenna shows E-plane and H-plane. We can also observe the co polarization and cross polarization of E and H planes. Here three different radiation patterns have been plotted with respect to three operating frequencies such as 3.3 GHz, 3.85 GHz and 5.25GHz.

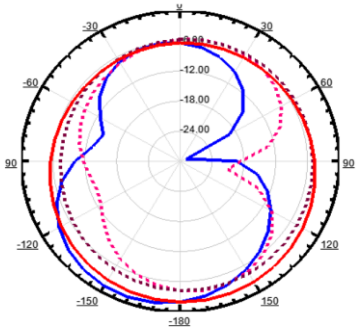


Fig.12: Radiation pattern at frequency 3.3GHz.

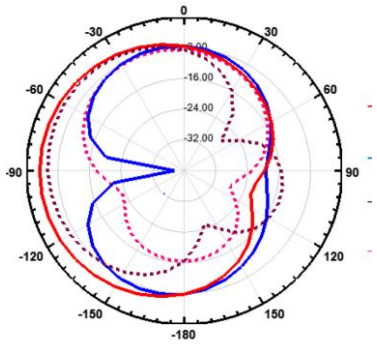


Fig.13: Radiation Pattern at frequency 3.85GHz..

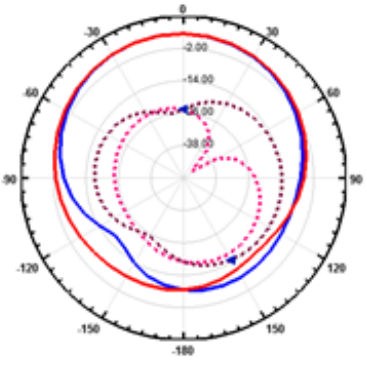
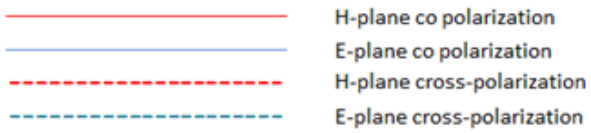


Fig.14: Radiation Pattern at frequency 5.25GHz



Gain of an antenna gives the degree of efficiency of the antenna and its directional capabilities. Here we observe 3.4dB at 3.3 GHz,-2.1dB at 3.3GHz and 2.185 dB at 5.25GHz respectively

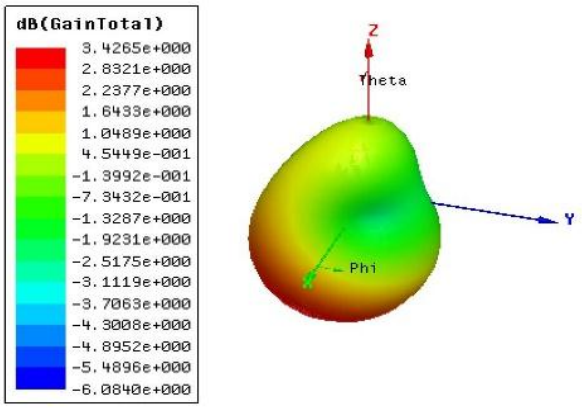


Fig. 15: Gain of antenna at frequency 3.3GHz

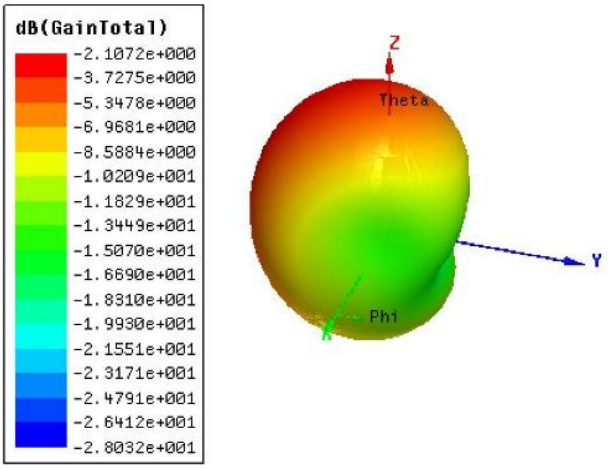


Fig. 16: Gain of antenna at frequency 3.85GHz

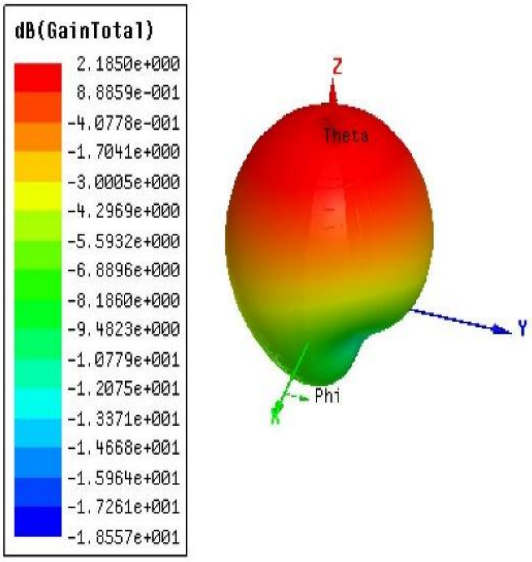


Fig. 17: Gain of antenna at frequency 5.25GHz

Parameters	Without Slot	With Slot
Frequency	3.3GHz,3.8 GHz,5.2GHz	3.3GHz,3.85GHz,5.25GHz
Gain	-1.99dB, -1.64dB, 2.11dB	3.42dB,-2.1dB,2.18dB

Fig. 16: Comparison table

4. Conclusion

The aim of this work is to design and simulate a multiband microstrip slot antenna with defective ground structure operating in three different frequency bands with microstrip feeding technique. For the realization of the antenna, L and T shape slot are made in ground plane. Designed Multiband Antenna resonates at 3.3 GHz,3.85 GHz and 5.25GHz with return loss -20.25 dB ,-20.22 dB and -16.42dB respectively with Gains of 3.42dB,-2.1dB and 2.18dB which is suitable for Wi-MAX and WLAN applications.

References

[1] Amiya B. Sahoo, Department of Electronics and Telecommunication Engineering, SSUT, 2017 2nd IEEE International Conference. Design of Multi-band Rectangular Patch Antennas using Defected Ground Structure (DGS).

[2] R.Er-rebyiy1,J.Zbitou1,A.Tajmouati1, M.Latrach2, A.Errkik1, L.El Abdellaoui1 . 1LMEET Laboratory FST of Settat, University of Hassan 1st Morocco 2Microwave Group, ESEO, Angers,France.2017 IEEE.A New Design of a Miniature Microstrip Patch Antenna Using Defected Ground Structure DGS.

[3] K. Akinwale Amusa Dept. of Electrical Electronics Engineering Federal University of Agriculture Abeokuta, 2017 IEEE 3rd International Conference. Effects of Slot Dimensions and Operating Frequencies on the Equivalent Magnetic Current Distributions in Slot Antennas.

[4] S. Imran Hussain Shah*, Shahid Bashir*, Syed Dildar Hussain Shah. University of Eng. & Technology, Peshawar, Pakistan, 2014 IEEE Compact Multiband microstrip patch antenna using Defected Ground structure (DGS).

[5] JOBINS GEORGE Assistant Professor ,Department of ECE Ilahia College of Engineering& Technology Muvattutupuzha, India. 2016 IEEE, Multiband Microstrip patch Antenna using parallel slots for wireless applications

[6] Bhanu Priya Kumawat(1), Santosh Meena(2), Sanjeev Yadav(3) Govt. Women Engineering College Ajmer, Rajasthan, India.2016. Square Shape Slotted Multiband Microstrip Patch Antenna Using Defect Ground Structure.

[7] L. Cheema, and K. K Sherdia, "Design of microstrip antenna with defected ground structure for UWB applications," International Journal of Advanced Research in Computer and Communication Engineering. July 2013.

[8] A. B. Sahoo, G. P. Mishra, M. R. Jena, and B. B. Mangaraj, "Optimal design and comparative study of circular patch antennas using different feeds for WLAN and WiMAX applications," International Journal on Communications Antenna and Propagation, vol. 6, no. 3, pp. 188-196, June 2016.

A Metamaterial Inspired, Slotted Multiband Patch Antenna with Reconfigurability

Banuprakash. R, Hariprasad. S.A

Abstract*: In this letter the antenna is designed for achieving the multiband frequency configuration with the dimension of 26*26*1.6 mm3 with the use of substrate of dielectric constant of 4.4. It is capable of operating at the frequency of 3.9 GHz,5.8GHz and 6.7GHz, with a gain of 2.9dB,4.6dB,-1.5dB respectively. By using the method like DGS, Slots and SSRR structure, the design is able to generate and operate at the above mentioned frequencies. Furthermore by placing a metallic switch on the rectangular shaped slot the proposed antenna can also be used as reconfigurable antenna to produce different frequency.

***Index Terms*: Slots, DGS, Reconfigurability, HFSS.**

I. INTRODUCTION

In recent years the rapid development of the antenna has led to the increased demand of multiband microstrip antenna[6]. This has changed the approach of antenna design in completely diverse way[2]. Antenna is a passive device which converts electrical energy into Radio Frequency energy and couple it to free space for transmission. Since the antenna is an elementary device for wireless communication setup the microstrip multiband antenna has given a new manner to accomplish this objective.

The performance of an antenna depends on the design parameters like dielectric constant, height of the substrate, frequency etc. There is an immense need of packed size and light weight antenna's which can be effectively bound together in present day communication systems. The micro strip patch antenna have been broadly utilized in elite satellite and remote specialized gadgets because of their low cost, compact shape, lightweight, simplicity of creation and similarity of combination with circuit technology. However, low transmission capacity, low power handling limit, low gain and directivity are the real disadvantages of patch antenna. Therefore, the challenge in microstrip antenna design is to increase the bandwidth and gain.

To attain good gain and bandwidth, at low frequency bands in handheld and portable wireless devices antenna size plays a dynamic role. For flexibility to various situations in wireless remote sensing and radar systems, antenna with numerous working frequencies is must [2] and patch antennas can be designed by engraving a portion of metal on ground plane either in periodic or non-periodic mode called as Defective Ground Structure (DGS). A break in the current distribution created by the slots make a positive influence on input impedance to generate supplementary resonant frequencies [5].

For better compatibility and to satisfy the developing needs of different portable electric devices, many wideband, ultra wideband and multiband antennas have been designed. In any case, multiband antennas are a preferred choice over other wide band and ultra wide band antennas as they ease the effects of electromagnetic impedance and pulse distortion. [1]. Overall, multiband resonant modes can be achieved by altering patch or ground plane. This can be achieved by adding multi-diverged strips and carved slots [3].

A. Reconfigurability of the Antenna

The progression in wireless communication technologies composed with the upward need of reconfigurable property of antenna for users has motivated the demand for smaller and multi-functional wireless antennas in communication device. Reconfigurable antennas have been proposed to fix a vital issue of employing the restricted spectrum effectively on the communication applications [4]..

II. ANTENNA GEOMETRY AND RESULTS

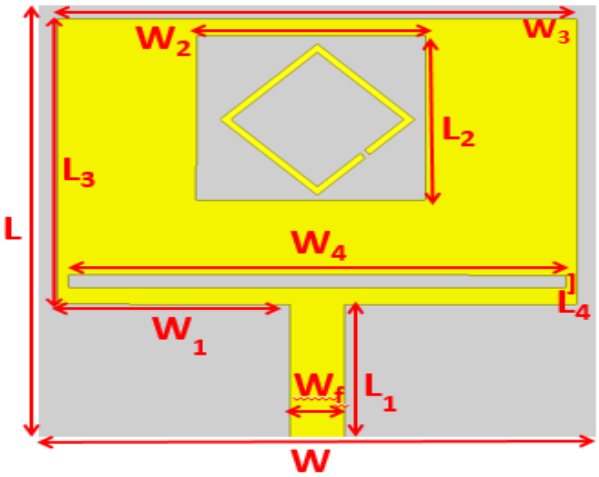


Fig1.Front View

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Banuprakash R, Telecommunication Engineering, BMS Institute of Technology and Management, Bangalore, India, r.bhanuprakash@bmsit.in
Hariprasad S A, Electronics and Communication Engineering, SET, Jain University, Bangalore, India.

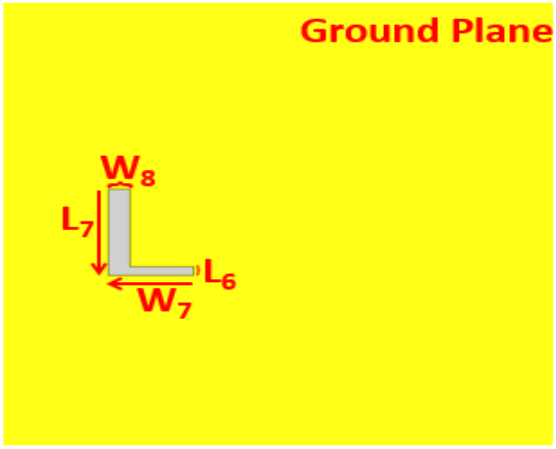


Fig.2. Back view

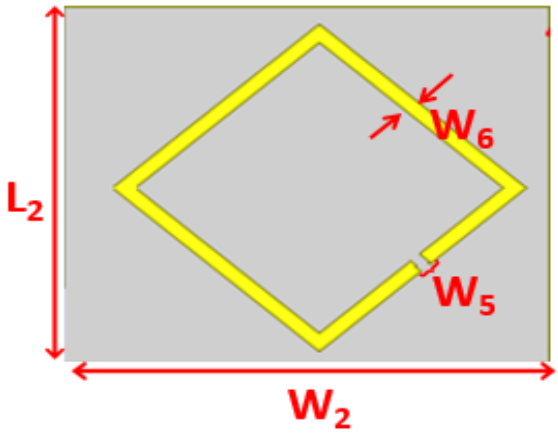
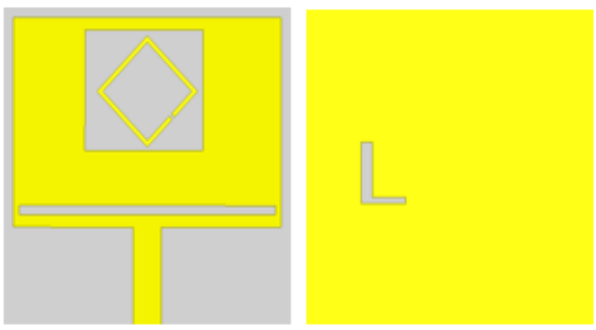


Fig. 3. SSRR structure

The measurements of the design are listed below:

W = 26 mm	L = 26 mm
W1 = 10.75 mm	L1 = 8 mm
W2 = 10.6 mm	L2 = 9.8 mm
W3 = 24 mm	L3 = 17 mm
W4 = 23 mm	L4 = 0.45 mm
W7 = 4 mm	L6 = 0.5 mm
W8 = 1 mm	L7 = 5mm

The above mentioned structure is obtained after the repeated iterations. The different steps which led to the final design and corresponding results are as follows



Patch Ground

Fig.4a) The proposed design

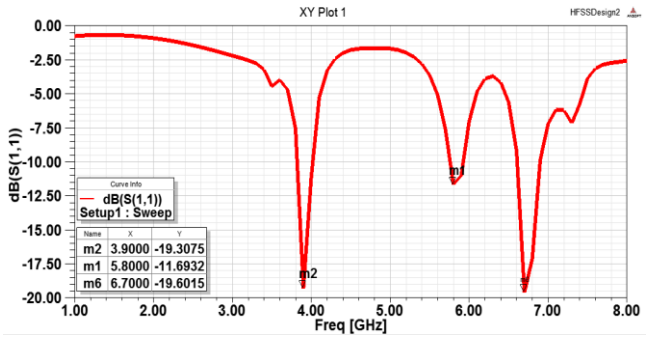


Fig. 4b). Plot of return loss for proposed antenna

And the initial designs which led to the proposed antenna are as follows

Step1:

Fig5.a) Patch Ground

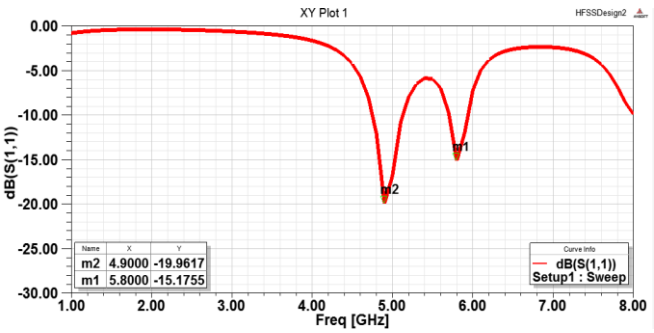
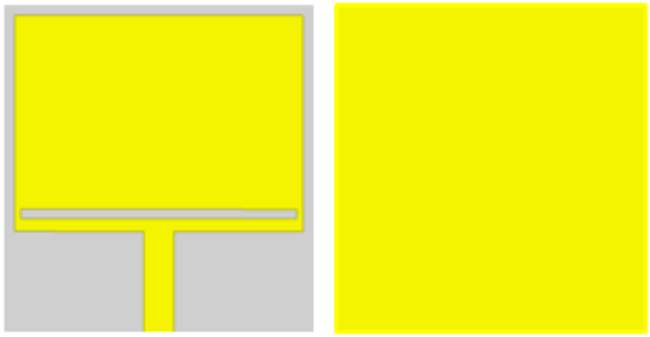


Fig.5.b) Frequency Vs Return loss

Fig.5(a,b). Initial design and the corresponding result

Step 2:



Patch Ground

Fig6.a) Design with slot

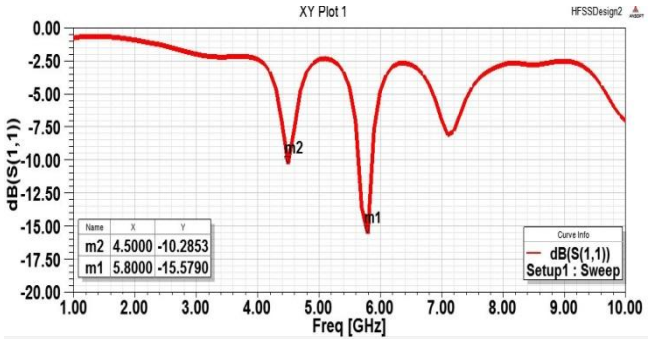
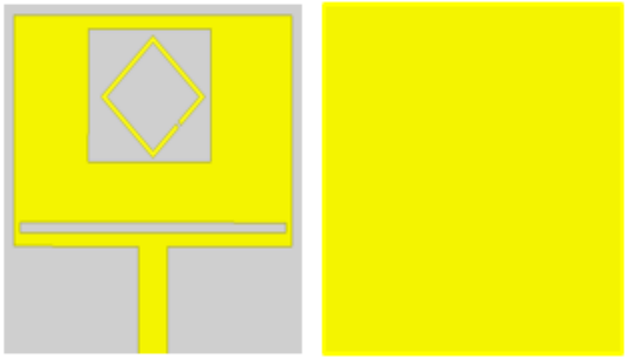


Fig.6 b) Return loss

Step 3:



Patch Ground

Fig.7 a) Patch with Square Split Ring Resonator

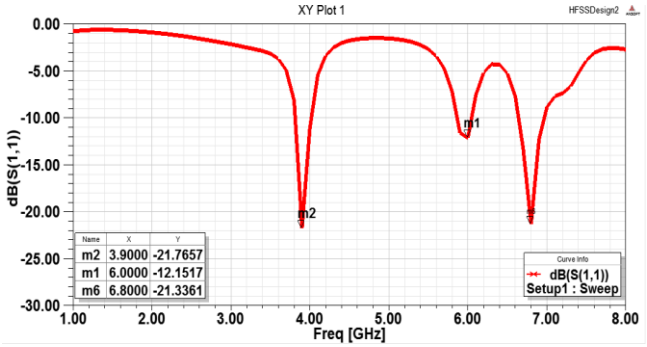


Fig.7 b) Return loss

The above mentioned steps have given the corresponding return loss values and hence giving the operating frequencies. From the above mentioned design steps and the corresponding results it shoes that initially the simple microstrip patch antenna is able to generate 4.9GHz and 5.8GHz frequencies but after the insertion of rectangular slot near the feed the antenna produced 4.5GHz and 5.8 GHz. Then to produce another frequency the use of SSRR structure is incorporated and the antenna is simulated to get the result. The antenna was then able to generate 3.9 GHz,6GHz and 6.8GHz.

To obtain a better gain an L slot is presented in ground plane hence leading to the defective ground structure (DGS). It produced the final set if frequencies of 3.9GHz, 5.8GHz and 6.7GHz with good gain.

The plot of gain for above mentioned frequencies are as follows

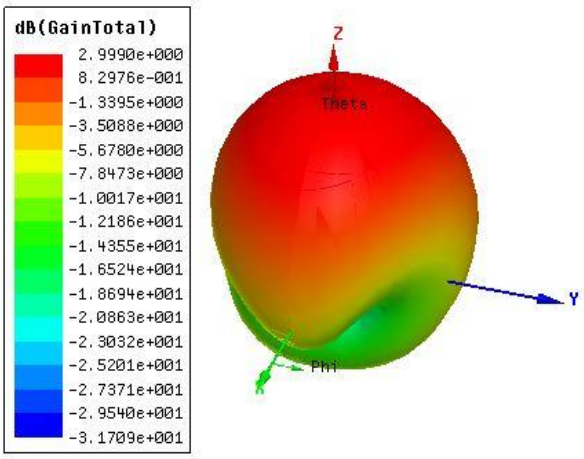


Fig.8a): For 3.9GHz

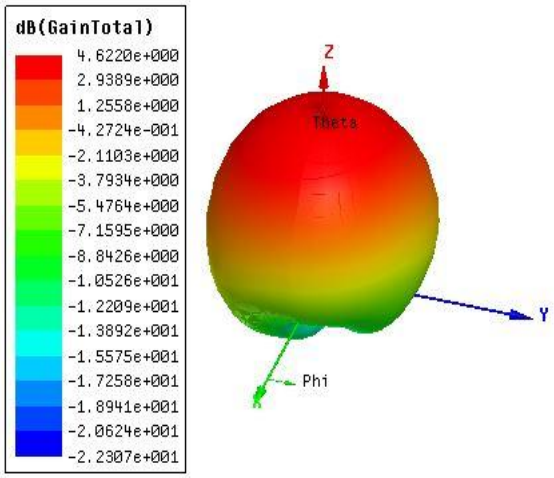


Fig. 8b): At 5.8GHz

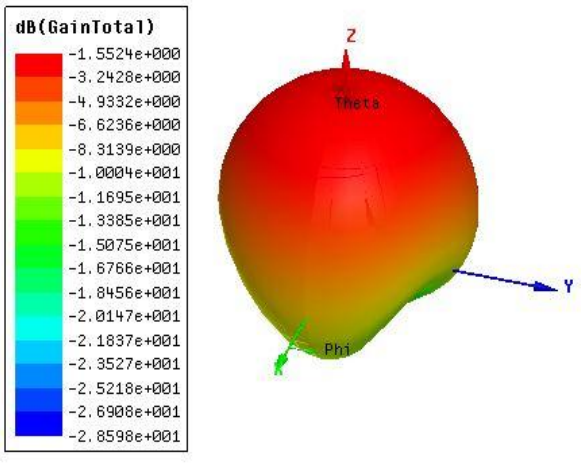


Fig. 8c): For 6.7GHz

From the above figures it is clear that the proposed antenna produces a gain of 2.99dB for 3.9GHz, 4.62dB for 5.8GHz and -1.55dB for 6.7GHz respectively.

Radiation patterns of the proposed structure :

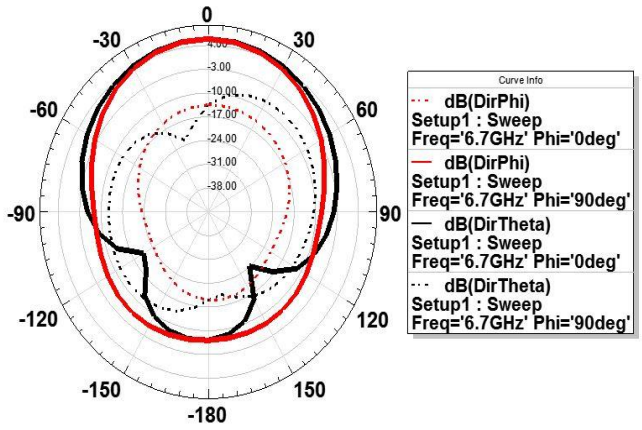


Fig.9a): For 3.9GHz

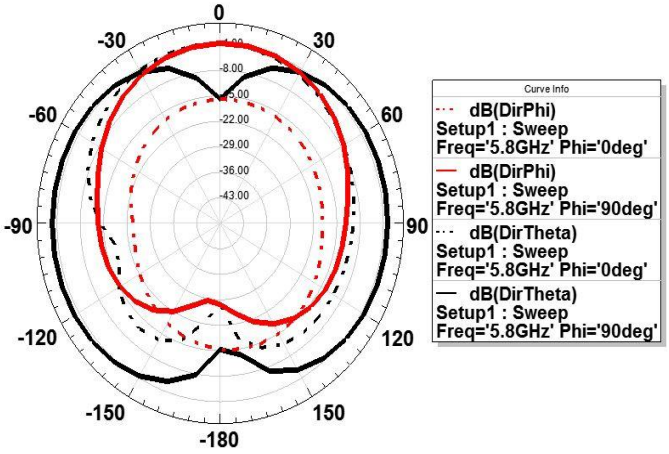


Fig.9b): For 5.8GHz

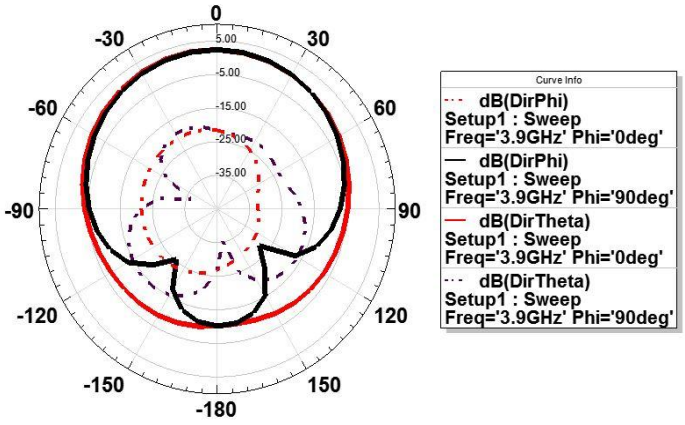


Fig.9c): For 3.9GHz

The above figures illustrate the radiation plot for the obtained frequencies.

Frequency Reconfigurability:

The antenna can be reconfigured to 6 GHz by placing a simple metal switch in the slot as shown in Fig 10.

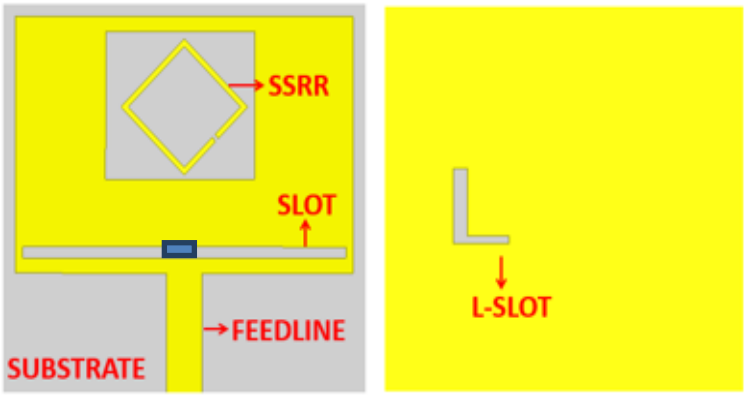


Fig.10: Antenna structure with a metal switch

The above mentioned reconfigurable antenna produces the following result

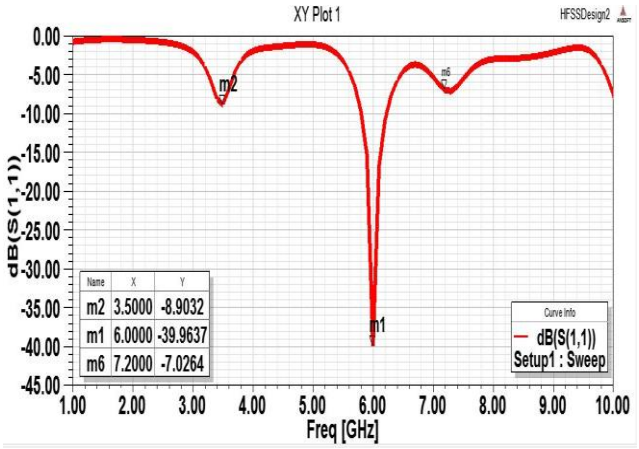


Fig.11: Return loss plot for the reconfigured antenna

Comparison table for result obtained in each step:

Step	Frequency GHz	S_{11} in dB	Applications
#1	4.9 5.8	-19.9 -15.1	• C-band • Wi-Max
#2	4.5 5.8	-10 -15	• C-band • WLAN
#3	3.9 6.0 6.8	-21 -12 -21	• Wi-Max • Lower satellite band • Satellite Television
#4 Proposed design	3.9 5.8 6.7	-19 -11 -19	• Middle Wi-Max • Upper Wi-Max • Satellite Television

Comparison of the proposed antenna:

Ref. no.	Year	Total area (mm^2)	Operating bands (GHz)	Reconfigurability
[1]	2015	50x50	2.54/3.55/ 5.7	NO
[2]	2017	40x40	3.04/3.83/4.83/ 5.76	NO
[3]	2016	38x38	2.4/3.5/5.8 1.52/1.6/1.5	NO
[5]	2015	56x44	3.1/5.52/7.3/9. 7	NO
Proposed Antenna		26x26	3.9/5.8/6.7	YES

III. CONCLUSION

The increasing demand for the antenna for multiband frequencies is increasing exponentially. In an effort to get a solution the above antenna is proposed with multiband frequency operation characteristics. The proposed antenna operates at 3.9GHz,5.8GHz and 6.7GHz with return loss of -21.7dB,-12.1dB and -21.3 dB respectively. It has produced a gain of 2.9dB,4.6dB and -1.5dB accordingly. The same antenna with the help of electric switches like metal switch can be modified to produce 6 GHz and made as a reconfigurable antenna. Hence the proposed antenna not only offers multiband frequency operation capability it also offers reconfigurability.

REFERENCES

1. Ali,Tanweer, K. Durga Prasad, and Rajashekhar C. Biradar. "A miniaturized slotted multiband antenna for wireless applications." Journal of Computational Electronics (2018): 1-15.
2. Boukarkar, Abdelheq, Xian Qi Lin, Yuan Jiang, and Yi Qiang Yu. "Miniaturized single-feed multiband patch antennas." IEEE Transactions on Antennas and Propagation 65, no. 2 (2017): 850-854.
3. Saraswat, Ritesh Kumar, and Mithilesh Kumar. "Miniaturized slotted ground UWB antenna loaded with metamaterial for WLAN and WiMAX applications." Progress In Electromagnetics Research 65 (2016): 65-80.
4. Park, Seong-Ook, Viet-Anh Nguyen, and Rao Shahid Aziz. "Multi-band, dual polarization, dual antennas for beam reconfigurable antenna system for small cell base Station." In Antenna Technology:" Small Antennas, Novel EM Structures and Materials, and Applications"(iWAT), 2014 International Workshop on, pp. 159-160. IEEE, 2014.
5. Ali, Tanweer, Mohammad Saadh Aw, and Rajashekhar C. Biradar. "A fractal quad-band antenna loaded with L-shaped slot and metamaterial for wireless applications." International Journal of Microwave and Wireless Technologies (2018): 1-9.
6. Banuprakash. R, Hariprasad. S.A."A Compact Multi-band Rectangular Slot Microstrip Antenna for Wi-MAX, WLAN and X-band Applications. "International Journal of Engineering &Technology(IJET),2018

AUTHORS PROFILE

Banuprakash R, presentaly working in Telecommunication Engineering, BMS Institute of Technology and Management, Bangalore, India, He is BE, MTech, and PhD. Prof. Banuprakash R were Resource Persons for the training program on RF communication at East West Institute of Technology in association with Technilab Instrument from 16th to 19th July 2018.

Hariprasad S A, I currently is Director, School of Engineering and Technology, Jain University, Bengaluru, India. His area is Embedded system

A Neural Network based Attendance Monitoring and Database Management System using Fingerprint Recognition and Matching

Dr. Seema Singh
Professor and Head
Dept. of Electronics and Telecommunication Engg
BMS Institute of Technology and Management
Bengaluru, India
seemasingh@bmsit.in

***Abstract*— Most authentication systems use fingerprints for identification. The uniqueness of fingerprint for each individual forms the basis of faultless identification. However, the image generated by the scanner may give varying results during each scan which thereby results in a major drawback in most existing systems. Thus, this paper involves the implementation of robust portable Neural Network based system to provide an efficient matching algorithm for fingerprint authentication systems. Image processing algorithms and appropriate choice of features for the training of neural networks is presented. The system is implemented on Raspberry Pi with appropriate interfacing modules to make the system standalone. As the proposed system is portable, it can be used as an attendance monitoring system in classrooms. The back-end system involves the processes of image acquisition and processing to create a suitable database. The corresponding hardware model is created in MATLAB and then deployed in the Raspberry Pi-3 module to form a stand-alone system.**

***Keywords*— Minutiae Extraction, Image Enhancement, Euclidian Distance, Back Propagation Neural Network, Fingerprint Matching, Raspberry Pi-3**

I. INTRODUCTION

Over the past few years many feature extraction algorithms have been found. These mainly focus on using various distinguishable features of fingerprints to improve the performance of the system. Currently, the attendance in most institutions is taken with pen and paper and is then transferred to a student information system manually by the professors, which is time consuming and also increases the chances of error as illustrated in paper [1]. The proposed system on the other hand is portable for a known set of students and can record data for about 60 students for their entire course. This system would obsolete the unethical way of giving attendance to the ineligible students.

In paper [2], it is stated that the extraction of minutiae requires good quality images which is not always easy as it might be degraded or corrupted due to the variations in skin and other effective conditions. In order to overcome this problem, it is necessary to carry out image enhancement before performing the matching. In the neural network-based approach used here, the minutiae are extracted after thinning the image of the fingerprint sample. The texture variations of the fingerprints that mainly lead to faulty results in the regular systems as illustrated in paper [3] are taken care of by the Neural Network based approach used here. Paper [4], provides detailed studies about various traditional approaches of fingerprint identification and mapping. The use of Neural Network is found to provide the fastest matching rate when compared to various other approaches which only relied on Image Processing.

An effective and unique identification parameter is found based on the fact that though any pair of corresponding feature values may be same for two individuals but the combination of all the feature values will never be the same according to Saurabh Verma and Soni1 [5].

Paper [6] deals with the implementation of a pattern matching algorithm to match and authenticate fingerprints. The system uses Back Propagation Algorithm to perform effective pattern matching to identify fingerprints. The existing methods presented for the detection of core points do not produce good results for faulty images and also detect false core points which degrades the performance. The proposed algorithm on the other hand is based on identifying the core nearest to the centre on the image which makes the computation of other parameters simpler with the core as the reference.

Neural network with its massive interconnection of parallel elementary processing units has following features:

- It makes real time processing of large volumes of data more readily realizable.
- It can model any degree of nonlinearity.
- It has an attractive property of learning and adaptation.
- Its non-algorithmic approach allows it to model a system without approximations, unlike conventional models.
- Its capability of handling situations of incomplete information and corrupt data makes it highly fault tolerant.

Neural networks have been used in various engineering and non engineering fields like safety critical flight control system [7], image based medical diagnostic system [8] and waste segregation system [9]. The system is also implemented on ARM processor. Therefore the neural networks implementation for finger print recognition is proposed with hardware implementation in this work. The integrated system of neural network for fingerprint image recognition and its implementation on standalone portable hardware is not explored in the literature.

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The fingerprint database is created in such system. Any finger print sensor may be used for this purpose to provide electronic print of the image. The choice of feature extracted decides the robustness of the recognition system. Various methods to identify the suitable parameters to create a database have been proposed in [11], [12]. These methods involve the use of various parameters that do not account for image orientation and shift. The Histogram based approach discussed requires detailed understanding of various other methods that follow. Thereby, the concept of computing the Euclidian Distance (ED) between the core and nearest bifurcations has been considered. The use of ED gives us unique data for each fingerprint and also accounts for the angular shifts [13].

Various neural networks based algorithms may be used to develop the finger print recognition system. Back propagation algorithm is computational intensive alternative but still holds the best choice for researchers due to its desired results. Variants of backpropagation algorithm are studied in this work. The recognition system is developed for the database where it recognizes any partial/degraded/differently oriented image of the stored finger print label. This developed system is downloaded in Raspberry Pi where it is interfaced with other accessories to make it a standalone system.

The proposed method deals with the hardware implementation using Raspberry Pi module (Version -3, Model B+) in connection with the LCD screen and fingerprint sensor (GT- 511C3) to make the system portable for applications like the Attendance Monitoring. Systems. Using MatLab, initially, the entire model is generated in the PC and then converted into an executable file which can be suitably dumped into the RPI.

II. PROPOSED SYSTEM

The database is created by extracting features from fingerprint image (through sensor) using image processing and neural network algorithm. The trained neural network and database is stored in Raspberry pi.

Further, for recognition and updation of attendance, the candidate's finger print image is converted to the feature vector through fingerprint sensor and image processing algorithms stored in raspberry pi. This feature vector is recognized using the trained neural network, stored in raspberry pi, which in turn update the attendance at backend, when connected to a computer in phases. Until then, the record is kept in the memory of Raspberry Pi. However this backend updation need to be done periodically as there is limited memory in Raspberry Pi.

The proposed system consists of working majorly in two domains- Image Processing and Artificial Neural Network and involves the following steps shown in Fig. 1:

a) Developing an updated database of features extracted from fingerprint via Image Processing

b) Using a suitable Neural Network to design a fast and robust system that is immune to errors

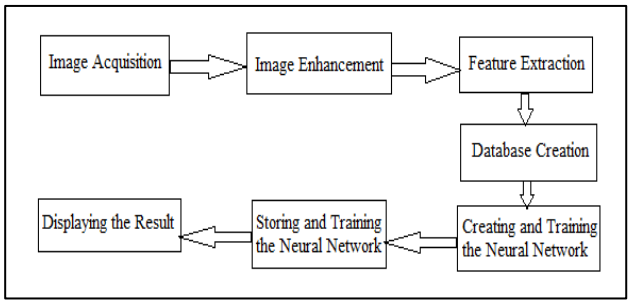

Fig 1. Block Diagram of Proposed System

The minutiae feature initially extracted include ridges and bifurcations. Ridges upon thinning result in false ridge endings and thereby lead to faulty results. Therefore, it was found that working only with bifurcations and core gave the most optimised results. The neural network recognition system includes two major phases- The Training Phase and the Testing Phase.

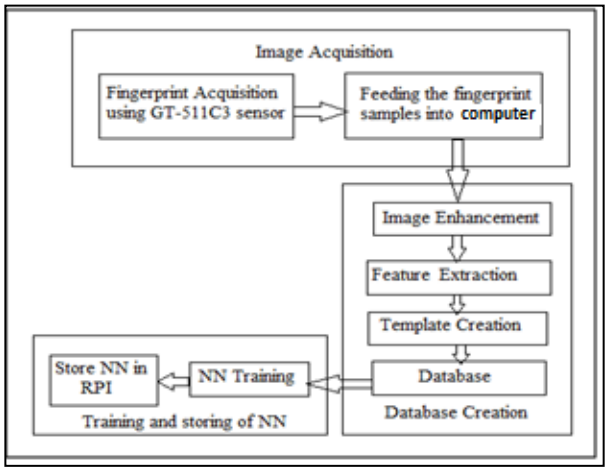

Fig 2. Training Phase

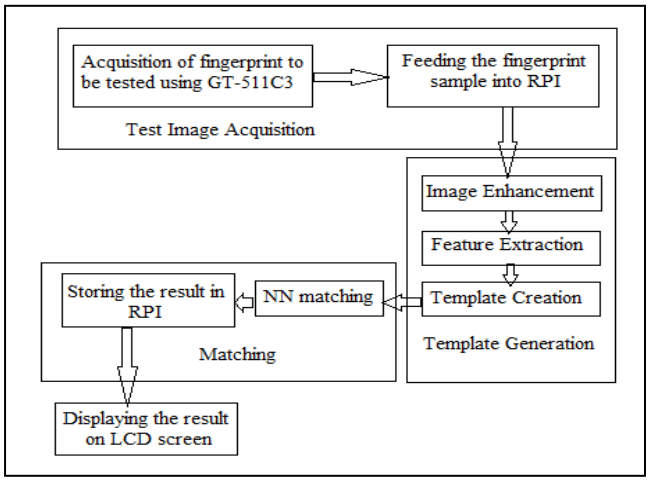

Fig 3. Testing Phase

III. IMPLEMENTATION

The functionality of the fingerprint sensor GT-511C3 is initially checked using the SDK tool and is then interfaced with the computer and Raspberry Pi-3 through which the images are extracted and stored. The sensor is used to just transfer the image to the computing system. Further image processing algorithms are used for feature extraction and updation of the specific feature vector in the database along with its mapped recognized label. Image processing steps are discussed further:

A. Fingerprint Image Enhancement

The Image enhancement process performed includes the following steps:

a) Binarization and Thinning: This involves converting the grey scale image into a binary image format which has two levels i.e. black and white. The thinning process involves removal of some foreground pixels which is useful for skeletonizing the image as shown in Figure 4.

b) Local Frequency Estimation: The Region of Interest (ROI) is determined from the scanned image and the remaining portion of the image is cropped out using this method.

Fig 4. Thinned Image

B. Fingerprint feature extraction

There are two kinds of features extracted- Global Features (Arch, Loop, Whorl) and Minutiae (Ridges and Bifurcations). The approach used in this paper mainly focusses on Core and Bifurcations. The image once processed is saved in a *TIF* file format which consumes lesser memory as compared to a *BMP* file. The Crossing Number concept is the most widely employed in order to determine the type of minutiae extracted. The following values of Crossing Number represent the specific features:

CN=1 indicates a ridge ending
CN=2 indicates a normal ridge
CN=3 indicates a bifurcation
CN>5 indicates a core

The ridge endings are later excluded as they were found to give faulty results after the thinning process was applied to them. For the instances when multiple cores are present in a fingerprint sample, the core closest to the centre of the image is retained while the others need to be discarded.

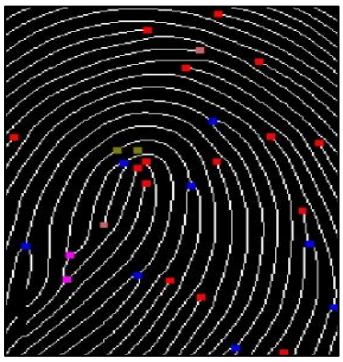

Fig 5. Extracted Features

The red points in Figure 5 indicate the ridges, the yellow points indicate the core (delta) whereas the blue points indicate the bifurcations.

C. Database creation

i) Comparison of various database creation techniques:

a) Using Coordinates and angle of the extracted features-
This methodology fails to account for the angular orientation of the fingerprints. Even though angular information is present, when compared with angularly shifted image of the same fingerprint the value of the angles changes and it is not possible for the neural network to derive any relation between the two images.

b) Histogram based database design-
In this methodology, the fingerprint image is divided into 16 blocks and histogram of each block is calculated individually and then tabulated into a database. The major drawback faced in this approach was that the angular orientation affected the results drastically and therefore desired results were not obtained.

c) Euclidean Distance based database design-
Identifying core of the fingerprint image and calculating Euclidean distance of the bifurcations with respect to the core can generate a set of values which remain constant even when angular orientation changes. Therefore, this method was observed to produce best results with angular invariant database.

ii) A database of the extracted features is made and stored to be used for further mapping. The 4 columns indicate the 4 parameters of the features extracted whereas the number of rows indicate the number of each feature. The algorithm extracts key features from the fingerprints and stores them in a matrix called 'minutiae' which contains the following data: [X, Y] coordinates, Crossing Number (CN), Theta, Euclidian Distance (ED).

The Steps for creating the database of the processed images include:

a) Detect the centre point and save it in the database

b) Detect the bifurcations and save it in the database

c) Compute the Euclidian Distance (ED) using the following formula-

$$ED = \text{sqrt}\left[(x_c - x_b)^2 + (y_c - y_b)^2\right]$$

Where, x_c is the x coordinate of the core

x_b is the x coordinate of the bifurcation

y_c is the y coordinate of the core

y_b is the y coordinate of the bifurcation

d) Sort the Euclidian Distance vector in ascending order

e) The Euclidian Distance vector with the improved features are stored in the database

f) This database is used for training of the Neural Network (Back-Propagation)

Since, the number of features in each of the scanned fingerprint is not constant thus the number of rows for each fingerprint database might vary. This would make the database unsuitable for training. Therefore, it is necessary to modify the database in order to get a fixed number of rows and columns. Also, the orientation of the fingerprint can affect the database values, Therefore, the Euclidean Distance removes the effects of angular orientation as Euclidean Distance remains same irrespective of the orientation. Consider the following two cases which require the addition or removal of rows in order to make the database of fixed size.

a) If the number of rows is less than the number desired, then the remaining rows are appended with other randomly chosen rows from the database with CN value as 3.

b) If the number of rows is greater than the value desired then the extra rows are equated to a null vector which thereby deletes them.

X	Y	CN	ED
168	240	7	0
183	244	3	15.52417
165	204	3	36.12478
124	251	3	45.35416
234	279	3	76.66159
166	162	3	78.02564
257	268	3	93.30059
223	141	3	113.2519
159	118	3	122.3315
273	147	3	140.264
42	117	3	176.0824
216	54	3	192.0937
135	40	3	202.7042
104	38	3	211.8962

Fig 6. Sample of Database created after calculation of Euclidian Distance and removing extra features

The Euclidian Distance as shown in Figure 6 is computed between the core and 12 nearest bifurcations.

IMAGE1	IMAGE2	IMAGE3	IMAGE4	IMAGE5	IMAGE6
204	48	168	12	204	228
12	240	12	240	228	228
7	7	7	7	7	7
0.953011	2.278847	2.095336	1.614081	0.245339	0.114919
25	43	233	26	235	46
51	31	227	42	217	229
3	3	3	3	3	3
0.965597	0.942463	0.317553	0.924352	0.2419	0.135418
99	28	92	218	26	41
31	42	230	32	226	215
3	3	3	3	3	3
1.025002	0.953336	0.340337	0.965065	0.243265	0.14377
120	223	84	94	202	159
31	44	213	40	226	203

Fig 7. Sample of Converted database in columns which can be fed to the Neural Network

D. Training of Neural Network

The use of Back Propagation Neural Network (BPNN) gives the best suited results for our application. The details of the Neural Network are given in Table 1.

TABLE I. TRAINING PARAMETERS

Parameter	Value
Input Neurons	48
Hidden Neurons	100
Output Neurons / No. of Classes	10
Iterations	67
Gradient Descent	1e-8
Training function in MATLAB	trainlm

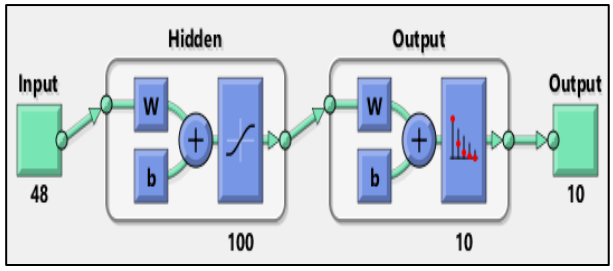

Fig 8. Neural Network

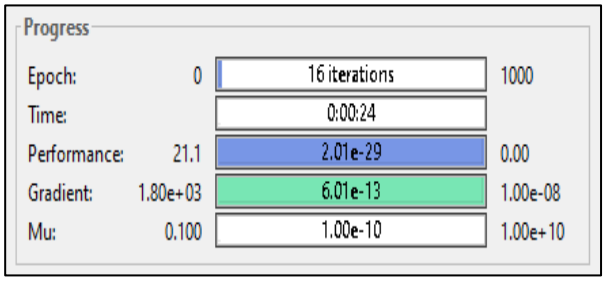

Figure 9: Training Process

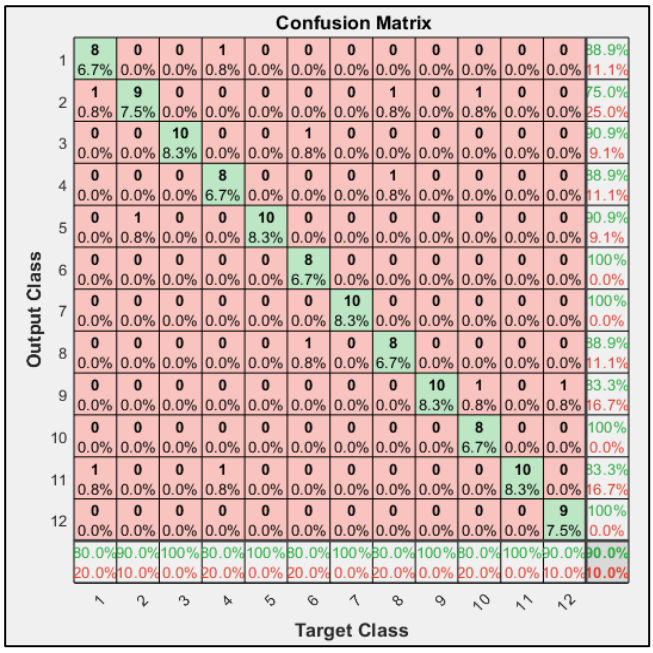

Fig 10. Confusion Matrix

A total of 100 fingerprint images were taken for the training for the neural network. The Neural network is trained till the percentage error is lesser than 0.1. The performance of the classification model can be shown using the confusion matrix in Figure 10. The trained Neural Network with this desired performance is saved in the RPI.

The features based on Euclidian distance between the centre point and the nearest neighbouring bifurcations are fed as the input to this neural network. The database of these neighbouring bifurcations based on the Euclidian distance proves to be more useful as it helps reduce the size of vector classification while keeping the same performance for classification.

E. Simulink Model

Initially, a time series object is created for the specified model. In order to run the Simulink model on RPI-3, the RPI board needs to be connected to the network and power supply.

```
final_model_ert_rtw  untitld_ert_rtw  untitled_ert_rtw
pi@raspberrypi-SU9BznHdzw:~/SDcard $ cd -
/home/pi
pi@raspberrypi-SU9BznHdzw:~ $ ls
bpnn.py                opencv3-RPI-STR.deb                ros_catkin_ws
bpnn.py.save           python-fingerprint-recognition     sdcard
catkin_ws              python-fingerprint-recognition.git SDcard
debug.log              raspberrypi_gettingstarted.elf     src
final_model.log        raspberrypi_gettingstarted_ert_rtw untitled_ert_rtw
get-pip.py             raspberrypi_gettingstarted.log
install_ros_indigo.sh  result.mat
pi@raspberrypi-SU9BznHdzw:~ $ ls
bpnn.py                          python-fingerprint-recognition.git
bpnn.py.save                     raspberrypi_gettingstarted.elf
catkin_ws                        raspberrypi_gettingstarted_ert_rtw
debug.log                        raspberrypi_gettingstarted.log
final_model_1_1.mat              result.mat
final_model_1_2.mat              ros_catkin_ws
final_model.log                  sdcard
get-pip.py                       SDcard
install_ros_indigo.sh            src
opencv3-RPI-STR.deb              untitled_ert_rtw
python-fingerprint-recognition
```

Fig 11. Data in Raspberry Pi

The Simulink model that was created is then built and run. The result obtained is stored in a .mat file and can be viewed as shown in Figure 12.

F. Retrieving and checking the result from RPI

In order to retrieve the file stored in the RPI, a communication link is first set up between the RPI and system. The matching algorithm is applied onto the test file after which the result will be displayed on the LCD Screen and will simultaneously be stored in the Raspberry Pi in a .mat file format. By running the model in MATLAB, the class to which the test image is mapped to is indicated. This result can then be retrieved later for maintaining the attendance record.

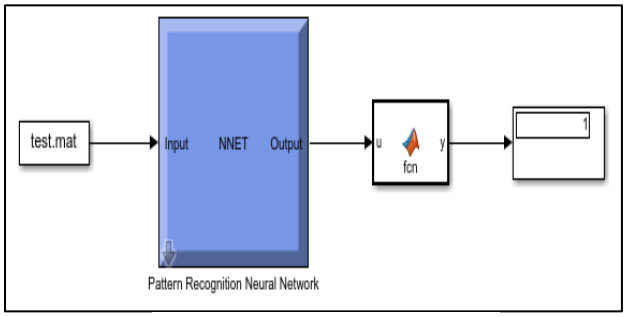

Fig 12. Simulink Model

G. Updating the Attendance Database

The final process includes updating the attendance in an excel sheet format. Once the attendance is taken, the excel sheet that holds the attendance record is updated.

IV. HARDWARE IMPLEMENTATION

The hardware implementation of this system involves the interfacing the fingerprint sensor with the Raspberry Pi which enables the result to be displayed suitably.

A. Hardware details

The Fingerprint sensor GT-511C3 is used for image acquisition whereas, the Raspberry Pi acts as the processing and storage unit. The RPI also helps in high speed matching of the images using Neural Network.

a) Fingerprint Sensor GT-511C3

This consists of an onboard ultra-thin optical sensor with a 32-bit CPU. This sensor uses a simple UART and USB protocol for communication. The sensor is capable enough to store about 200 fingerprint images and also provides 360-degree recognition. However, in the proposed system, an angular variation of up to 15-degree is considered. Also the sensor is used to capture the finger print image only. A USB to TTL module was used to establish a communication link between the RPI and GT-511C3 using the pins indicated in Figure 13. The baud rate for communication was set as 115200.

Fig 13. GT-511C3 Fingerprint Sensor

b) Raspberry Pi -3 Module

This is a Linux based microcomputer based on ARM architecture. The specification includes: 4* ARM Cortex A53 CPU, 1GB RAM, 40 Pin header GPIO, Ports- HDMI, 3.5mm analogue audio-video jack, 4× USB 2.0, Ethernet, Display Serial Interface (DSI), Camera Serial Interface (CSI).

The Simulink Model is generated and run on this RPI module. The use of this module provides portability to the system.

B. *Hardware setup configuration*

In order to implement a Simulink model on the Raspberry Pi, the required support packages are installed and Raspberry Pi is selected as target hardware. The Simulink model is built into the Raspberry Pi. For storing the result, .mat file logging is enabled in the target hardware properties.

C. *Simulink model setup*

The Neural Network model is created using a Simulink block and the input data is converted into a time series format. The input to the Neural Network is a column, i.e. the transpose of extracted feature vector of the specific finger print image.

D. *Model configuration parameters*

In order to implement the designed model on the hardware, it is necessary to configure the Simulink to match the hardware specifications of the Raspberry Pi.

E. *Running the model on Target Hardware*

The model is run on the target hardware by using the *external* option. The output can be observed on the Simulink scope. The model can be made standalone by choosing the deploy on hardware option and the output can be observed on the LCD screen.

V DISCUSSION OF RESULTS

The Back-Propagation Algorithm used for training the system uses 48 input neurons, 100 hidden neurons and 10 output neurons. The database of the reduced features based on the Euclidian distance proves to be more useful as it helps reduce the size of vector classification while keeping the same performance for classification. The overall accuracy of the system was found to be 90%. The function used for training in MATLAB is the *trainlm* function. The training algorithms like *trainlm, trainscg* and *trainbr* were compared with variations in parameters like, learning rate, epochs, type of function at the hidden layer and output layer. It was observed that training accuracy of *trainscg* and *trainbr* could be improved by changing various parameters, but *trainlm* offered the best and most accurate predictions. Table 2 shows the comparison in accuracy of the mentioned training algorithms with other parameters kept constant.

TABLE II. PERFORMANCE OF VARIOUS BACK PROPAGATION ALGORITHMS

Various Back-Propagation Algorithms	**Number of Hidden Nodes**	**Accuracy (%)**
Levenberg-Marquardt	100	90.0
	150	88.4
Scaled Conjugate Gradient	100	76.0
	150	76.8
Bayesian Regularization	100	48.3
	150	45.0

TABLE III. COMPASIRON WITH EXISTING SYSTEM

Parameters	**Existing System**	**Proposed System**
Security	System is compromised if attacker gains access to the database.	Highly secure as only trained neural network needs to be stored on the system. Database is stored remotely.
Robustness	Can not tolerate scratches or dirt in fingerprint image.	Can tolerate scratches and dirt to an extent.
Efficiency	Less efficient as existing system compares test data with all the fingerprints stored in database.	Highly efficient because comparison is done by using a neural network which produces results instantaneously.

VI. CONCLUSION

The neural network based system for fingerprint identification was simulated on Matlab/ Simulink. By computing the Euclidian distance between the core and the nearest neighbour bifurcations, it can be observed that the robustness of the system has increased when compared to many other available algorithms that are used in fingerprint authentication systems. The function used for training in MATLAB is the *trainlm* function. It can be observed that the use of this function is best suited for training when compared to the *trainbr, trainscg* functions available. This system would allow us to update the database regularly as needed in applications like the Attendance Monitoring System.

This method of matching fingerprint expressions after enhancement of the poor-quality images provides an output of much higher accuracy. The accuracy of the system is found to depend on various factors like number of iterations, learning rate, orientation of image, hidden layers, quality of image and its processing techniques.

All the components were interfaced appropriately to make a standalone system for fingerprint recognition and periodical update of attendance or similar application.

VII. FUTURE SCOPE

The future scope of this work involves reducing the size of the hardware used in order to make it a compact system which thereby increases the portability. The propose system is a prototype constructed with the use of discrete components which can be further developed into a complete portable module after integrating all the components including the LCD. The database created can be managed by providing remote access to the system. The neural network structure can also be improvised further in terms of computational complexity and speed of operation.

REFERENCES

[1] Debidutt Acharya and Arun Kumar Mishra, “Wireless Fingerprint Based Student Attendance System”, Rourkela-769008, 2010.

[2] Naresh Kumar, Parag Verma- Fingerprint Image Enhancement and minutia matching, International Journal of Engineering sciences & Engineering Technologies, June 2012, Volume 2(3), pp:37-42

[3] Ravi J, K B Raja, Venugopal K R - University Visvesvaraya College of Engineering. “Fingerprint Recognition using Minutia Score Matching” International Journal of Engineering Science and Technology, Vol. 1(2), 2009, Page 35-42

[4] Hamsa A. Abdullah Nahrain University, College of Engineering Journal (NUCEJ) Fingerprint Identification System 234 Fingerprint Identification System Using Neural Networks Vol.15 No.2, 2012 pp234 - 244 NUCEJ Vol.15 No.2

[5] Soni1, Saurabh Verma IOSR Journal of Electronics and Communication Engineering (IOSR-JECE), Volume 11, Issue 6, Ver. IV (Nov.-Dec .2016), pp. 79-82

[6] Navrit Kaur Johal and Prof. Amit Kamra. “A Novel Method for Fingerprint Core Point Detection”. International Journal of Scientific & Engineering Research Volume 2, Issue 4, April-2011.

[7] Seema Singh et al, “Drift fault accommodation system of a transport aircraft using Neural network models”, 2018 IEEE International Conference on Advances in Computing, Communications and Informatics (ICACCI) - Special Session: Mathematical Modeling and Scientific Computing, December 2018. pp 2464-2470.

[8] Seema Singh, V Tejaswini, Rishya P, AmitMutgi, "Neural Network Based Automated System for Diagnosis of Cervical Cancer", International Journal of Biomedical and Clinical Engineering (IJBCE), IGI Publishers, Volume 4, Issue 2, September, 2015, pp 26-39.

[9] Seema Singh, Mamatha K R et al, “Waste segregation system using artificial neural network” selected for International Conference on "Cognitive Science and Artificial Intelligence" (ICCSAI-2017) Helix International Journal, Vol 7, Issue 5, pp 2053-2058

[10] MATLAB help documentation, mathworks 2017

[11] Balti A., Sayadi M., and Fnaiech F. (2012). Improved features for fingerprint identification. MELECON - IEEE Mediterranean Electrotechnical Conference, IEEE Xplore, pp. 878-883, Hamamet, Tunisia

[12] Balti, A., Sayadi, M., and Fnaiech, F. (2012). Reduced features for Fingerprint Characterization. International Review on Computers and Software. Volume 7, Number 6, pp. 37-43, ISSN:1109-2750

[13] Ala Balti, Mounir Sayadi, Farhat Fnaiech- SICISI Unit, High school of sciences and techniques of Tunis (ESSTT), “Fingerprint Verification Based on Back Propagation Neural Network”. CEAI, Vol.15, No.3 pp. 53-60, 2013

[14] Seema Singh et al, “Hardware implementation of a neural network based robust sensor fault accommodation system in flight control system”, International Conference on Intelligent Computing and Control Systems (ICICCS 2017), IEEE conference proceedings pp 962-966

Drift fault accommodation system of a transport aircraft using Neural Network models

Dr. Seema Singh
Assosiate Professor
Dept. of ECE
BMSIT&M
Bangalore, India
seemasingh@bmsit.com

Shashank S
Student
Dept. of ECE
BMSIT&M
Bangalore, India
shash668@gmail.com

Shrisha S Hegde
Student
Dept. of ECE
BMSIT&M
Bangalore, India
shrishashegde02@gmail.com

Tapas Kumar Paul
Student
Dept. of ECE
BMSIT&M
Bangalore, India
tapaspaul6262@gmail.com

Rani Reddy
Student
Dept. of ECE
BMSIT&M
Bangalore, India
ranireddy981@gmail.com

***Abstract* – The primary requirement of safety critical systems is to provide acceptable levels of service even in the presence of stuck and drift faults. It is imperative for control systems such as a Flight Control System (FCS) to detect these faults and accommodate the same. This is best done by neural networks (NNs). The work carried out in this paper lies with the induction of drift faults, and designing a Neural Network (NN) to detect and accommodate the sensor fault. The lateral dynamics of the Boeing 747 jet transport aircraft is used to validate the proposed system. All faulty conditions and models are designed and tested in MATLAB/Simulink.**

Keywords – Drift fault, Knowledge based Neural Network, Flight control system, Sensor fault accommodation, MIMO plant, lateral dynamics, MATLAB, Simulink.

I. INTRODUCTION

Sensors play an important role in almost every system, more so in the case of a Flight Control System (FCS). If these sensors fail during flight, the faulty sensor signals will be fed back to the pilot who would work with these failed sensor values which may lead to the flight flying out of the Safe Region of Operation (SRO). Prevention of such failures in an FCS can be achieved by either building efficient sensors or building more efficient fault detection and accommodation systems.

Traditionally, faults were detected using hardware redundancy methods or analytical redundancy methods. In hardware redundancy, more than one sensor is used for the same parameter measurement; this method leads to increase in power consumption, building cost, volume and weight. In analytical redundancy, a mathematical model of the system is used to generate an estimated signal, which is compared with the actual sensor signal, to give a residual. If the residual is greater than a set threshold value, it is inferred by the system that a fault has occurred.

Popular analytical redundancy methods include, Kalman filters and Luenberger observers. Once the fault is detected using the residuals, reconfiguration of the failed sensor is done by replacing the failed sensor output with the analytically generated sensor output. The sensor estimate of the mathematical model continues to be in feedback, thus receiving healthy sensor data in the feedback loop.

These methods work in case of single sensor failure at any given time. Multiple sensors failing simultaneously can put an aircraft in a highly unstable, unrecoverable state. The accuracy of such sensor fault accommodation system relies heavily on the mathematical model because its estimated signal is used for both sensor fault detection and reconfiguration. Therefore, this method will be sensitive to modelling errors. If the actual system is nonlinear in nature, it is a matter of degree of non-linearity that determines whether this method will be successful in the detection of a failure. These algorithms are reliable only when the system experiences one of the 'n' pre-programmed failures. These models are also subject to changes due to varying flight conditions.

Extensive work has been carried out in the field of fault detection and accommodation using Neural Networks which is given as follows – B. Hardekopf [1] states that the designer has to select a suitable feature followed by identifying and evaluating the thresholds. Georg Jager et al. [2] states that most of the time, a threshold cannot be determined during design-time; this can be solved by using adaptive thresholds or by using filters to generate a residual, which is again used as a threshold to detect faults. Usually, spectral filters are used to detect sensor fault signals too [3].

Artificial Neural Networks (ANNs) are information processing models inspired by the brain. ANNs have been prevalent for their adaptive and non-linear input-output mapping ability [4].

It is stated by Ahmed and El Sayed [5] that, "AI-based methods such as neural networks and fuzzy logic have been prevalent, as these methods have proven to increase reliability and also reduces false alarms". The work carried out by [5]

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involves detecting faults in an automotive internal combustion engine using ANNs.

In paper [6], a detailed analysis of a Fault Detection (FD) scheme applied on an Electromagnetic Suspension (EMS) with 70 fault scenarios is presented. The tests consist of scenarios with a number of typical sensor fault characteristics. The results show that, "a single NN estimator scheme can be used in the Fault Detection and Isolation (FDI) instead of multiple estimators which has less complexity and computational resources. A few simple modifications in the proposed architecture allow the replacement of the bank of estimators with a typical NN". The results show that this new approach has strong potential to replace multiple estimators used in FDI schemes in industrial applications.

Seema Singh et al. [7] presented the simulation of stuck fault for Boeing 747 lateral dynamics using observers to detect and accommodate the stuck fault.

This paper presents the detection and accommodation of drift faults which can be viewed as the generalised case of stuck fault.

II. MATERIALS AND METHODS

The Boeing 747 jet transport aircraft model is the aircraft in consideration throughout the length of this paper. The lateral dynamics of the aircraft takes two inputs (rudder, aileron) and produces 'x' state vector as the output. This vector has four states, viz, $\boldsymbol{\beta}$, $\boldsymbol{\psi}$, $\boldsymbol{\theta}$, $\boldsymbol{\varphi}$. The simplified trim state space model of the aircraft during cruise flight at MACH = 0.8 and H = 40,000ft, is given in the following equations. 'x' is the state vector, $x = [\boldsymbol{\beta}, \boldsymbol{\psi}, \boldsymbol{\theta}, \boldsymbol{\varphi}]^T$, $\boldsymbol{\beta}$: sideslip angle (rad), $\boldsymbol{\psi}$: yaw rate (rad/s), $\boldsymbol{\theta}$: roll rate (rad/s), $\boldsymbol{\varphi}$: bank angle (rad) [8].

$$\dot{x} = Ax + Bu, \qquad y = Cx + Du,$$

$$A = \begin{bmatrix} -0.0558 & -0.9968 & 0.0802 & 0.0415 \\ 0.598 & -0.115 & -0.0318 & 0 \\ -3.05 & 0.388 & -0.4650 & 0 \\ 0 & 0.0805 & 1 & 0 \end{bmatrix}$$

$$B = \begin{bmatrix} 0.00729 & 0 \\ -0.475 & 0.00775 \\ 0.153 & 0.143 \\ 0 & 0 \end{bmatrix}$$

$$C = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$D = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$$

A. Aircraft dynamics

An aircraft has six degrees of freedom coming under two kinds of dynamics – lateral and longitudinal. Longitudinal dynamics involves pitching of the aircraft; lateral dynamics involves yawing and rolling of the aircraft. To keep things simple, this paper deals with only the lateral dynamics – actuating the rudders and the ailerons grounded.

Fig. 1 shows the implementation of aircraft dynamics in Simulink. The state space equations are implemented here. The input is the multiplexed signal of rudder and aileron; A and B matrix are incorporated using a gain block. To extract *beta* and *phi* demux is used.

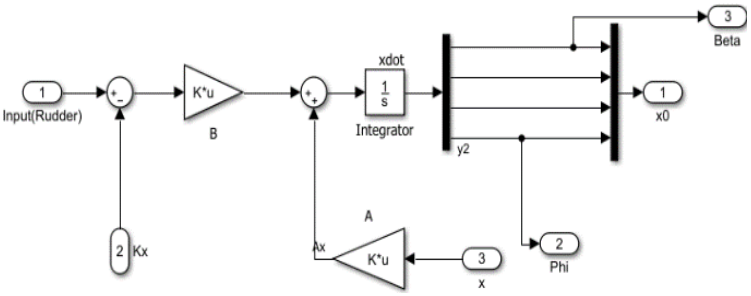

Fig 1. 747 Jet lateral dynamics internal working

B. Aircraft's controller

Flight controller and the aircraft model together forms the FCS. As shown in Fig. 2, controller subsystem is used to provide control law (***Kx***) in the feedback loop of the plant. The 747 jet controller takes two inputs – 'Beta' sensor output value and 'xFaulty' signal. Controller has two tasks:

(i). In case of fault, 'xFaulty' state vector replaces '$\boldsymbol{x}$' state vector and fault propagates with control law signal (K * *xFaulty*) in the feedback loop and creates closed loop instability in all the elements of '$\boldsymbol{x}$' state vector.

(ii). Incorporate reconfigured '$\boldsymbol{\beta}$' state in the feedback loop which is received from 'Reconfiguration' subsystem.

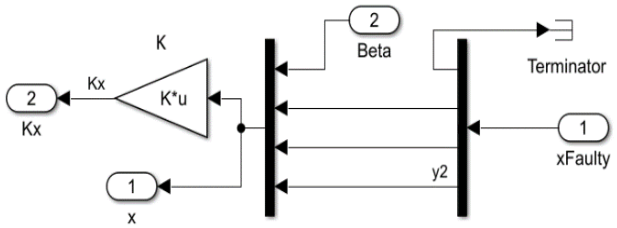

Fig 2. 747 Controller's internal working

C. Fault induction

Fault is a condition where the sensor does not perform as expected. The different kinds of sensor faults are – *drift*, *scaling, noise, hard fault* and *intermittent faults*. This paper only deals with drift faults. Drift fault is a time varying offset from the nominal statistics of a sensor output. The time varying offset can be either linear or non-linear. The general equation for a drift fault is, Y = X + S(t) + noise, where S(t) is the time-varying offset value [9].

Fault is induced by the fault induction model by taking the 'x' state vector and extracting only the '$\boldsymbol{\beta}$' sensor value to induce fault. This is shown in Fig. 3.

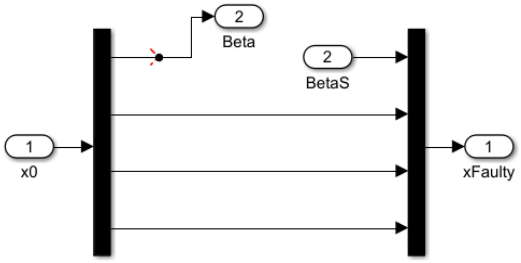

Fig 3. Fault induction model internal working

III. NEURAL NETWORK MODELS

An Artificial Neural Network (ANN) is a computational system inspired from a human/animal brain. A brain consists of millions of structures called neurons with billions of connections amongst these neurons. In an animal/human brain, learning is done through the modification of synaptic weights between the neurons. Similarly, in ANNs neurons learn by the modification of weights. Hence, NNs have a capability to extract meaning from imprecise data. It can be used to extract patterns or features or detect trends in the data that is otherwise not perceived by humans or algorithmic patterns. A trained NN is used to analyze category of information like pattern recognition, image recognition or fault detection and accommodation.

The two kinds of NN models used for fault detection and accommodation in this paper are:

A. Knowledge – based NN model

In this approach the NN is trained with data which has some form of knowledge about the fault. For fault detection training, intermediate signals are used. The data should have certain important features of the faults and signify system behaviour in the presence of faults.

In this paper training data used has enough discrimination power to detect faults which are – *rudder input signal, beta value, phi value* and the *control law* (**Kx**). So the input layer has 5 input nodes. To obtain the number of nodes in hidden layer, training was carried out for 8 to 19 hidden nodes and performance was best for 12 hidden layers. As the output of KBNNFD is to detect presence of faulty signal, only one node is sufficient in the output layer. Finally, the structure of KBNNFD is 5 - 12 - 1. Trainlm algorithm is used to train the neural network.

For the selection of the transfer function for hidden and output layers, the performance of neural networks trained by different transfer function are compared and one giving the best performance is utilised in the model. The performance is best with tansig transfer function, used in hidden and output layers. Tansig is depicted in fig 4.

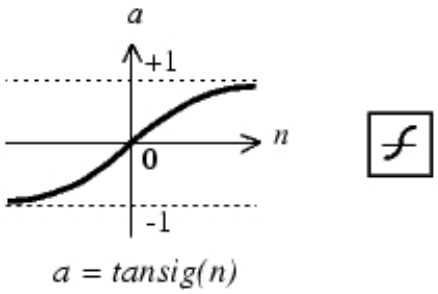

Fig 4. Tansig

B. Model based

This NN model was used to accommodate the fault once a fault was detected by the KBNN. In model-based approach, the NN approximates the functional relationship between the input-output pair of the system; the system can either be linear or non-linear. Input-output pair is similar to those used by traditional full order observers, which assume that at least one of the sensors is healthy and available for observation of the other sensor. Here, ***Φ*** sensor is assumed to be healthy and forms an input for the MBNN.

IV. DRIFT FAULT INDUCTION

As discussed earlier, drift fault is the time varying offset from the nominal statistics of the sensor outputs. A MATLAB Function block from the Simulink library is used, which can be programmed according to our needs by writing a MATLAB script. The model is as shown below. The block is programmed to have four inputs – ***u, t, slope*** and ***d*** where ***u*** is the healthy beta sensor value, ***t*** is the simulation time, ***slope*** is the slope of the drift fault needed to be induced and ***d*** is the time at which the fault is induced. Once these inputs are obtained the fault is calculated using the formula given in section II.

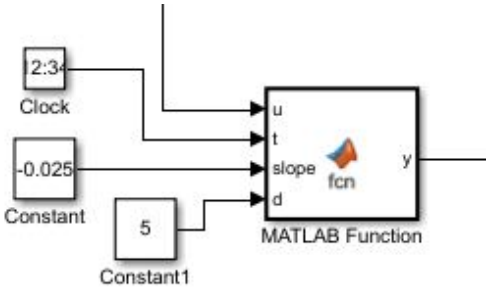

Fig 5. Drift fault Simulink model

The program for inducing fault that is put in MATLAB function block is shown in fig 6.

```
function y = fcn(u,t, slope, d)
    if(t < d)
        y = u;
    else
        y = slope * t - (slope * d) + u;
    end
end
```

Fig 6. MATLAB function

V. SIMULATION SETUP

Figure 7 shows the complete Simulink model NNSFA for drift fault. There are two inputs (rudder and aileron), out of which only rudder input is actuated by a command of '0.3' radians for 8s, from 0s to 8s for the simulation. Aileron input is grounded. Aileron input alone or both the inputs can be excited, if required. '747 jet lateral dynamics' takes the inputs and provides '$\boldsymbol{x}$' state vector. Two of the four states, i.e. $\boldsymbol{\beta}$ & $\boldsymbol{\phi}$ are the outputs of the sensors of the aircraft. Out of the two sensors, '$\boldsymbol{\phi}$' is always considered as fault free, and shown as one of the outputs of aircraft. '$\boldsymbol{\beta}$' sensor failure will be simulated and analyzed in rest of the subsystems of the model. '$\boldsymbol{x}$' vector is fed to 'Fault Induction' subsystem for further simulation. 'Fault Induction' subsystem is used for induction of drift fault of '$\boldsymbol{\beta}$' sensor only. 'MBNN' subsystem estimates the sensor output $\boldsymbol{\beta}_N$ and uses healthy sensor state '$\boldsymbol{\phi}$' from '747 jet lateral dynamics' subsystem and control law '$\boldsymbol{Kx}$' for estimating the sensor state. 'Reconfiguration' block provides the estimated signal from 'MBNN' subsystem instead of faulty sensor signal in the feedback loop. It is done with the help of a switch which switches over to MBNN estimate '$\boldsymbol{\beta}_N$' instead of faulty sensor output '$\boldsymbol{\beta s}$' as soon as fault is indicated by KBNNFD fault indicator signal Km. Controller's tasks are to provide control law '$\boldsymbol{Kx}$' and to incorporate '$\boldsymbol{\beta}$'.

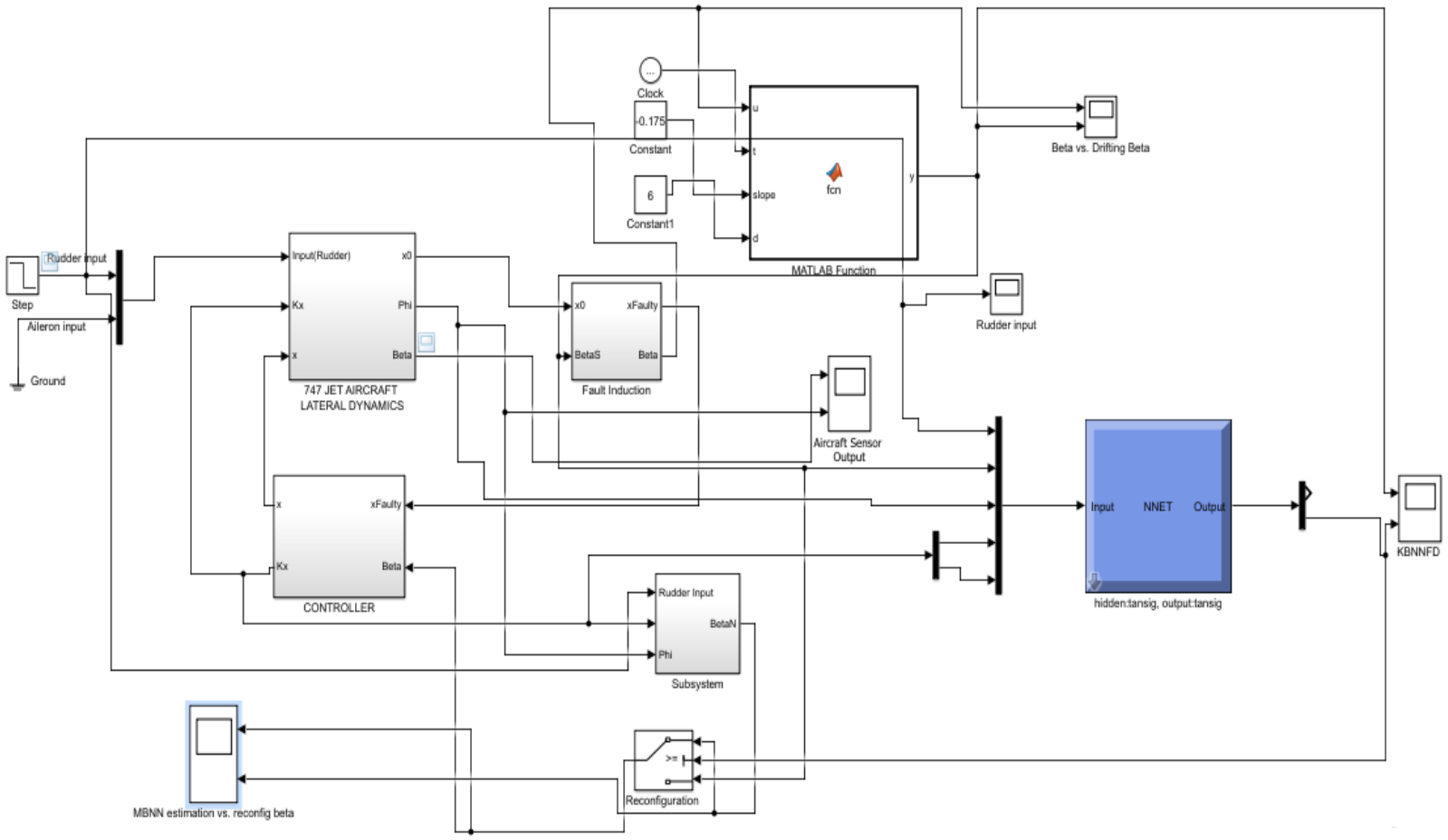

Fig 7. NNSFA Model

VI. DISCUSSION OF RESULTS

The model is designed for inducing fault in $\boldsymbol{\beta}$ and detecting and accommodating the same. The simulation is carried out for 10 seconds. Here few cases are considered in order to understand the relation of slope of drift fault and the delay in detecting the drift fault.

A. Case - I

This is a drift fault of slope = -0.025 at t = 5s, induced by the fault induction block of section IV. The KBNNFD and MBNN output are as shown in figures 8 and 9 respectively. The delay in detection of the fault was found to be 0.34 sec.

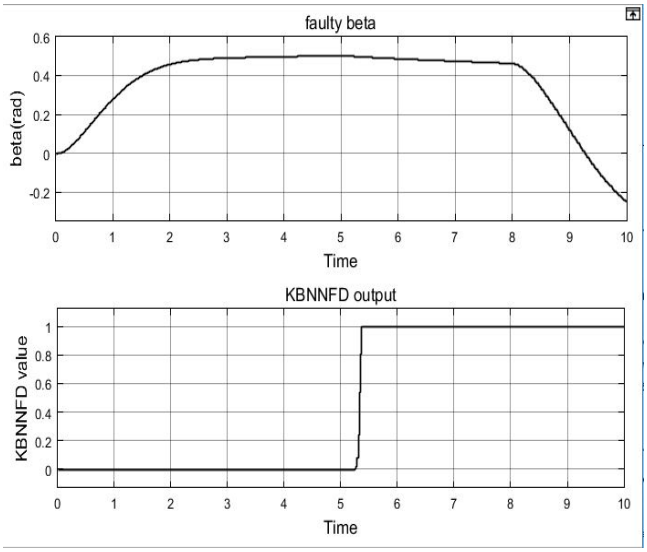

Fig 8. KBNNFD output for case I

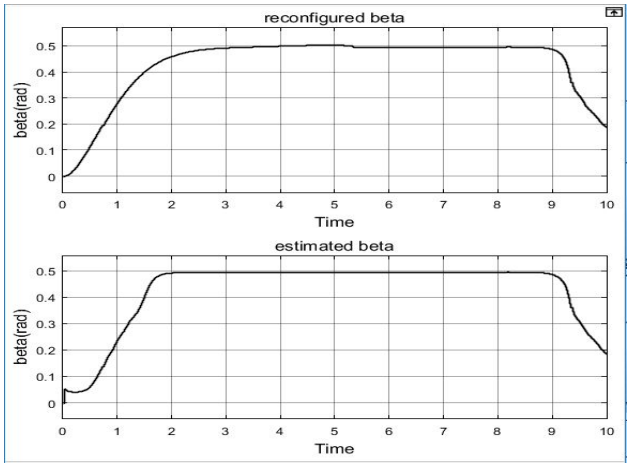

Fig 9. MBNN output for case I

B. Case - II

This is a drift fault of slope = -0.175 at t = 5s, induced by the fault induction block of section V. The KBNNFD and MBNN output are as shown in figures 10 and 11 respectively. The delay in detection of the fault was found to be 0.08 sec.

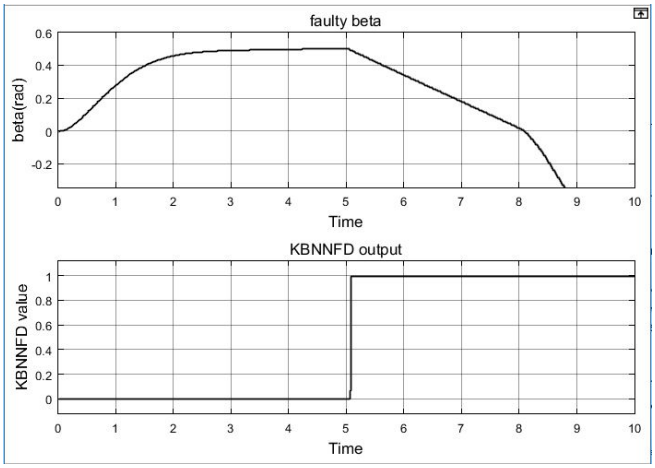

Fig 10. KBNNFD output for case II

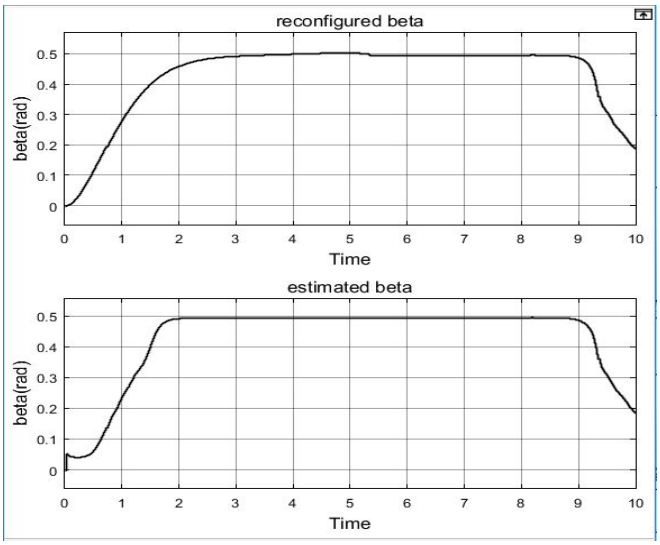

Fig 11. MBNN output for case II

C. Case - III

This is a drift fault of slope = -0.025 at t = 4s, induced by the fault induction block of section IV. The KBNNFD and MBNN output are as shown in figures 12 and 13 respectively. The delay in detection of the fault was found to be 0.48 sec.

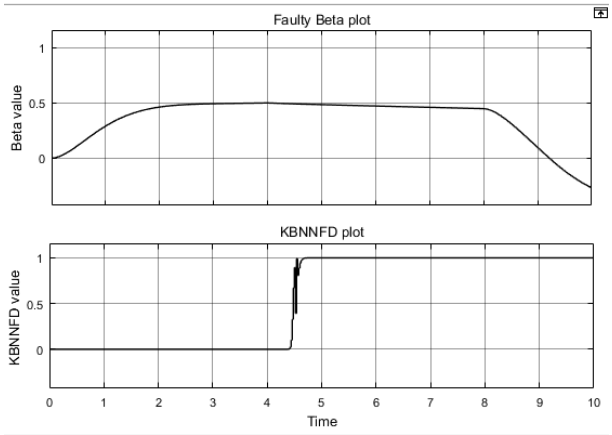

Fig 12. KBNNFD output for case III

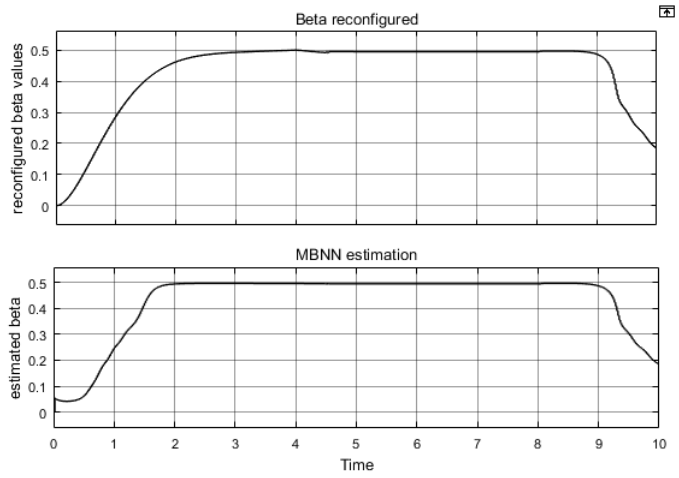

Fig 13. MBNN output for case III

D. Case - IV

This is a drift fault of slope = -0.025 at t = 7s, induced by the fault induction block of section IV. The KBNNFD and MBNN output are as shown in figures 14 and 15 respectively. The delay in detection of the fault was found to be 0.24 sec.

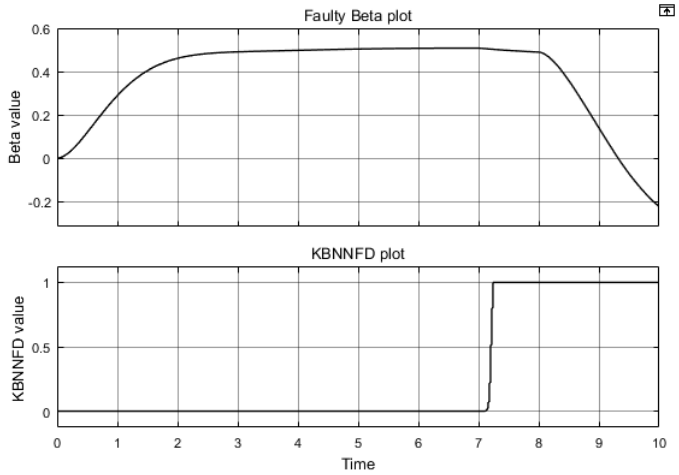

Fig 14. KBNNFD output for case IV

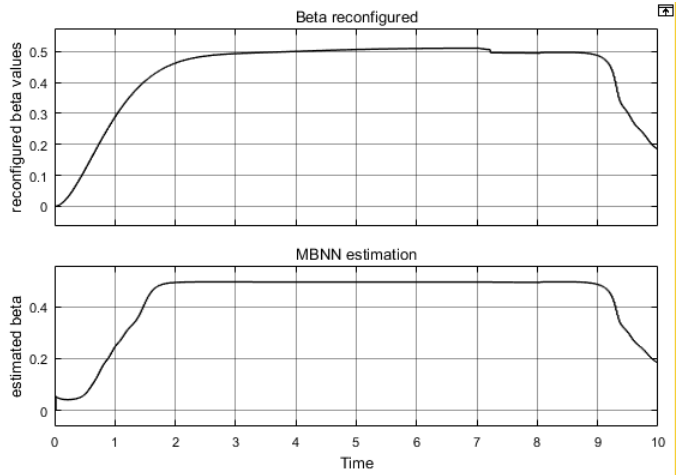

Fig 15. MBNN output for case IV

E. Case - V

This is a drift fault of slope = -0.125 at t = 4s, induced by the fault induction block of section IV. The KBNNFD and MBNN output are as shown in figures 16 and 17 respectively. The delay in detection of the fault was found to be 0.18 sec.

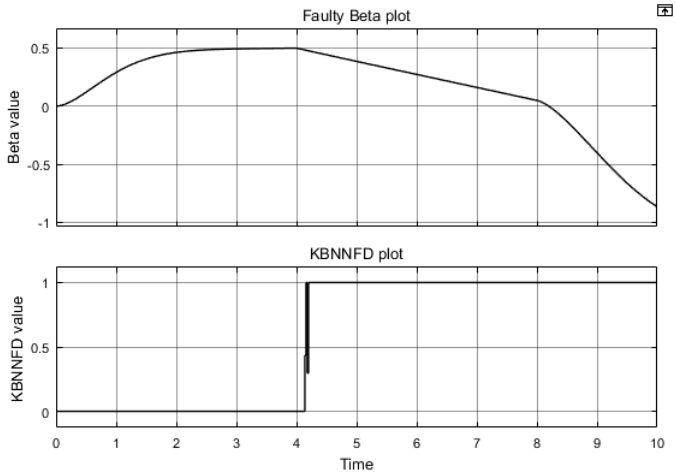

Fig 16. KBNNFD output for case V

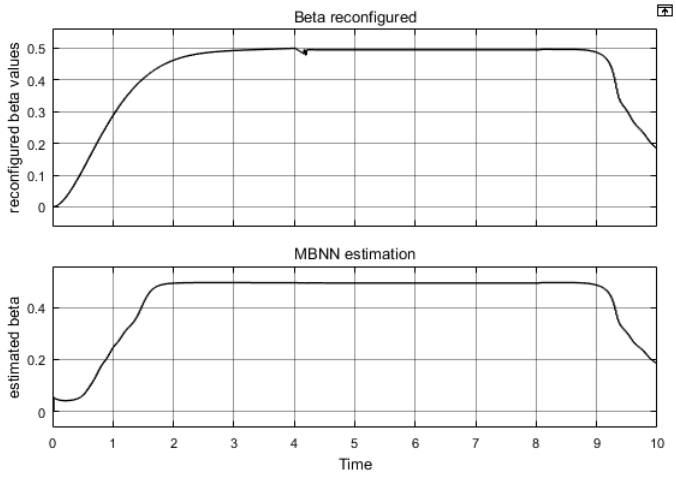

Fig 17. MBNN output for case V

The simulation results presented here indicates that the drift faults with lower slopes are complicated to detect than higher slopes and may take significant amount of time if training of neural network is not appropriate. The time delay for different time instants with different drift slopes is given in table 1.

Slope / Time	-0.025	-0.075	-0.125	-0.175
4 sec	0.48 s	0.22 s	0.16 s	0.12 s
5sec	0.34 s	0.14 s	0.1 s	0.08 s
6 sec	0.28 s	0.12 s	0.08 s	0.08 s
7 sec	0.24 s	0.1 s	0.08 s	0.06 s

Table 1. Delay at different time instants

VII. CONCLUSION

The NNSFA model was modeled on Simulink and the timing constraints were verified on software. The KBNNFD and MBNN were designed to detect drift faults and reconfigure drift fault affected sensor values. The KBNNFD had some delay which is not significant enough to affect the flight operations. The MBNN had a few fluctuations in the plot but once again not significant enough to affect the flight.

Future work for this paper would be design and train a NN which can classify and detect different faults. The work can be extended more than one unhealthy sensor. To take the work further the whole NNSFA can be implemented on hardware to check the timing constraints in real – time.

REFERENCES

[1] B. Hardekopf et al., "Secure and fault-tolerant voting in distributed systems," in Proceedings of IEEE Aerospace Conference, vol. 3, 2001.

[2] Georg Jager, Sebastian Zug, Tino Brade, Andr´e Dietrich, Christoph Steup, Christian Moewes, "Assessing neural networks for sensor fault detection" Int. Conf. Comp. Intell. Virtual Env. Meas. Sys. App., pp. 70–75, May 2014.

[3] J. E. White and J. L. Speyer, "Detection filter design: Spectral theory and algorithms," IEEE Transactions on Automatic Control, vol. 32, no. 7, pp. 593–603, 1987.

[4] Z. Runxuan, "Efficient Sequential and Batch Learning Artificial Neural Network Methods for Classification Problems," Singapore, 2005.

[5] Ryan Ahmed, Mohammed El Sayed, S. Andrew Gadsden, Jimi Tjong, and Saeid Habibi, "Automotive Internal Combustion Engine Fault Detection and Classification using Artificial Neural Network Techniques", Journal of IEEE transactions on vehicular technology, 2013.

[6] K. Michail, K. M. Deliparaschos, S. G. Tzafestas, and A. C. Zolotas, "AI-based actuator/sensor fault detection with low computational cost for industrial applications," IEEE Trans. Control. Syst. Technol., vol. 24, no. 1, pp. 293–301, Jan. 2016.

[7] Seema Singh, T.V. Rama Murthy, "Simulation of sensor failure accommodation in flight control system of transport aircraft: A modular approach", World journal of modeling and simulation, vol.11 (2015), No.1, pp.55-68.

[8] Seema Singh, T.V. Rama Murthy, "Neural network-based sensor fault accommodation in flight control system", Journal of intelligent systems 2013; 22(3): 317-333.

[9] Edward Balaban, Member IEEE, Abhinav Saxena, Member IEEE, Prasun Bansal, Kai F. Goebel, and Simon Curran, "Modeling, Detection, and Disambiguation of Sensor Faults for Aerospace Applications" IEEE sensors journal, 2009, pp. 1907 – 1917.

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Blocking Probabilities, Resource Allocation Problems and Optimal Solutions in Cognitive Radio Networks: A Survey

Mallikarjuna Gowda C.P
Department of TCE
B.M.S Institute of Technology,
Bengalur, India (Affiliated to VTU, Belagavi)
cpmallikarjunagowda@bmsit.in

Vijaya Kumar T
Department of ECE
S.J.B Institute of Technology,
Bengaluru, India (Affiliated to VTU, Belagavi)
tvijaykumar@sjbit.edu.in

***Abstract*— The limited electromagnetic radio spectrum can be managed efficiently to accomplish the requirements of various users by the use of cognitive radio networks (CRN). Resource allocation (RA) models established and explored by various researchers around the world are seems to be varied and there is no continuity that bring consistency and clarity in thoughts. In this paper we addressed this problem and methods established for solving RA difficulties in CRN are deliberated. The proposed optimal solution models are gathered and categorized based on certain exceptional criteria, and their advantages and drawbacks are emphasized. The Performance parameters like blocking probability is evaluated for the tandem network and are estimated using the first fit method and the random assignment methods. The blocking probabilities are calculated for both PU and SU using MATLAB.**

Key words*— Cognitive radio networks, Resource allocation, Optimization, Blocking Probability.

I. INTRODUCTION

Spectrum scarcity problem due to the increasing demand for wireless communication has grown from time to time, and it is not expected to reduce any time; research disclose that the problem is not due to inadequate spectrum, then it is due to inefficient utilization of the allotted spectrum by current networks; a significant resolution to this problem is to allocate the spectrum dynamically and reclaim of a spectrum space by more than one proprietor by a technique called dynamic spectrum access (DSA); This new DSA paradigm can be realized by cognitive radio networks (CRN), which is accomplished by superior ways of handling the spectrum [1]. The architectural categorization defined in the literature categorizes CRN as i) centralized, distributed or mesh [2–5]. ii) primary-secondary networks (underlay [6], overlay [7, 8] and hybrid networks [9]) iii) cooperative and non-cooperative [10 - 13]. In this paper, the important features of resource availability and the several approaches established to legally use the inadequate resources for CRN are discussed. This paper is structured as follows: Section - II provides an indication on resources in CRN; Section – III offers a report of resource problem originations in CRN; Section IV deliberates the different methods established and engaged by investigators in exploring results for their resource exploitation difficulties in CRN; lastly, the concluding opinions are delivered in Section V.

II. RESOURCE ALLOCATION IN CRN:

The resources like electromagnetic spectrum, bandwidth and power which are used in wireless communication form the pillar on which the tasks of such systems depend. The wireless communication system developers had mechanisms in their design by which their limited resources are to be assigned, to achieve the maximum in their operations. In CRN, RA strive for addressing the challenges in assigning the limited resources, like frequency band, sub channels and time slots etc., in a way that is impartial to all users in the network. RA problems in CRN are solved by using the methods: i) Rate adaptive ii) margin adaptive [14, 15]. The reasons for which RA problems in CRN are more difficult compared to other wireless networks are as follows: i) likely variations in the available spectrum [16]. ii) Challenge related with seeing CRN as a heterogeneous network. iii) Inadequacy in networking and throughput of CRN.

III. RA PROBLEM FORMULATION IN CRN:

The different investigations have shown that, RA difficulties are established as optimization problems in CRN, which are defined as non - deterministic polynomial-time hard (NP-hard) optimization difficulties. NP-hard difficulties can be resolvable in polynomial time and purely by a non-deterministic algorithm. Evolving universal RA prototypes in CRN with condensed computational difficulties and can provide results in time, is a budding issue. Discovering significant and suitable approaches to solve RA difficulties in CRN is a stimulating study. A survey of the methods [35] established by various investigators in the arena is addressed in this paper.

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IV. CATEGORIZATION OF RA SOLUTIONS IN CRN:

The different methods to solve RA problems in CRN are:

- Classical optimization techniques;
- Study of problem structure;
- Heuristics or meta-heuristics (global optimization);
- Game theory (multi-objective optimization);
- Soft computing-based optimization.

A. Solutions using Classical Optimization:

RA difficulties in CRN can be established as i) linear programming problem ii) non – linear problem. In [17], simplex approach is used to find optimal solution to their frequency-time allocation problem. When SUs are permitted to transmit in coherence with PUs the difficulty of combined transmit beam forming and power control of SUs are solved by using interior point approach [18]. Lagrangian duality technique [12, 48] can be used for solving convex optimization problems, if RA problem is non-linear and obeys convexity. RA problems in CRN are solved by using the following methods: branch-and-bound [29], branch and-cut [46], lift-and-shift [47], dual decomposition [11], barrier method [13,14], gradient decent approach [15], etc. The drawbacks of these methods are as follows: i) not suitable to any regular optimization model, ii) non-linear programming problems obeying convexity is huge iii) finding solutions with these methods require high complications and calculation period.

B. Solutions by Studying Problem Structure:

1) Solution by Decomposition or Separation:

A unique RA problem may be divided into many modest problems and solved each separately, with a reduced amount of effort. The results are joined to provide the absolute answer to the original problem. Primal-dual decomposition technique is used for finding optimal solution to their RA problem by decomposing it into discrete power allocation sub problems [34]. In [35], the authors established a CRN complement method that disintegrated their usefulness maximization difficulty into

- Optimizing SINR assignment
- Power
- Interference temperature.

In [33] the problem of channel assignment, spectrum sensing, and power allocation in cellular CRN is addressed using decomposition method. Without losing optimality the mixed integer non-linear programming difficulty was disintegrated into optimal: i) channel assignment ii) spectrum sensing iii) power allocation. The major benefit of this technique is computational complexity is reduced. Drawbacks are every difficulty cannot be decomposable, and several difficulties loose significant meaning when tried to be disintegrated into minor problems.

2) Solution by Linearization:

In CRN RA problems are typically non-linear in nature. The non-linear optimization problem occurs when linearity of the constraints or objective function may not be known. In [27], RA problem is solved by using combinations of linearization, relaxation and reformulation techniques. The logarithm function is used to transform the non-linear function into linear form in the linearization part. The benefit of this method is the simplicity. The major task with this method is that, very difficult to find an equivalent linear functions when certain functions appear in the constraints or objective function of RA difficulties in CRN.

3) Solution by Relaxation:

Difficulties with channel distribution are binary in nature that is by assigning the value of 1 or 0, when the channel is allocated or not allocated to the user respectively. The difficulties may be solved by permitting the decision variable or relaxing integer constraints [27]. The main problem with this method is suboptimal results can be achieved.

4) Solution by Approximation:

It is very difficult to solve problem when definite functions, acting in the objective function that extract linear, nonlinear or a convex problem. Finding solutions can be simple, if an estimated standby to such functions may be acquired. Simply a suboptimal solution to the unique problem can be realized. The advantages due to the approximation of such functions are significant reduction in complexities of calculations, problem investigates and time to arrive at results. To exploit total network efficacy, a piece-wise linear function is estimated as efficacy function and suggested for solving an LP-based cluster allocation algorithm [19]. Drawback of this method is that the estimated novel function might have additional variables, causes to raise in the resolution variables of the problem.

5) Solution by Reformulation:

A reformulation of the novel problem without losing its details may be misused by proper identification of different stuffs of the problem. It is simple version of the novel problem, classical optimization tools may be used in obtaining sustainable results [26, 28]. Optimization of radio resource practice in heterogeneous cognitive wireless networks were established [28]. The benefit of a

reformulation method is with much less computational complexity an optimal solution can be obtained for very difficult problems. The disadvantage of this technique is the difficulty in discovery of exceptional structure that can be optimistic.

C. *Solutions by Heuristics or Meta-Heuristics:*

The answers to the RA difficulties in CRN by means of heuristics are problem-specific and offer suboptimal results. The benefits are results may be achieved at reduced time frame and the difficulties in obtaining solutions by using classical optimization may be solved by evolving heuristic. Solving RA problems in CRN using heuristics are as follows:

1) *Greedy algorithms:* It is established in such a way that it chooses whatsoever is presently or instantly the best next step, irrespective of some better steps later [12,19,20].

2) *Water-filling schemes:* It is established from the knowledge of the water jug problem [24]. The techniques are simple to progress and very near to optimal solutions with condensed complexities can be obtained.

3) *Pre-assignment and re-assignment algorithms:* In pre assignment, definite quantity of resources, like sub channel or power are primarily pre-allocated as base resources to all users in advance the other resources are optimally pooled between the remaining users. More resources are allocated to all users to accomplish a greater total capacity for each run of the algorithm. The algorithm checks after each run that the constraints are not violated and a reallocation of resources is again approved to pursue to increase the total usefulness of the network [25, 26].

4) *Recursive – based / iterative – based heuristics:* The distribution of resources by using these techniques to all users in the network is carried out either recursively or iteratively. Selection structure and repetition structure are used by recursion and Iteration methods respectively. These techniques gradually rise efficacy till further minor amount of improvement results in either iteration or recursion techniques [27,28]. Meta-heuristics is an algorithm designed to solve nearly a wide range of hard optimization problems [29]. Illustrations of meta-heuristics used for RA in CRN are as follows:

5) *Genetic algorithms (GA):* GAs are used by describing resources in the form of chromosomes and genes and the users QoS requirements are given as input to the algorithm procedure. In [30, 31] improving spectrum allocation, utilization in CRN is achieved using genetic algorithm.

6) *Simulated annealing:* An optimal temperature is found by iterative controlled 'heating' and 'cooling' of the search space, which corresponds to an optimal utility. This method used in solving distribution or efficacy expansion problems in CRN [32, 33].

7) *Evolutionary algorithms:* Mimicking the development of discrete structures via methods of collection, recombination and mutation imitation, for generating better results. Illustrations are ant colony, coco search, bee colony, particle swarm optimization, etc.

8) *Tabu searches:* It uses the past of the hunt, to discharge from local minima and to implement an explorative approach. The distinctive of this method is based on the use of mechanisms encouraged by the human memory [36]. The drawbacks with these approaches are the scarcities in analytical depictions of the difficulties and the non-transferability of the information developed in solving a problem.

D. *Solutions by Multi-Objective Optimization:*

A method of concurrently optimizing many contradictory objectives, subject to certain restrictions are solved by using game theory [37], which converts multi-objective problems into single-objective optimization difficulties by using methods such as Min-Max method, reducing dimension the virtual target method, sequencing method, feasible direction method, interactive programming method etc.

E. *Solutions through Soft Computing:*

Computer - based programming is used in assigning resources to customers inside the network. The established programmes use smart methods such as neural networks, artificial intelligence, fuzzy systems and Q – learning in motivating the optimization methods [32]. An artificial intelligence method is used in evolving a decision-making tool for assigning resource in CRN [33]. Spectrum assignment in CRN using fuzzy neural system is proposed in [34].

V. SIMULATION RESULTS:

In this section, simulation results are presented for two algorithms based on first fit, random assignment for primary units allocation and secondary units allocation. The models are simulated for a tandem networks that has the 10 nodes, 10 channels with 3 Erlangs of load per link and 20 nodes, 11 channels with 5 Erlangs of load per link. In both the cases, the number of PU calls are 80% of the total calls received. That means, for 2000 iterations, there are 2000 calls received, of which 1600 calls are PU calls

and the remaining 400 calls are SU calls.

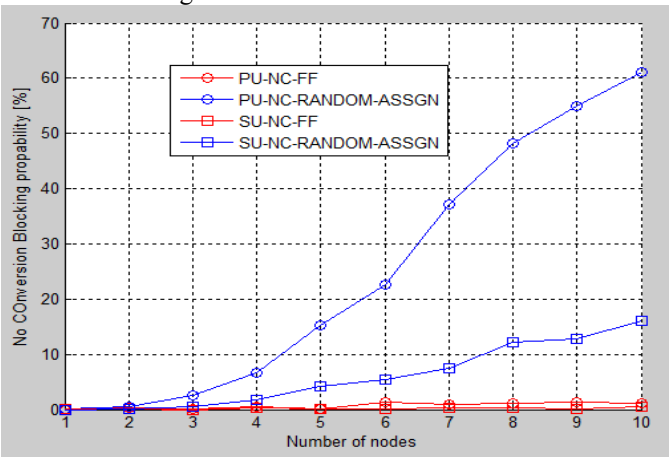

Figure 1: Blocking Probability of First Fit and Random Distribution for a load 3 Erlangs per link and with 10 Channels, 10 Links (nodes) and 2000 iterations

The call is said have been blocked when there are no free channels available for assignment in a link. The blocking probability is calculated using

$$P_{blocking} = \frac{N_{block}}{N_{gen}} \quad (1)$$

where

$P_{blocking}$ is the blocking probability,

N_{block} is the number of calls blocked and

N_{gen} is the number of calls generated.

The blocking probability can be calculated using the infamous Erlang B formula

$$P_{blocking}(L,C) = \frac{\frac{L^C}{C!}}{\sum_{j=0}^{C} \frac{L^j}{j!}}$$

where

$P_{blocking}(L,C)$ is the blocking probability,

L is the load and

C is the number of channels or wavelengths.

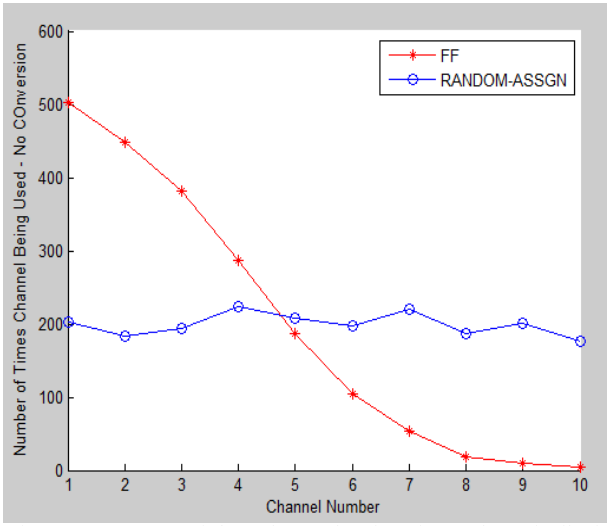

Figure 2: Frequency of channel usage by First Fit, Random Distribution for a load 3 Erlangs per link and with 10 Channels, 10 Links (nodes) and 2000 iterations

Fig. 1 shows the blocking probability of the PU and SU assignment with first fit and random assignments. The network has 10 Channels, 10 links and there was a load of 3 Erlangs per link. It can conclude from Fig. 1 that the random assignment has higher blocking probability than that of the fit method both for the PU and SU. However the problem with first fit method is, the channels in the tail end of the frequencies are not utilized to its capacity. There is always more utilization on the channels near the head end of the sequence of channels.

It can be observed from Fig. 2 that with first fit method, channel 1 is used 500 times for assignment and Channel 2 is used 440 times, whereas the channels 7, 8, 9 and 10 are used less than 100 times. In case of the random assignment, all channels are used approximately 200 times, but the blocking probabilities are high as shown in Fig. 1, i.e. 62% for PU and 17% for SU. In case for First fit, it is 3% and 1.5% respectively for PU and SU.

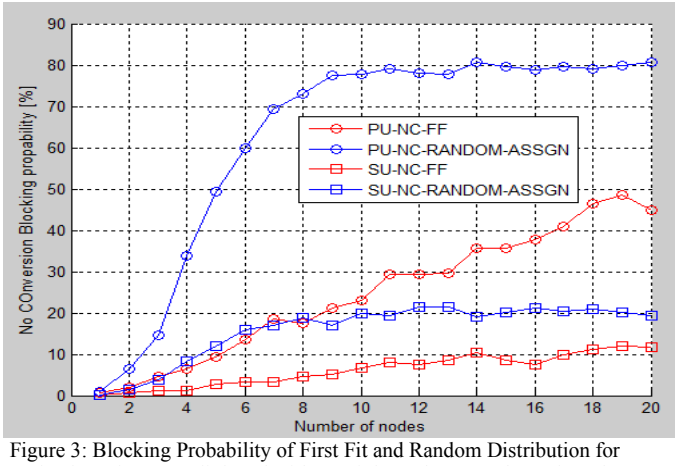

Figure 3: Blocking Probability of First Fit and Random Distribution for a load 5 Erlangs per link and with 20 Link (nodes), 11 Channels and 2000 iterations

When the load is increased to 5 Erlangs per link in a 20 links and 11 channel networks, the blocking probabilities are very high with 80% for PU and 20% for SU, as shown in Fig. 3, when the random assignment was used. In case of first fit assignment, it is 45% for PU and 12% for SU. The increase in the blocking probabilities can be attributed to the high load on each link. The frequency distribution of channel assignment is provided in the Fig. 4.

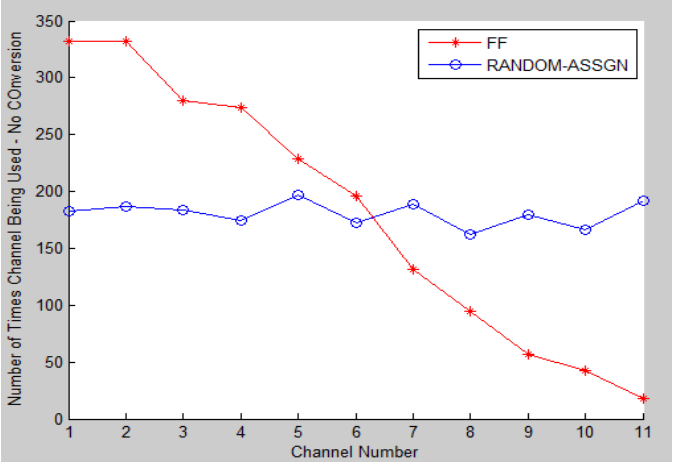

Figure 4: Frequency of channel usage by First Fit, Random Distribution for a load 5 Erlangs per link and with 20 Links (nodes), 11 Channels and 2000 iterations

In both the simulations, it can be observed that the first fit assignment method has lower blocking probabilities compared to that of the random assignment both for PU and SU. Since in this case, the SU are assumed to be 20% of the total calls, and PU is 80%, the blocking probabilities in PU is high and that has been demonstrated in the Fig. 1 and 3. The First fit assignment method always considers the first channels in the order at the time of each assignment and there will always be some free channels at the tail end of the channel sequence. Hence the FF method has very low blocking probabilities compared to the random assignment methods.

VI. CONCLUSIONS

A survey of the key methods for Resource allocation in Cognitive Radio Network, as engaged by many investigators in the arena, delivered. The survey finds the significant challenges with RA in CRN, different thoughts, techniques engaged by investigators in pursuing feasible results to the RA difficulties in CRN and the Performance parameters like blocking probability is evaluated for the tandem network and are estimated using the first fit method and the random assignment methods. The blocking probabilities are calculated for both PU and SU using MATLAB.

REFERENCES

[1] L E Doyle, Essentials of Cognitive Radio. The Cambridge Wireless Essentials Series (Cambridge University Press, New York, 2009)

[2] K-C Chen, Y-J Peng, N Prasad, Y-C Liang, S Sun ,in Proceedings of the second International Conference on Ubiquitous Information Management and Communication. ICUIMC'08. Cognitive radio network architecture: Part ii –trusted network layer structure (ACM, New York, 2008), pp.120–124.

[3] C Xin, X Cao, in Global Telecommunications Conference, 2009. GLOBECOM, 2009, IEEE. A cognitive radio network architecture without control channel, (2009), pp. 1–6.

[4] S Senthuran, A Anpalagan, O Das, Throughput analysis of opportunistic access strategies in hybrid underlay overlay cognitive radio networks. IEEE Trans. Wirel.Commun.11(6),2024–2035(2012).

[5] H Xu, B Li, Resource allocation with flexible channel cooperation in cognitive radio networks, IEEE Trans. Mob. Computing 12(5), 957–970 (2013).

[6] J-C Liang, J-C Chen, Resource allocation in cognitive radio relay networks. IEEE J. Sel.AreasCommun.31(3),476–488(2013).

[7] Z- QLuo, WYu, An introduction to convex optimization for communications and signal processing. IEEE J.Sel. Areas Commun.24(8),1426–1438(2006).

[8] Y Rahulamathavan, K C umanan, S Lambotharan, in Signal Processing Advances in Wireless Communications (SPAWC), 2010 IEEE Eleventh International Workshop On. Optimal resource allocation techniques for MIMO-OFDMA based cognitive radio networks using integer linear programming, (2010), pp.1–5.

[9] Z Mao, X Wang, Efficient optimal and suboptimal radio resource allocation in ofdma system. IEEE Trans. Wirel. Commun.7(2),440–445 (2008).

[10] M- S Cheon, S Ahmed, FAl- Khayyal, A branch-reduce-cut algorithm for the global optimization of probabilistically constrained linear programs. Math. Program.108(2), 617–634(2006).

[11] C Shi, YWang, PZhang, in Global Communications Conference (GLOBECOM), 2012 IEEE Joint spectrum sensing and resource allocation for multi-band cognitive radio systems with heterogeneous services, (2012), pp.1180–1185.

[12] RXie, FRYu, HJi, Dynamic resource allocation for heterogeneous services in cognitive radio networks with imperfect channel sensing. IEEE Trans. Veh.Technol. 61(2), 770–780 (2012).

[13] S Wang, M Ge, C Wang, Efficient resource allocation for cognitive radio networks with cooperative relays. IEEE J. Sel. Areas Commun.31(11), 2432–2441(2013).

[14] S Du, F Huang, S Wang, Power allocation for orthogonal frequency division multiplexing-based cognitive radio networks with cooperative relays. IET Commun. 8(6), 921–929(2014).

[15] W-CPao, Y-FChen, Adaptive gradient-based methods for adaptive power allocation in OFDM-based cognitive radio networks. IEEE Trans.Veh. Technol. 63(2), 836–848(2014).

[16] S Kim, B G Lee, D Park, Energy-per-bit minimized radio resource allocation in heterogeneous networks. IEEE Trans. Wirel.Commun.13(4),1862–1873 (2014).

[17] S Bashar, Z Ding, Admission control and resource allocation in a heterogeneous OFDMA wireless network. IEEE Trans. Wirel. Commun. 8(8), 4200–4210(2009).

[18] S Cicalo, V Tralli, Adaptive resource allocation with proportional rate constraints for uplink SC-FDMA systems. IEEE Commun. Lett. 18(8), 1419–1422(2014).

[19] M H Hassan, M J Hossain, Cooperative beam forming for cognitive radio systems with asynchronous interference to primary user. IEEE Trans. Wirel. Commun. 12(11),5468–5479(2013).

[20] M Pischella, J-C Belfiore, Distributed margin adaptive resource allocation in MIMO OFDMA networks. IEEE Trans. Commun. 58(8),2371–2380 (2010).

[21] Y T achwali, F Basma, H H Refai, Cognitive radio architecture for rapidly deployable heterogeneous wireless networks. IEEE Trans.Consum. Electron. 56(3), 1426–1432(2010).

[22] P Li, S Guo, W Zhuang, BYe, On efficient resource allocation for cognitive and cooperative communications. IEEE J. Sel.Areas Commun.32(2), 264–273(2014).

[23] M Hasegawa, H Hirai, K Nagano, H Harada, K Aihara, Optimization for centralized and decentralized cognitive radio networks. Proc. IEEE.102(4), 574–584(2014).

[24] Y Rahulamathavan, S Lambotharan, C Toker, A Gershman, Suboptimal recursive optimization frame work for adaptive

resource allocation in spectrum-sharing networks. IET Signal Process. 6(1),27–33(2012).
[25] P Mitran, L BLe, C Rosenberg, Queue-aware resource allocation for downlink OFDMA cognitive radio networks. IEEE Trans. Wirel. Commun. 9(10), 3100–3111(2010).
[26] E Driouch, W Ajib, A Ben Dhaou, in Computing, Networking and Communications (ICNC), 2012 International Conference On. A greedy spectrum sharing algorithm for cognitive radio networks, (2012), pp.1010–1014.
[27] T Peng, W Wang, QLu, W Wang, in Wireless Communications, Networking and Mobile Computing, 2007. Wi Com2007. International Conference On. Subcarrier allocation based on water-filling level in ofdma-based cognitive radio networks, (2007),pp.196–199.
[28] A Alshamrani, XShen, L-L Xie, Qos provisioning for heterogeneous services in cooperative cognitive radio networks. IEEEJ.Sel. Areas Commun. 29(4),819–830(2011).
[29] R Meng, YYe, N-g Xie, in Intelligent Control and Automation (WCICA),2010 8th World Congress On. Multi-objective optimization design methods based on game theory, (2010),pp.2220–2227.
[30] DN Nguyen, M Krunz, in Global Communications Conference (GLOBECOM), 2013 IEEE. Heterogeneous spectrum sharing with rate demands in cognitive MIMO networks, (2013),pp.3054–3059.
[31] R Xie, F R Yu, H Ji, in Communications (ICC), 2012 IEEE International Conference On Spectrum sharing and resource allocation for energy-efficient heterogeneous cognitive radio networks with femto cells, (2012), pp.1661–1665.
[32] R Xie, F R Yu, H Ji, Y Li, Energy-efficient resource allocation for heterogeneous cognitive radio networks with femto cells. IEEE Trans. Wirel. Commun.11(11),3910–3920(2012).
[33] .M Venkatesan, A Kulkarni, Soft computing based learning for cognitive radio. Int.J.Rec.TrendsEng.Technol.10(1),112(2014)
[34] Y Huang, J Wang, H Jiang, in Networks Security Wireless Communications and Trusted Computing (NSWCTC), 2010 Second International Conference On. Modeling of learning inference and decision-making engine in cognitive radio, vol.2, (2010), pp.258–261.
[35] Babatunde S. Awoyemi, Bodhaswar T.J. Maharaj and Attahiru S.Alfa, Solving resource allocation problems in cognitive radio networks: a survey. EURASIP Journal on Wireless Communication and Networking, 2016.
[36] M-SCheon, SAhmed, FAl-Khayyal, A branch-reduce-cut algorithm for the global optimization of probabilistically constrained linear programs. Math.Program.108(2), 617–634(2006).
[37] M Bocus, J Coon, C Canagarajah, J McGeehan, S Armour, A Doufexi, Resource allocation for OFDMA-based cognitive radio networks with application to h.264 scalable video transmission. EURASIPJ. Wirel. Commun. Netw. 2011 (1), 245673 (2011).
[38] L Wang, W Xu, ZHe, J Lin, in Power Electronics and Intelligent Transportation System (PEITS), 2009 2nd International Conference On. Algorithms for optimal resource allocation in heterogeneous cognitive radio networks, vol.2, (2009), pp.396–400.

ATTACK RESISTANT SECURE KEY MANAGEMENT IN WIRELESS SENSOR NETWORKS

Siddiq Iqbal[1], Prerana.S[2], Priyanka.M.N[3],Sukrutha.H[4],Ganesh PurushottamShanbhag[5]
[1,2,3,4,5]Dept of TE, BMS Institute of Technology and Management, Bengaluru
[1]siddiq@bmsit.in,[5]alvganeshps@gmail.com

***Abstract*- A sensor node has limited security so it needs effective key distribution and management mechanism for secure communication. This paper aims at proposing the Secure Key Management in WSN. The main objective is to evaluate and enhance certain issues like attack on the nodes, security in communication between the nodes, energy consumption and throughput. The concept of communication between the nodes using keys and establishing a secure connection helps in securing the network. The scheme used in our paper to secure the network is Advanced Blom's Single Space Key Distribution.**

Keywords: Security, Impact of attacks, Throughput and Residual energy.

I. INTRODUCTION

To establish communication through the radio channel in Wireless sensor network large number of micro sized sensor nodes are used as multi hop communication points. In modern society Wireless sensor networks find wide range of applications such as health care, environment, agriculture and military. Key management scheme includes key creation, distribution of key, updating keys and mechanism post node setup.In a wireless network, sensor nodes are self-dependent very small objects.The key management scheme supports three types of keys to secure message communicationthrough encryption between pair of nodes.They are the pair wise,group and network keys.The network key is used to encrypt the broadcast messages and also authenticate fresh nodes joining the network. All the nodes in a cluster have common shared group key. The shared pairwise key is used for communication by node pair [1].

Wireless Sensor Networks consists of Sensor Nodes (SNs) which consists of a single or a multiple hop localized routes which are used to sense the environment of importance and report the monitoring data to the Base Station (BS) [2].

WSN nodes are susceptible to various attacks namely capture attack, data movement jamming and denial of service due to wireless connectivity, arrangement and close interactions with their physical surroundings. As a result, any communication in the network has to be secured. For securing the communication in between nodes, the basic requirement is to distribute cryptographic keys during initial setup [3].

Several key management schemes have been proposed for WSN's. These can be divided in to two broad categories. The first category is that of key pre-distribution techniques where the secret keys are selected from a key pool and distributed to the sensor nodes before the nodes are deployed. The second category is that of key computation. The key computation is based on some mathematical concept such as matrix and polynomials [4].

Pair wise schemes have been proposed in which a node store***(n-1)*** unique keys. This scheme provides sufficient Security as the compromise of any single node will not reveal the secrets of any other node. However, as the number of nodes increases the system fails to scale as more memory will be required to store the keys. [5]. As a solution to a variety of real-world challenges, the use of wirelesssensors is increasing due to the fact that they provide real-time monitoring and are potentially low-cost solutions. The sensors are vulnerable to be physically attacked when sensors are deployed in severe environment. Encryption keys must be established among sensor nodes before a WSN can exchange data. Hierarchical key management scheme can save the computing power and transmitting energy [6].

Compared to traditional sensors, the Wireless network is better as they are built using sensor nodes which are small, with limited processing and computing resources. From the environment and based on some local decision process or application of the network deployed in the area,these sensor nodes can sense, measure, and gather information, they can transmit collected data to the user or sink node[7].

The sensor networks are prone to different types of malicious attacks when sensor networks are deployed in an antagonistic environment. An adversary easily listens to traffic; impersonate one of the network nodes. Communication should be encrypted and authenticated to provide security. Key agreement problem has been widely studied in general network environments. There are three types of general key agreement schemes: trusted-server schemes, public-key schemes, and key pre-distribution schemes [8].

For ensuring revocation connectivity between nodes on the lower level of the network architecture, IoT relies on wireless sensor networks (WSNs).Key protocols can be classified into centralized and distributed protocols. The central entity decides to revoke certain keys or nodes in the network in the centralized mode. The distributed mode is faster and requires less messages to send, but is more complex to implement [9].

Intermediate network nodes should combine results from individual sensors to conserve power. The summary of the important information from a group of sensors is obtained from aggregation. It collects results from several sensors and calculates a smaller message. This group operation needs secure group communications. For secure group communication in WSN, Group key establishment is the bottle neck[10].

Constraints that make conventional security impractical inWSNs are: Limited battery lifetime, as well as the limited memory and computation capacity. Mainly the focus of the protocols should be on the conservation of energy. Nodes are not able to memorize keys of significant size, or carry out complex protocols in the majority of WSN's.Toextend this lifetime, and prolong network functionalities conserving node energy is important[11].

According to whether rekeying is done before or after the key distribution, the key management could be classified into static and the dynamic key management. The dynamic key management is more appropriate for the long-lasting networks than the static key management which has dynamic and extendibility properties [12].

In this Paper, we have presented the Secure Key Management scheme which is based on Blom's Single space key management for key generation and distribution. Vulnerability of the nodes tophysical capture, Insecurity of the data transmission, Limited memory resources and the complexity in the inclusion of the nodes at later stages is considered.

WSNs can be divided into homogeneous sensornetworks and heterogeneous sensor networks (HWSNs). The nodes ina homogeneous sensor network have the samestructure, but in a heterogeneous sensor network (HWSN),the nodes adopt different structures according to their different tasks. HWSNs have many unique advantages overhomogeneous sensor networks, and thus have been widelystudied and applied. [13]

The rest of the paper is organized in the following order. In section II the preliminaries are presented. Secure key management for the wireless sensor networks is proposed in section III. Performance metrics and simulation results are presented in the section IV and finally section VI presents the conclusion.

II. PRELIMINARIES

BLOM'S SINGLE SPACE KEYDISTRIBUTION SCHEME

An exposed problem is to how to achieve unthreatened communications between the sensor nodes in the network and how to set up secret keys between the communicating sensor nodes.

This kind of problem is known as the key agreement problem, which has beenwidely studiedin general network environments. Thethree types of general key agreement schemes aretrustedserver schemes, publickey schemes, and key pre-distribution schemes.

The trusted serverschemes are dependentupon a trusted server for key agreement between the sensor nodes.This kind of scheme is not suited for sensor networksas, in the places where WSNs are deployed,it cannot be generally assumedthat any trusted infrastructure is in place.Public-key schemes are dependedupon asymmetric cryptography and they require some sort of public-key infrastructure to be in place. Pre-distribution schemes are used where key information is distributed to all sensor nodes prior to deployment. This scheme seems most appropriate for WSNs compared to the others.

Blomhas proposed a key pre-distribution scheme where any pair of sensor nodesare allowed in a sensor network which can establish a pair wise secret key. Anypair of nodes can find a secret pair wise key between the pair by the key pre-distribution scheme presented by Blom. This scheme has a requirement for nodes to store λ+1 key, where λ *is less than N*. Unlike the (N -1) pair wise key scheme, this scheme is not cent percent resilient against capturing the node. Instead it has the following λ-secure property: till an adversary is compromised at most, uncompromised nodes, nodes aresecure. When there is an adversary compromise more than λ-nodes, all pair wise keys in the entire network are compromised.

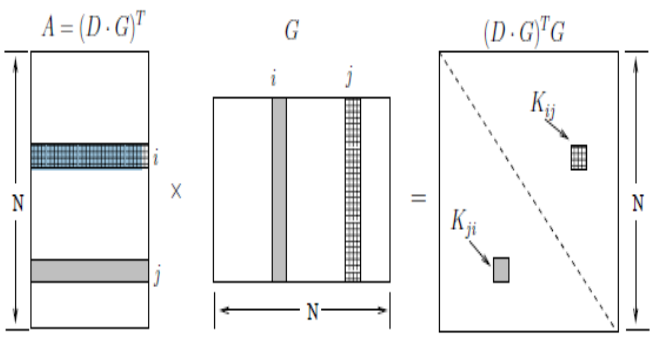

Fig. 1. Generating Keys in Blom's Scheme

The threshold λis treated as a security parameter in which the selection of a larger λleads to a more secure network. However, λalso determines the amount of memory required to storekey information, as increasing λleads to higher memory usage. The goal of our scheme is to increase the network's resilience against node capture in a probabilistic sense without using too much memory.Blom's scheme uses singlekey space to ensure that any pair of nodes can compute a shared key.

A trusted party gives every participant a secret key and a public identifier, which will enable any two participants to independently create a shared key for communicating with each other. But, if an attacker can compromise the keys of at least k users, they can break the scheme and reconstruct every shared key. Blom's scheme is a form of threshold secret sharing.

Now, we shall briefly describe how the Blom'slambda based secure key predistribution system will work:

1) Firstly, in the initialization phase, matrix G of order a ((λ+1) x N) is constructed over a finite field GF (q) by the base station, where the network size N and q greater than N. Matrix G is the public information matrix; the contents of G can be discovered by any sensor nodes, and even the malicious nodes areallowed to know G.

2) Then, a random symmetric matrix D of order (λ+1) x (λ+1) is created by the base station over GF (q).
3) Later, the base station calculates matrix A of order N x (λ+1)= $(D\cdot G)^T$, where $(D\cdot G)^T$ is the transpose of D·G. Matrix D will be kept secret, and it will not be exposed to any other node.
4) A·G is a symmetric matrix. If K = A·G, and as already known $K_{ij}= K_{ji}$, where $K_{ij}$is an element in K located in the i^{th} and j^{th}, row and column. $K_{ij}$is used as the pairwise key between i and j sensor nodes.
5) At first, the sensor nodes interchange their columns of matrix G when the pairwise key is established amongst the nodes i and j, and later the nodes compute $K_{ij}$and K_{ji}, accordingly, by utilizing their private rows of matrix A. The columns of G matrix can be transmitted in plaintext as it is public information.

MILLER-RABIN PRIMALITY TEST

To check ifthe given number is prime or notprime ,primality test is used. In general, prime factors cannot be generated using primality test, this testcan only state whether the given number is prime or not,unlike in integer factorization. Computationally factorization is known to be a hard problem, butprimalitytesting is reasonably easy. The number is prime or composite can be proved by using some primality tests.

Miller-Rabin primality test has been named after Michael Rabin and Gary Miller. In 1980 Rabin discovered a randomized polynomial-time algorithm to checkif a number is prime, which was closely related to the study carried out by Miller in 1976 on deterministic algorithm.

Miller Rabin is relatively simple additionto Fermat's little Theorem that allows us to test for primality with a muchhigher probability than Fermat's little theorem. Although there exist many primality test algorithms this proves to be most practical.

Compared to other primality test algorithms Miller Rabin test is faster in testing the large numbers. It is also referred as Rabin-miller test.Others tests such as Fermat and Solovay-Strassen tests are comparable to the current algorithm .

This test depends on equality or set of equalities that holds true for prime values, then verifies if it holds true for the given number, that is being tested for primality.

This algorithm is most practical known primality testing algorithm. RSA encryption is used in different software libraries, these libraries use primality testing algorithm, an example for this is Open SSL. Miller Rabin proves that the number is composite, unlike other primality tests which prove that a given number is prime.So, instead of calling this as primality test, it can be called as compositeness test.

All composites are detected by miller Rabin test. There may be at least 75% (Miller Rabin) numbers which are rare witnesses of compositeness, for each composite number n.

Miller Rabin is relatively simple extension of Fermat's little Theorem that allows us to test for primality with a much higher probability than Fermat's little theorem.

The probability for a composite number to be declared prime can be used to detect the miscalculation made by the primality test.

By trying all possible values below a certain limit, the Rabin algorithm can be made deterministic. The test is still reliable if the problem in general is set to a limit.

In practice, we can implement the Miller-Rabin test as follows:

1) Given n, find s so that $n-1=2^sq$ for some odd q.
2) Choose a random $a \in \{1,...,n-1\}$
3) If $a^q=1$ then n is passed (later exit)
4) For i=0,..,s−1 see if $a^{2^sq}=-1$. If so, nis passed (later exit).
5) Or else n is composite

VANDERMONDE MATRIX:

Vandermonde matrix is named after Alexandre - Théophile Vandermonde. It is a matrix with the terms of a geometric progression. It is $m \times n$ matrixfor all indices i and j.

$$V = \begin{bmatrix} 1 & \alpha_1 & \alpha_1^2 & \dots & \alpha_1^{n-1} \\ 1 & \alpha_2 & \alpha_2^2 & \dots & \alpha_2^{n-1} \\ 1 & \alpha_3 & \alpha_3^2 & \dots & \alpha_3^{n-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1 & \alpha_m & \alpha_m^2 & \dots & \alpha_m^{n-1} \end{bmatrix}$$

Fig 2.Vandermonde matrix

The Vandermonde matrix evaluates a polynomial. It is the matrix of the linear map that maps the vector of coefficients of a polynomial to the vectorof the polynomial at the values appearing in the Vandermonde matrix.

III. PROPOSED METHODOLOGY

1. BASIC SCHEME

The formation of sensor nodes in the network WSN's can be classified as hierarchical and flat networks. The nodes are divided into several clusters and each cluster has a head in a HWSN. A cluster head which leads a group of general sensor nodes plays the head of the cluster network. Every node reportsto a base station (BS) through cluster head. They communicate with neighbors and transmit data to BS one by one. The hierarchical WSN has better scalability. However, a cluster head handles the keys of all nodes of the same cluster. Serious problems might arise in the cluster when the head is compromised or damaged.

It becomes important to encrypt and authenticate the messages communicated between sensor nodes, to achieve security in wireless sensor networks. The keys for performing encryption and authentication must be agreed by the communicating parties.Due tolarge amount of memory and network, Pre-distribution of secret keys for all the node pair is not viable.

Sensor networks have various requirements:

1) Integrity: Data integrity ensures that the data obtained by the recipient node is same as the data sent by the sender node and is not altered by any adversary.
2) Authentication and Confidentiality: Authentication before data transmission between the two nodes (sender and receiver) must be done. Receiving node must be ensured that the data is sent from a trusted node and not from any malicious node. Also, the data that is sent must not be exposed to any other nodes and must be received only by the authenticated receiver.
3) Reliability, Availability and Resiliency: It ensures that the data is available to access at all times required by the authorized nodes and also the proper connectivity of the nodes. This ensures protection and security from attacks such as denial of service attacks.
4) Data freshness: It is ensured that only fresh data should be delivered to the nodes.

In this paper, we provide a skeleton in which wemake use of key pre-distribution scheme which considerablyprovides the improvisedflexibility of the network as compared to the previous schemes.

The probability of communication between the alive nodes is compromised to zero closely when the total count of compromised nodes does not cross the threshold.

KEY GENERATION AND DISTRIBUTION PHASE

In the key pre-distribution phase, the key setup server first constructs a (λ+ 1) X n matrix G over a finite field Fq = GF(q), where q is prime and n is the number of sensor nodes which is considered in the network. Here G is considered as public information, that is, any sensor node can know the contents of G and even adversaries are allowed to know G.

Then the setup server generates a random (λ+ 1) X (λ+ 1) symmetric matrix D over GF(q) and computes another matrix A as A = (D.G)T , where $(D.G)^T$ is the transpose of the matrix D.G. We note that A is of order n X (λ+ 1). Matrix D is kept secret and thus it is not disclosed to any sensor node also. We see that A .G = $(D.G)^T$.

$G = G^T .D^T . G = G^T .D. G = (A. G)^T$,since D is a symmetric matrix. Thus, A .G is also a symmetric matrix of order n X n. If we let K = A. G and $K = (k_{ij})_{nxn}$, then we have $k_{ij} = k_{ji}$. Finally, the setup server loads the following information's to each deployed sensor node i (i = 1, 2... n):

i. i-th row of matrix A.
ii. j-th column of matrix G.

After the deployment every node in the wireless network locates the address of its physical neighbors within its range of communication. The columns of G matrix should be exchanged between the sensor nodes and then using their private rows of matrix A, whenever the nodes I and j want to establish a pair wise secret key between them, the secret keys (**k_{ij} and k_{ji})** can be calculated respectively.

Since the matrix K is symmetric, so $k_{ij} = k_{ji}$.

Since matrix G is public, the matrix columns of the nodes can be communicatedonly in plaintext. The computed key k_{ij} (= k_{ji}) can be stored for later use such as secret communications by i and j nodes. If any λ+1 columns of G are linearly independent, then this scheme proves that it isλ–secure. When no more nodes are compromised, the λ–secure property assures that no nodes apart from i and j can calculate their secret key (k_{ij} or k_{ji}).

If 64 bit key length is used, then the value of q should be such that it is the smallest prime number greater than 264, in the finite field GF(q)each pair wise key is denoted by an element. Let g be chosen as a primitive element belonging to GF (q) and n < q.

We can design a possible G as follows: when g_1, g_2, g_3... g_n are all distinct,it can be proven that any λ+ 1 columns of G are linearly independent.The λ value can increase the security property but it is not feasible due to limited sensor node memory.

$$G = \begin{pmatrix} 1 & 1 & 1 & \cdots & 1 \\ g & g^2 & g^3 & \cdots & g^n \\ g^2 & (g^2)^2 & (g^3)^2 & \cdots & (g^n)^2 \\ & & \vdots & & \\ g^\lambda & (g^2)^\lambda & (g^3)^\lambda & \cdots & (g^n)^\lambda \end{pmatrix}.$$

Fig 3. Generated matrix

2. ATTACK INTRODUCTION PHASE

Security has a vital importance in wireless sensor networks. Adversaries can introduce various kinds of attacks and for countering these attacks cryptography is used. Sensor nodes are deployed in unfavorable and unreachable area. Nodes can be physically taken into captive or damaged by attackers as it is not possible to find the location of the node post deployment.

Due toverylimited resources like bandwidth, energy, processing and data storage capabilities of nodes in WSNs, traditional security techniques cannot be applied directly. The sensor node has less hardware which is not competent of executing security protocols with are highly complex.The two attacks which we have introduced in our scheme are exhaustion attack and identity replication attack.

There are various types of attacks in WSN's:

1. **EXHAUSTION**:To consume all the resource energy of the victim node, by obliging it to perform calculations or to transceive unnecessarily data.

2. **IDENTITY REPLICATION ATTACK**: Attacker can clone nodes, and place it in different part of the network in order to collect majority of information traffic. It is based upon giving the same identity to different physical nods. The attack can be mounted because in a WSN there is no chanceof knowing that a wireless sensor node is compromised.

3. **TAMPERING:** Result of physical access of the node by an attacker; thegoal of this attackis to recover the cryptographic data like the keys used for ciphering.

4. **BLACK HOLE**: A node alters the routing information to indulgethe passage of the data by itself. The mission is to clone a sink or black hole in the network.

5. **SELECTIVE FORWARDING**: A node acts as a router, the malicious nodes may refuse to forward certain messages and simply drop the data which is to be sent to the destination node.

6. **SYBIL ATTACK**: Attacker can steal and use the identities of the random nodes in order to take part in distributed algorithms such as the election.

SECURITY PARAMETERS

Wireless Sensor Networks which has limited storage, processing power, bandwidth, and energy require a special security approach. The security requirements of networks concerning availability, integrity, confidentiality, freshness, authentication, access control, and non-repudiation has difficulty hardware and energy constraints of the wireless sensors.

Availability: The availability gives time of response of the system to transmit information from one source to the good destination. The other meaning of availability is that the services of network are available to the authorized parts if necessary and ensures the services of network in spite of Denies of Service attack (DoS).

Integrity: Integrity is a service which guarantees that the during transmission the data are not being modified. Integrity also protects the network against the modification of messages.

Confidentiality:Confidentiality is the guarantee that the information of a sensor node is not available or revealed only with its recipient or the receiver.

Freshness: Some measurements in time is provided in WSNs; we must make sure that each message is fresh. The freshness of data infers that the data are new, and it ensures that no adversary or attacker can replay the previous messages.

Authentication: An adversary cannot simply limit or modify the message. He can add additional messages. So, the receiver must make sure that the data which is being used come from the correct source. The authentication is necessary for many tasks in addition to the construction of WSNs.

Access control:Access control gives to the legitimate participants a qayto detect the messages which comes from the external sources of the network.

Non-repudiation: Itensures that the source origin of a message data cannot deny having sent the message before.

PROPOSED SCHEME

Freshness of keys is introduced in the scheme to make the existing scheme more efficient in terms of security. Matrix generation process is the same as in the Blom's scheme. Here the Matrix G(public info matrix) is generated once at the Base Station but the remaining matricesD(private info matrix), K(symmetric key matrix)and A are generated again and again for every single round. The sensor nodes send data repeatedly to Cluster Head when all the sensor nodes present in the particular cluster have finished sending data then it is termed as one round. Hence, even though the malicious node attacks the network and steals the key by eavesdropping it will not be able to use any of keys as the key value would have changed by the time the malicious node tries to communicate hence it fails to attack.

Each sensor node has a unique key which will be generated and distributed using Blom's Key pre-distribution scheme. Beforecommunicating Node sends the node ID and keys to the Cluster head.The CH then creates the (λ+1)rows and 'N' number of columns. The first row will be selected and the first column key will be distributed to the first sensor node.

In the similar manner, for all the N number of SN's N number of keys will be generated and distributed which are unique in nature for the first round. The communication happens in this manner for the total number of rounds.

Suppose a cluster has 10 nodes, each node communicates and sends the data one by one. The CH recalculates the key values again using the matrix based key generation scheme and regenerates the (λ+1)rows and 'N' number of columns. Before the next round begins the CH distributes all the keys again and then starts the communication.

In such a case if the malicious node when it attacks the network will not be aware of the changed value of the key and tries to communicate with the cluster head using the previous key itself. Then the CH gets to know about the node transmitting the data with the unchanged key value.

For the same node ID's the present key value would not have changed which is an indication of the identity replication attack. Whenever there is replication the packets will be dropped by the CH as it finds out the malicious attack. Hence, the network is made secure against the Identity replication attack.

Only way for the malicious node to disturb and interfere in the communication is to make the packet drop happen and drain out the resources of the attacked sensor node which is termed as the Exhaustion attack.

At the same time, if the other node sends the data then they collide with each other and the packet drop happens. That particular sensor node does not receive the ACK packet. So,the SN sends the packet again and hence, the packets sending ratio will be increased. Hence, the residual energy decreases at a faster pace.

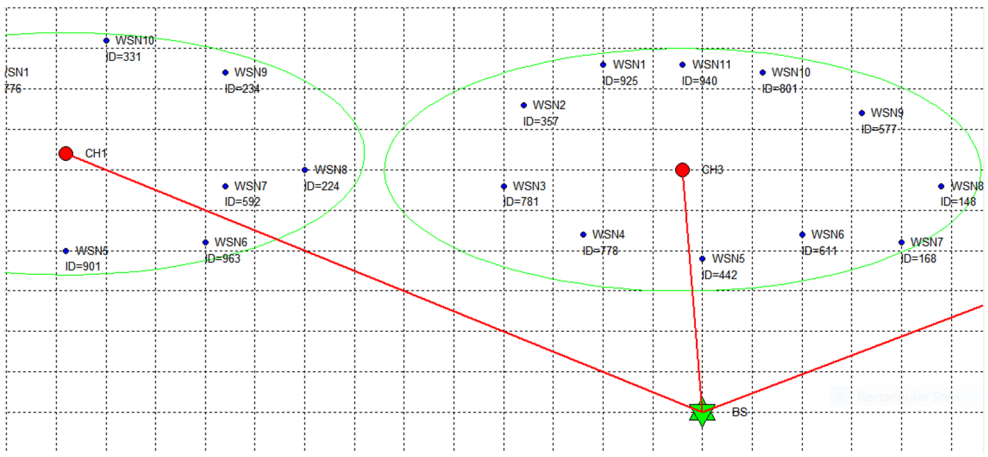

Fig 4. Network Model consisting of 2 Clusters

The fig 4 shows the network deployment of a hierarchical WSN consisting of a base station, two clusterswith unique IDs assigned to sensor nodes respectively. The base station is at the center of the network between two cluster heads.

IV.SIMULATION RESULTS:

The tool used for performance evaluation is MATLAB. A network is considered here, Cluster heads are 2 in number, maximum number of sensor nodes in each cluster are 10& 12 respectively. 500 number of rounds was taken and nodes with initial energy of 0.5J.

The proposed scheme is executed and the average results with graphs are provided. The simulation results are compared with and without security for the impact of attacks.The parameters considered for performance evaluation are:

1. ***Residual Energy***: The energy remaining in a sensor node after each round.
2. ***Throughput***: The rate of successful message delivery over a communication channel.

GRAPHS PLOTTED WITH AND WITHOUT SKM:

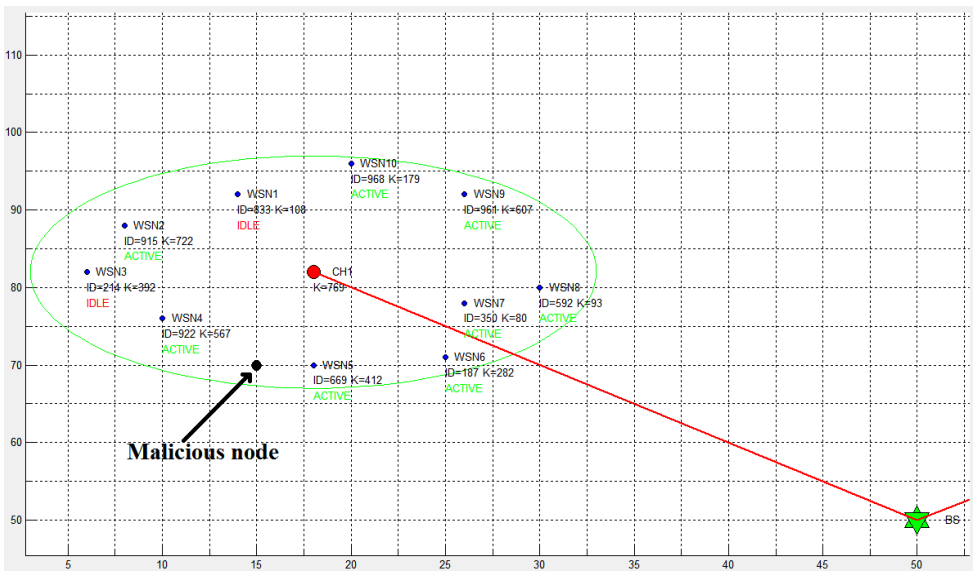

Fig.5.Closer view of the network on which malicious node is placed. It shows the IDLE nodes

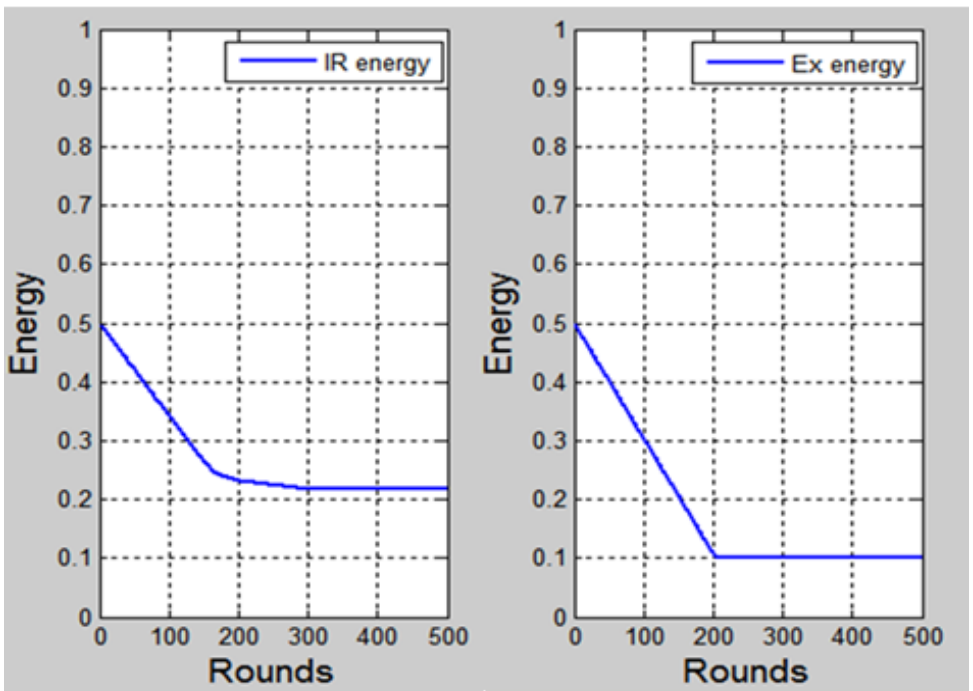

Fig 6. Comparison of energy between Identity Replication attack and Exhaustion attackwithout SKM(Secure Key Management)

The fig6 shows thatin identity replication attack and exhaustion attack there will be a few IDLE nodes, As SKM is not introduced in the network, there are more changes of theft so energy of overall network will decrease as all sensor nodes are not working.

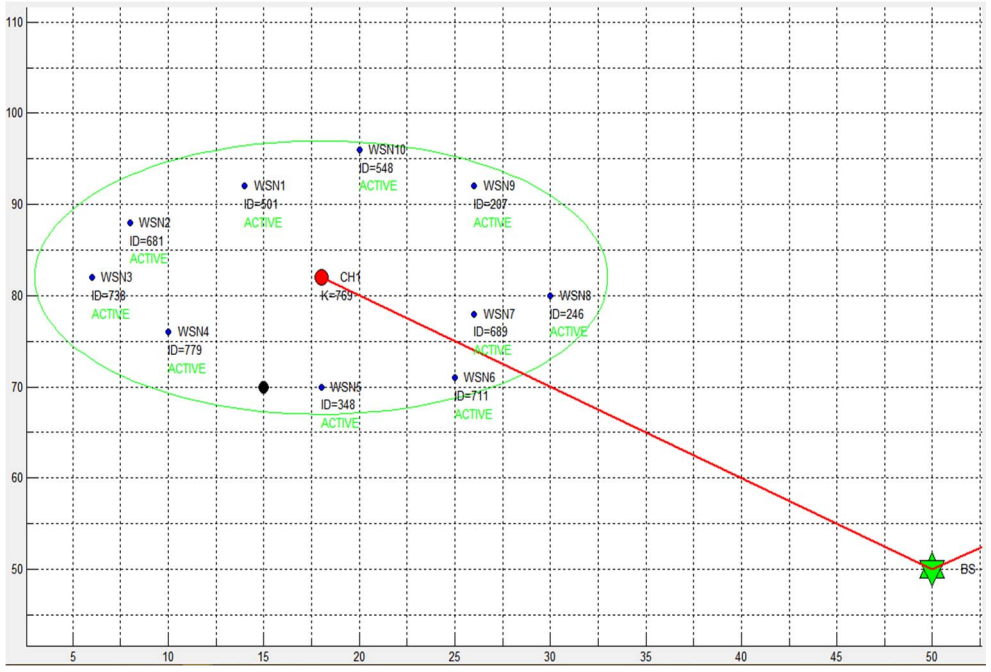

Fig 7. Closer view of network on which SKM is introduced

The figure 7 shows the cluster on which malicious node is placed (black in color). Since the introduction of SKM there will not be any IDLE nodes as there are less chances of making any nodes IDLE by a malicious node.

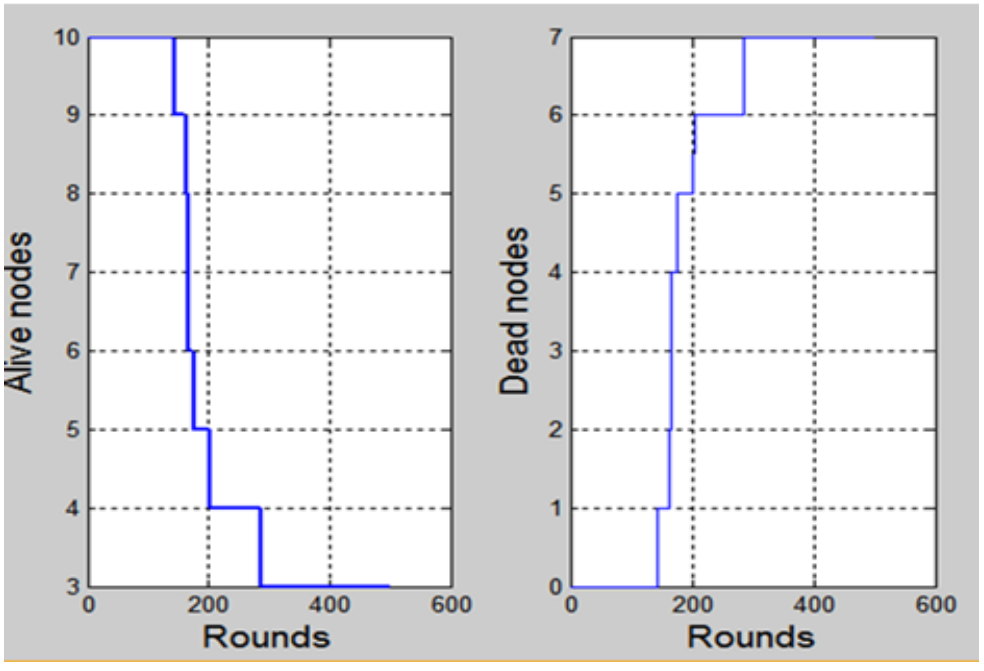

Fig 10.Alive nodes and Dead nodes v/s rounds

The fig10 shows thealive nodes are the nodes which are alive in the network and are ready to take part in communication whereas the dead nodes are dead and they cannot take part in the communication.

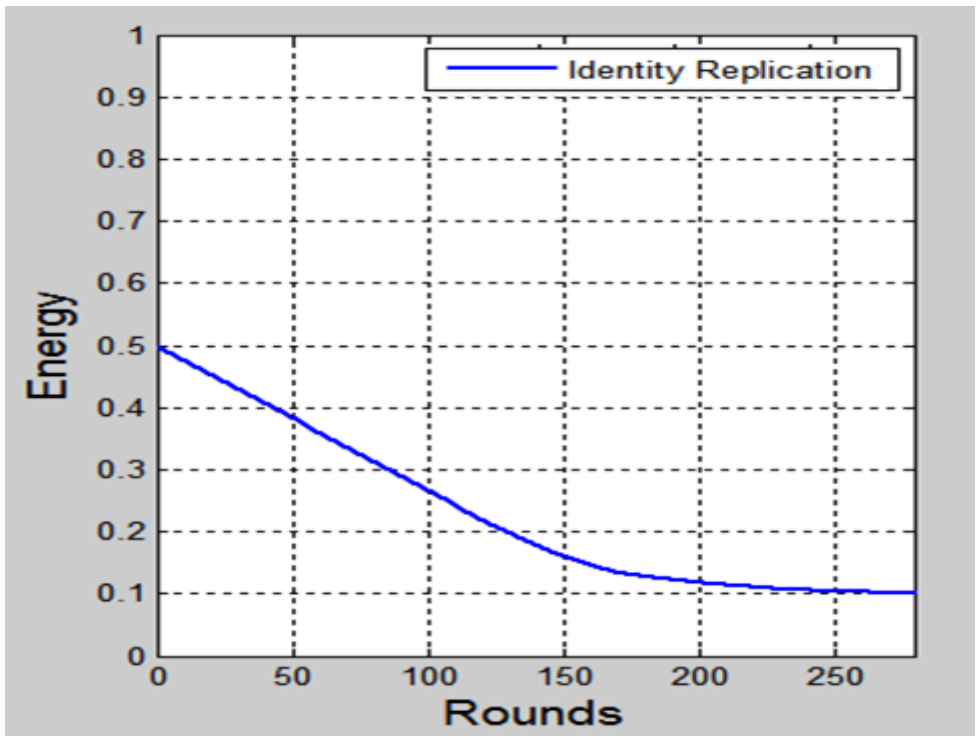

Fig 8. Identity Replication Attack v/s rounds with SKM(Secure Key Management)

The fig8 shows thatin identity replication there will not be any IDLE nodes. So, energy of overall network will decrease drastically as all sensor nodes are working.

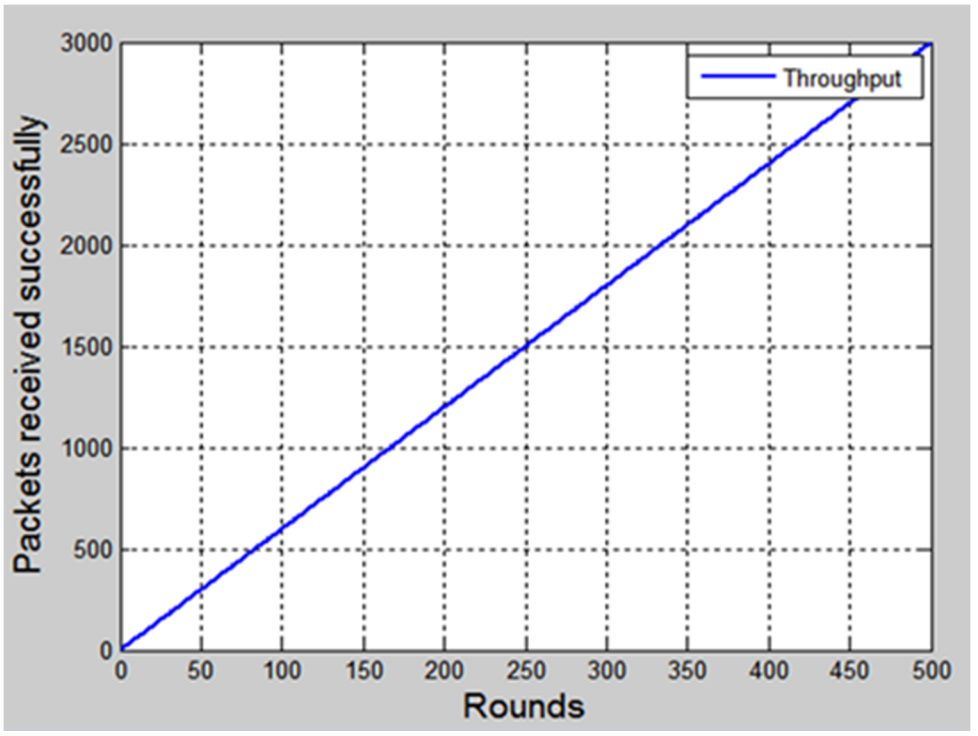

Fig 11. Throughput v/s Rounds without SKM

The fig11 shows the packets received at the receiver successfully which is the throughput. The graph indicates the throughput without Secure Key Management Scheme.

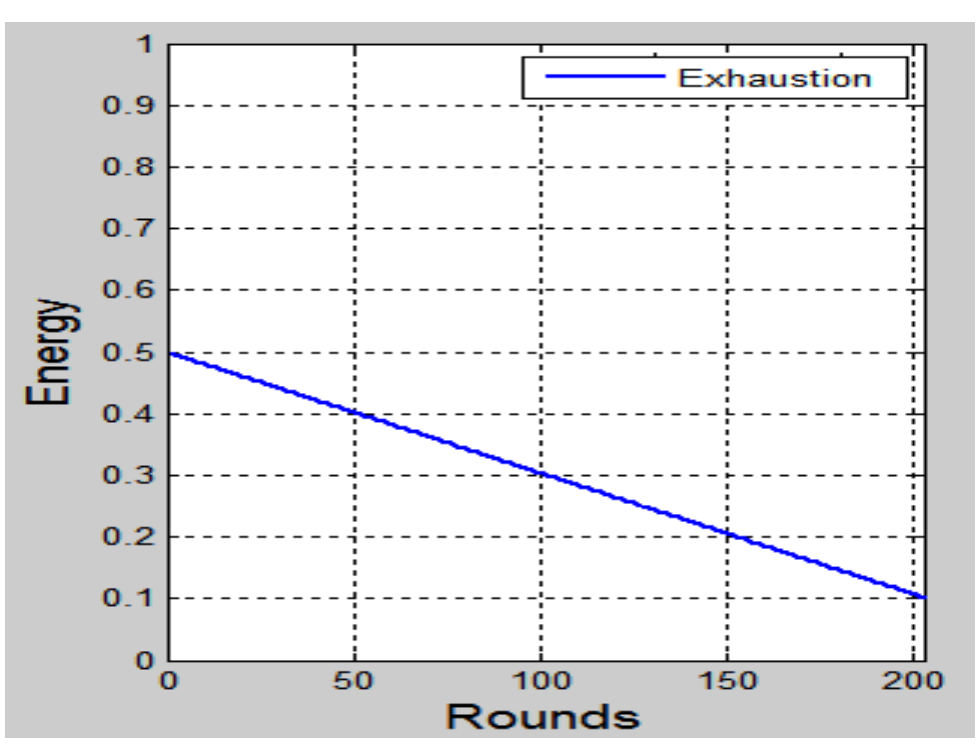

Fig 9. Exhaustion Attack v/s rounds with SKM(Secure Key Management)

The fig9 shows thatin exhaustion attack there will not be any IDLE nodes because of this there will be no chances of energy drain from the sensor nodes as SKM is introduced. So, energy of overall network will decrease drastically as all sensor nodes are working.

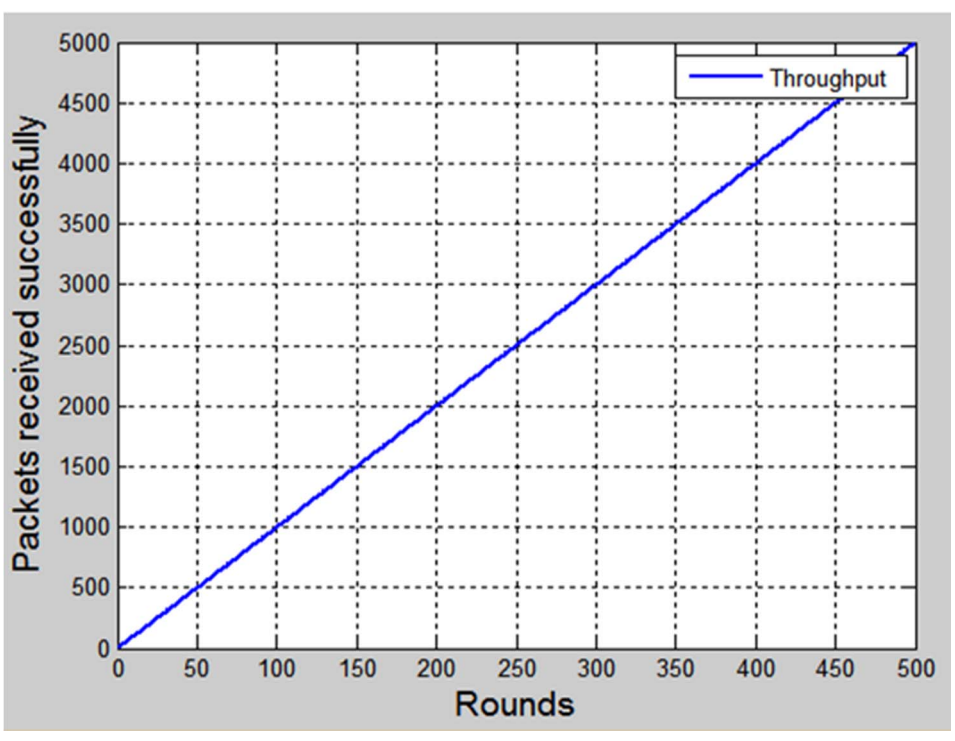

Fig 12. Throughput v/s Rounds with SKM

The fig12shows the packets received at the receiver successfully which is the throughput. The graph indicates the throughput with Secure Key Management Scheme.

V.CONCLUSION

In this paper we have proposed a secure key management in wireless sensor networks. Vulnerability of the nodes to physical capture, Insecurity of the data transmission, Limited memory resources and the complexity in the inclusion of the nodes at later stages is considered.The performance of the network is evaluated based on Security, Impact of attacks and Throughput. Minimizing the memory usage is also of main importance. The efficiency of the system is increased, and achieved security in the WSN. There is substantial improvement in the performance of the network.

VI. FUTURE SCOPE

The system proposedso far has been implemented considering static wireless nodes. This systemprovides enhancement, gains in Energy efficiency, Throughput, Network lifetime, and Stability period. As the virtue of wireless nodes is mobility, it can be incorporated into the system using advanced routing protocols that support mobility and enhance efficiency of the system.

An effective tool in reducing the system power consumption without decreasing the performance is Dynamic Power Management. The effects of very large node densities needs to be investigated. Developments in this regard can be taken into consideration to make the system more reliable.

REFERENCES

[1]Xinyang Zhang, Dr. Jidong Wang, "An Efficient Key Management Scheme in Hierarchical Wireless Sensor Networks",ICCCS, IEEE, 2015

[2] P. Raghu Vamsi, Krishna Kant, "A Taxonomy of Key Management Schemes of Wireless Sensor Networks", 5thIEEE, ICACCT, 2015, pp. 290-296.

[3] Nisha, Mayank Dave, "Storage as a Parameter for Classifying Dynamic Key Management Schemes Proposed for WSNs", ICCTICT, IEEE, 2016

[4]SaifurRehman, Cui Gang,DalaijargalPurevsuren, "A Hybrid Key Management Scheme for Ad-hocWireless Sensor Networks to improvesecure linkEstablishment", 6thICSCSS, IEEE, 2015

[5] T. T. Chakavarika, B. K. Chaurasia, S. K. Gupta, "Improved Energy Efficient Key Management schemein Wireless Sensor Networks",ICCSP, IEEE, 2016, ,pp. 2135-2140.

[6] Bin Tian,YangXin,Shoushan LU0, Xiou Yang, Dong Li,Zhe Gong,Yixian Yang:"A novel key management method for wireless sensor networks", 3rd International Conference on Broadband Network and Multimedia Technology IEEE, 2010, pp. 1106-1110.

[7]JaydeepBarad, BintuKadhiwala:"Improvement Of Deterministic Key Management Scheme For Securing Cluster-Based Sensor Networks",1st IEEE International Conference on Networks and Soft Computing (ICNSC), 2014, pp. 55-59.

[8] Wenliang Du And Jing Dengyunghsiang S. Hanpramod K. Varshneyjonathan Katz And Aram KhalilI: "A Pairwise Key Pre-Distribution Scheme For Wireless Sensor Networks", ACM Transactions on Information and System Security, Vol. 8, No. 2, May 2005, pp 228-258.

[9] Ismail Mansur, GerardChalhoub and Pascal Lafourcade: "Key Management inWireless Sensor Networks". *J. Sens. Actuator Netw.* 2015, pp. 251-273

[10]Eric Ke Wang, Lucas C.K.Hui and S.M.Yiu: **"**A New Key Establishment Scheme For Wireless Sensor Networks",IJNSA, Vol 1, No 2, July 2009, pp. 17-27.

[11] Mohamed-LamineMessai: "Classification of Attacks in Wireless Sensor Networks", International Congress on Telecommunication and Application'14 University of A.MIRA Bejaia, Algeria, 23-24 APRIL 2014.

[12]Chen Chen, Zheng Huang, Qiaoyan Wen, YajunFan: "A Novel Dynamic Key Management Scheme For Wireless Sensor Networks", 4th IEEE IC-BNMT, 2011, pp.549-552.

[13] Yong Xu, Fen Liu, "**Hybrid Key Management Scheme for Preventing Man-in-Middle Attack inHeterogeneous Sensor Networks",** 3rd IEEE, 2017, pp. 1421-1425.

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A Miniaturized antenna for Worldwide Interoperability for Microwave Access and Satellite Applications using Square Patch

Sindhoor Venkatraman Hegde[1],Banuprakash.R[2], Pooja C R[3], Nandhini H[4], , Varsha L V[5]
[2]*Assistant professor and* [1, 3,4,5]*Students, BMSIT&M,* Bangalore, India
sindhoor.chavatti@gmail.com, r.bhanuprakash@bmsit.in

***Abstract*— A multiband antenna with a microstrip feed is implemented. The prototype of patch antenna is designed on dielectric material called Flame Retardant-4 that has permittivity of 4.4. The proposed antenna has a volume of 1000mm^3 with a square shaped DGS (defected ground structure) to realize different frequencies. This wraps three varieties of frequencies such as 3.5GHz, 6.8GHz and 9.6GHz which are valid for WiMAX, Satellite Uplink and X-Band applications correspondingly. The planned antenna has shown sensible radiation characteristics at numerous operative bands that are appropriate for multiband operations.**

Index Terms - DGS, Wi-MAX, Satellite uplink, HFSS.

I INTRODUCTION

In modern world there is a drastic implementation of the wireless communication for compact devices. This also created a huge demand for the antennas which are compact and are able to operate at multiple frequencies. This has evolved the approach of an antenna design totally in different manner. An antenna is a transition device which can couple the guided medium wave to the free space [1][5]. It retains the characteristics of both receiver and transmitter. Since this is an elementary device for wireless communication setup the micro strip multiband patch has given a new approach to accomplish this objective [4].

There are different feeding technique like proximity, co-axial, aperture feed and microstrip line feed. Among all these microstrip line feed is preferred to achieve impedance matching [8]. Slots and DGS mainly improve the efficiency of the antenna, enhancement of the bandwidth, gain, VSWR, radiation pattern and also reduce the return loss. The use of high dielectric and thickness of substrate plays an important role design structure.

Patch antennas has physical features such as better directivity, low production cost, reliability, ease of construction and easy integration with circuit component which are widely incorporated in designing the communication modules[7].

Here our aim is to design and analyse a miniaturized patch antenna with acceptable gain for various wireless applications.

II DEFECTED GROUND STRUCTURE

Defective ground is formed when a small portion is removed from the ground plane of a micro strip antenna, this results in a disturbance in the current distribution over the ground plane which in turn results in a alteration in electromagnetic excitation [9][6]. Different shapes of slots such as square, triangle etc are used in DGS[3]. Since the transmission line with DGS shows band rejection characteristics. It is applied for enhancing the characteristics of the antenna [11].

Calculation formula for Microstrip Patch Antenna [13]

1. The width(W) of the micro strip antenna is given as-

$$W = \frac{c}{f_0}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

Where, Resonant Frequency, f_0
Dielectric Constant, $\varepsilon_r = 4.4$
Speed of light $c=3*10^8$ m/s

2. The effective dielectric constant (ε_{reff}) is
Where W/h>1

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{w}\right)^{-0.5}$$

3. The Length extension(ΔL) is

$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.3)}{(\varepsilon_{reff} - 0.218)}\frac{\left(\frac{w}{h} + 0.264\right)}{\left(\frac{w}{h} + 0.8\right)}$$

4. The effective length (L_{eff}) is

$$L_{eff} = \frac{C}{2f_o\sqrt{\varepsilon_{reff}}}$$

5. The Actual Length (L) is given by

$$L = L_{eff} - 2\Delta L$$

6. The Ground Plane dimension is given by

$$L_g = L + \frac{\lambda}{2}$$

$$W_g = W + \frac{\lambda}{2}$$

Antenna Geometry:

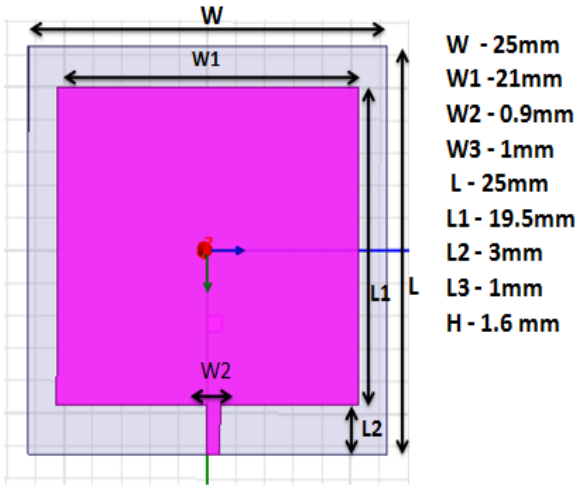


Fig. 1: Front image of the patch

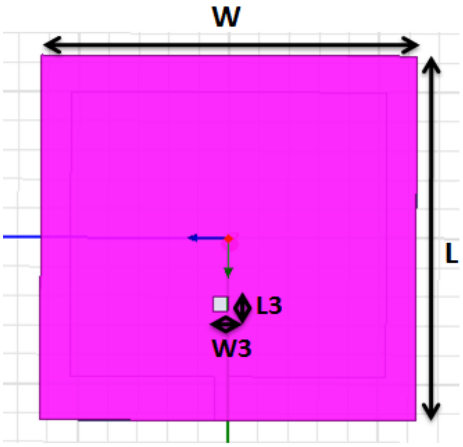


Fig2: Rear sight of ground plane

To attain the multiband frequencies a square-shaped slot is incorporated to create the irregularity in the ground plane as portrayed in the figure 3.

Results

To study the of characteristic of patch, parametric analysis, trial and error methods are carried out.

Return Loss

The S parameter gives return loss of patch antenna. This indicates mismatching of input and load impedances. This is also known as reflection coefficient [6].

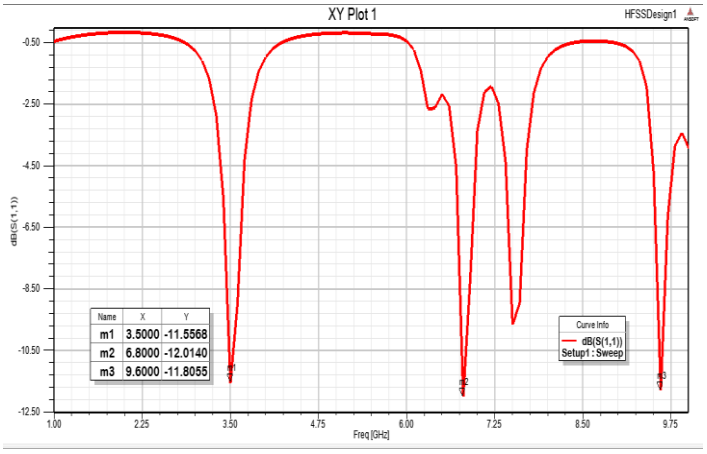


Fig. 3: Return loss (S_{11}) versus Frequency

III VOLTAGE STANDING WAVE RATIO

This is a function of reflection coefficient which describes how well the antenna is matched to connected transmission line. The value from 1-2 is acceptable.

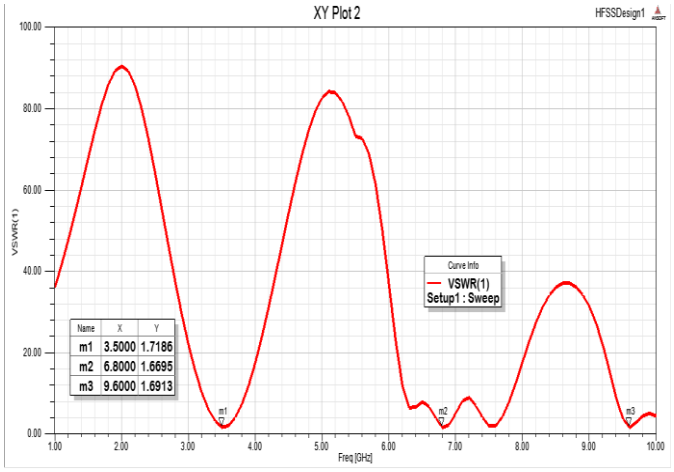


Fig.4: VSWR v/s Frequency

Surface Current Distribution

The following picture depicts the current distribution over radiating patch and ground plane of antenna. DGS varies the current distribution in ground plane of an antenna gives the ability to operate at diverse frequencies as shown in Figure 5a-7b. The following simulation results show the front and rear image of the antenna for attained frequencies.

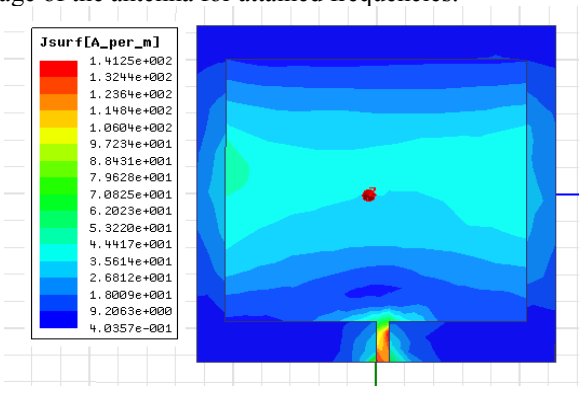


Fig.5a: At 3.5GHz

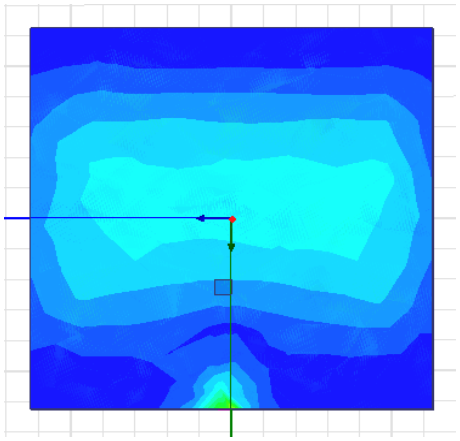


Fig 5b. Back view at 3.5GHz

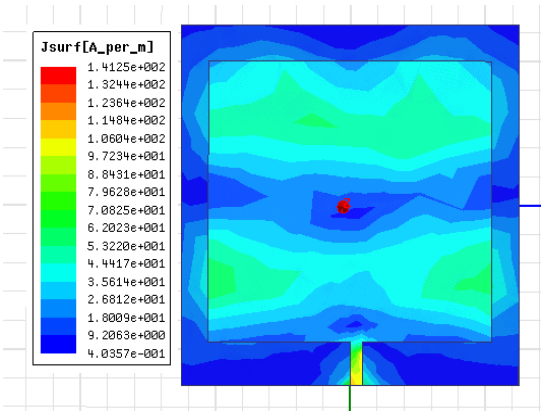


Fig.6a: For 6.8GHz.

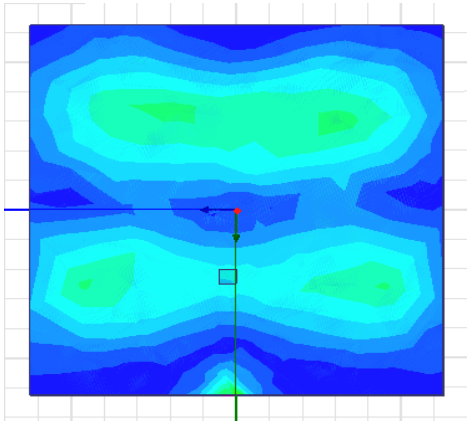


Fig.6b: Rear view at 6.8GHz

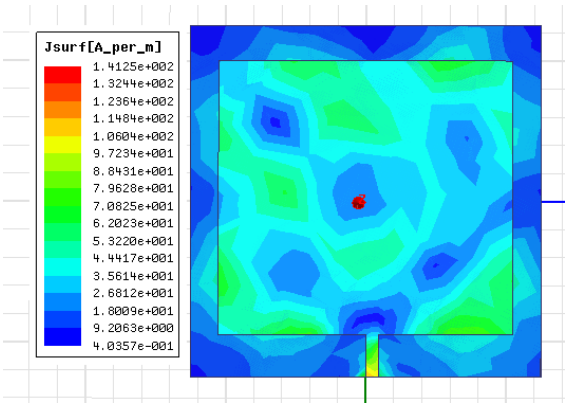


Fig.7a: At 9.6 GHz.

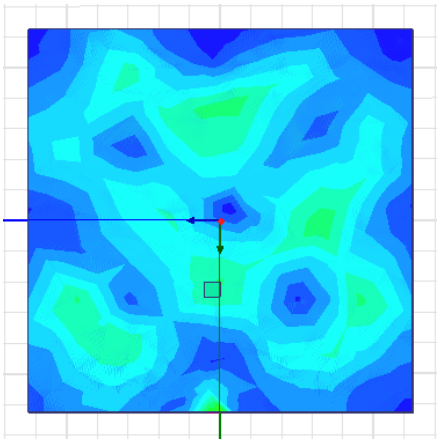


Fig.7b: At 9.6GHz

IV RADIATION PATTERNS

The 3 dimensional radiation pattern of microstrip patch antenna in electric(YZ) and magnetic (XZ) planes at 3.5GHz,6.8GHz and 9.6GHz are plotted as depicted in fig 8-10 respectively. The proposed antennas radiation plot shows a nearly omni directional pattern in H-plane and bi-directional pattern in E-plane at three frequencies.

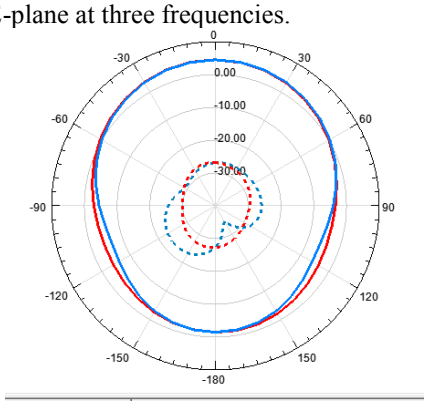


Fig 8: For 3.5GHz

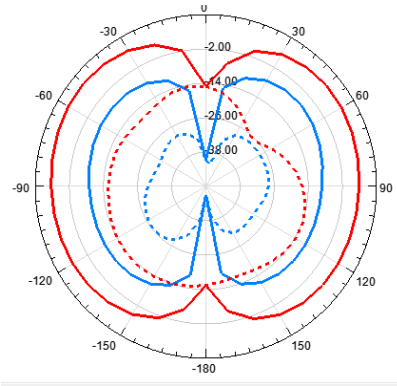


Fig 9: At 6.8GHz

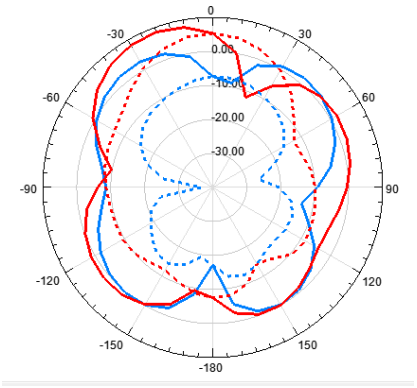
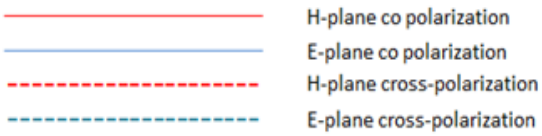


Fig 10: For 9.6GHz

Reference	Antenna volume mm^3	Frequencies	Return loss	VSWR	Gain (dBi)
[11]	6400	0.9GHz 3.5GHZ	-22.94 -25.08	1.3 1.1	6.7 8.429
[12]	1632	5.8GHz	-32	1.264	-10
[9]	3125	1.6GHz	-13.97	1.65	-
Proposed antenna	1000	3.5GHz 6.8GHz 9.6GHz	-11.55 -12.01 -11.80	1.7 1.6 1.6	0.848 2.976 6.980



Gain

The degree of efficiency and directional capabilities of an antenna can be represented by the gain of an antenna. Here we observe gain of + 0.843dB at 3.5GHz and + 2.97dB at 6.8GHz and +6.9dB at 9.6GHz

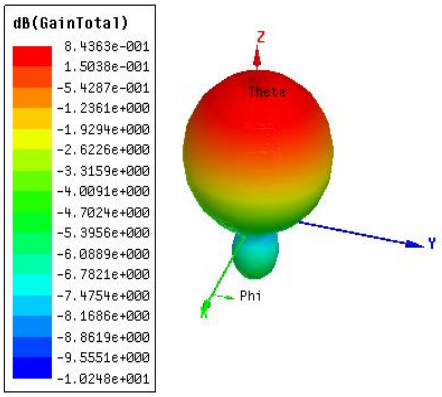


Fig. 11: At 3.5 GHz

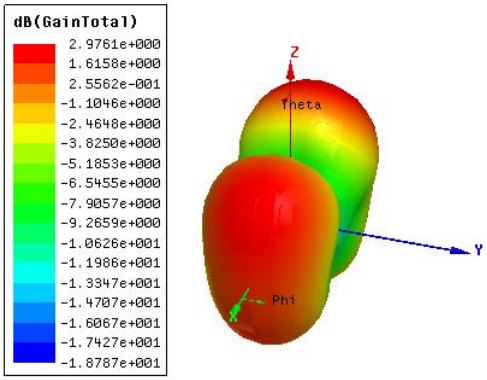


Fig. 12: For 6.8 GHz

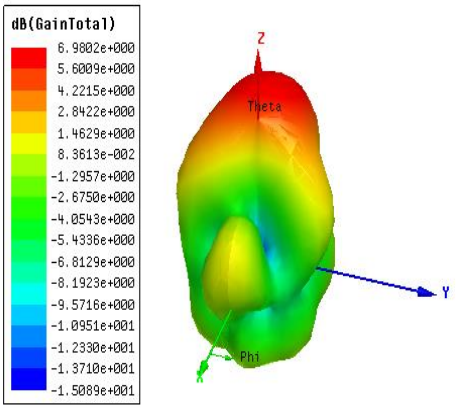


Fig. 13: At 9.6GHz

Comparison Table

From the above comparison table it is clear that the designed antenna is not only miniaturized but also shows that the antenna exhibits the ability to operate at multiple frequencies.

V CONCLUSION

The aim of this patch antenna is to achieve multi band resonant frequencies with positive gain which is compact and portable microstrip patch antenna. To attain these characteristics DGS is incorporated in the design. The designed Multiband microstrip patch antenna produces three frequencies as 3.5GHz , 6.8GHz and 9.6GHz with acceptable gain of 0.8dB, 2.97dB and 6.9dB respectively. These frequencies are well suited for Worldwide Interoperability for Microwave Access, satellite UpLink and X-Band applications.

REFERENCES

[1] Banuprakash.R, Hariprasad.S.A."A Compact Multi-band Rectangular Slot Microstrip Antenna for Wi-MAX, WLAN and X-band Applications."In Internstional Journal of Engineering &Technology(IJET),2018.

[2] Banuprakash.R, GSPN Amith, Gagana N, Ravi AG, Pavanashree C." Design of Multiband Antenna for Wimax and WLAN Applications Using DGS."In Internstional Journal of Engineering &Technology(IJET),2018

[3] Zheng, Tianning, Bin Wei, Bisong Cao, Xubo Guo, Xiaoping Zhang, Dan Wang, Cheng Feng, Zhan Xu, and Zhaojiang Shang. "Design of a high-power superconducting filter with novel DGS structures." IEEE Transactions on Applied Superconductivity 24, no. 6 (2014): 1-5.

[4] Kumawat, Bhanu Priya, Santosh Meena, and Sanjeev Yadav. "Square shape slotted multiband microstrip patch antenna using defect ground

structure." In Information, Communication, Instrumentation and Control (ICICIC), 2017 International Conference on, pp. 1-4. IEEE, 2017.

[5] Zhang, Qi-Tao, Y. C. Jiao, Y. Ding, and B. Li. "Design of a planar monopole multiband antenna with U-and L-shaped slots." In Microwave Technology & Computational Electromagnetics (ICMTCE), 2011 IEEE International Conference on, pp. 331-333. IEEE, 2011.

[6] Bohra, Sakshi, and Tazeen Shaikh. "UWB Microstrip Patch Antenna for Breast Cancer Detection." International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE) 5 (2016).

[7] Liu, Wen-Chung, Chao-Ming Wu, and Yang Dai. "Design of triple-frequency microstrip-fed monopole antenna using defected ground structure." IEEE transactions on antennas and propagation 59, no. 7 (2011): 2457-2463.

[8] Latha, S., and PM Rubesh Anand. "Circular polarized microstrip patch array antenna for wireless LAN applications." In Wireless Communications, Signal Processing and Networking (WiSPNET), International Conference on, pp. 1197-1200. IEEE, 2016.

[9] Thatere, Ajay, Dwejendra Arya, and P. L. Zade. "Wi-Fi microstrip antenna with DGS." In Power and Advanced Computing Technologies (i-PACT), 2017 Innovations in, pp. 1-6. IEEE, 2017.

[10] Aggarwal, Ishita, Malay Ranjan Tripathy, and Sujata Pandey. "Metamaterial inspired multiband slotted antenna for application in IOT band." In Green Engineering and Technologies (IC-GET), 2016 Online International Conference on, pp. 1-4. IEEE, 2016.

[11] Nurjihan, Shita Fitria, and Achmad Munir. "Effect of DGS incorporation for bandwidth enhancement of UWB microstrip BPF."In Wireless and Telematics (ICWT), 2017 3rd International Conference on, pp. 39-42. IEEE, 2017

[12] Banuprakash.R ,Hariprasad S.A, Dinah.C.J ,Hamsa.T.C "Bandwidth enhancement of Circular Microstrip patch antenna using different feeding techniques".

[13] Balanis, Constantine A. "Antenna Theory:Aeview." Proceedings of the IEEE 80, no. 1 (1992): 7-23.

A miniaturized dual band microstrip antenna for Worldwide interoperability microwave access and C band radio navigation

Banuprakash.R[1], Chethana C[2], Lekhya Sindura N[3], Madhushree M[4], Mahima Rajendra Dhingreja[5]
[1]Assistant professor , [2,3,4,5]Students, Department of TE, BMS Institute of Technology & Management, Bengaluru
r.bhanuprakash @ bmsit.in

ABSTRACT—Here a 26 x 32 x 1.6 mm^3 sized dualband microstrip antenna that realized the frequencies 3.4Ghz and 6.7Ghz for the applications wimax and radionavigation respectively is designed. FR4 dielectric with permitivity 4.4 is the dielectric material used. The S_{11} in dB with standing wave ratio for the generated frequencies are -28.29 and -23.01 with 1.08 and 1.15 respectively. It comprises of a rectangular slot on the patch to achieve impedance matching. The analysis of return loss, gain and radiation patterns was done using HFSS tool.

Keywords—Wi-Max, Radio navigation, HFSS, Slot

INTRODUCTION

In recent years the rapid development of the antenna has lead to the increased demand of multiband microstrip antenna. This have changed the approach of antenna design in completely different way. Antenna is a passive device which transforms the energy from electrical form to Radio Frequency form and couple it to free space for transmission. Since the antenna is a elementary device for wireless communication setup the microstrip multiband antenna has given a new manner to accomplish this objective [1-5].

The permittivity with high value and less size made these antennas catch the consideration for applications like mobiles instruments, GPS receivers and other products of wireless communication. Because of their less weight and even skeleton this antenna is well suited for airborne and spacecraft [10]. For various wireless applications multiband antennas can function at diverse band of ferquencies. A compressed structure is desired to fulfill the precise requisite [6].

The permitivity, thickness of the substrate, frequency etc are significant parameters for the analysis of performance of an antenna. There is a massive need of compressed size and low weight radiating elements integration into modern communication systems with ease[8]. However, the foremost drawbacks of microstrip antennas are little bandwidth, less power handling capacity, small gain and directivity [7].

For handheld and portable devices the antenna size is the key in attaining gain and bandwidth. An E shaped and rectangular slot antenna is analysed for ISM band at 5.75GHz [9].

Due to greater potential of the geometry elliptical microstrip antennas are considered for diverse of electrically small low profile antenna applications [11]. Reactive loading is achieved by etching slot on a radiating element and the resonance is improved by hitting a slot [12].

I. ANTENNA DESIGN CONSIDERATIONS

Width (W) -

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r+1)}{2}}}$$

Calculation of Effective length (L)-

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}}$$

Where h is height of the substrate, f_o is resonant frequency.

II. ANTENNA GEOMETRY

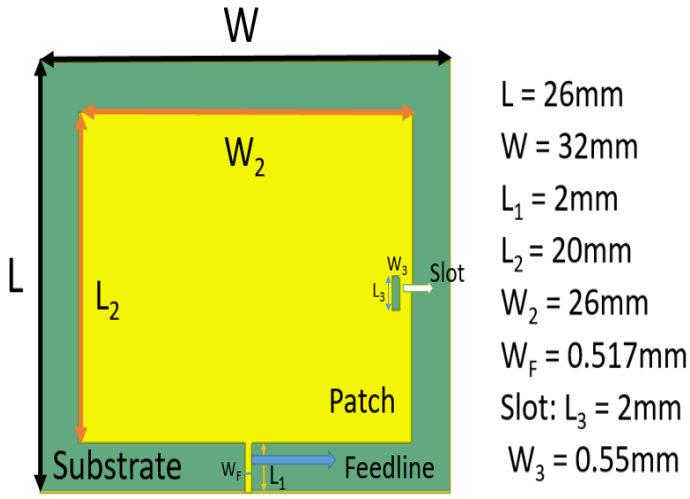


Fig1: Front view of the antenna with slot

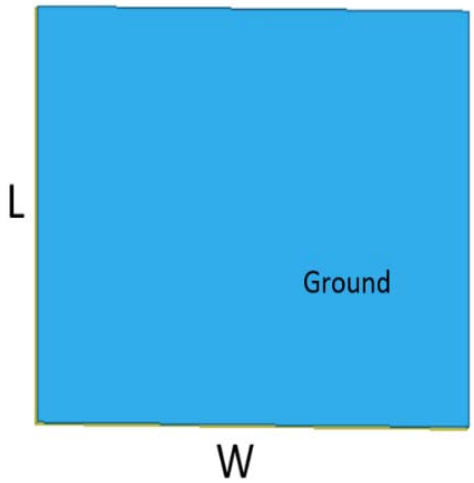


Fig2: Back view of the antenna

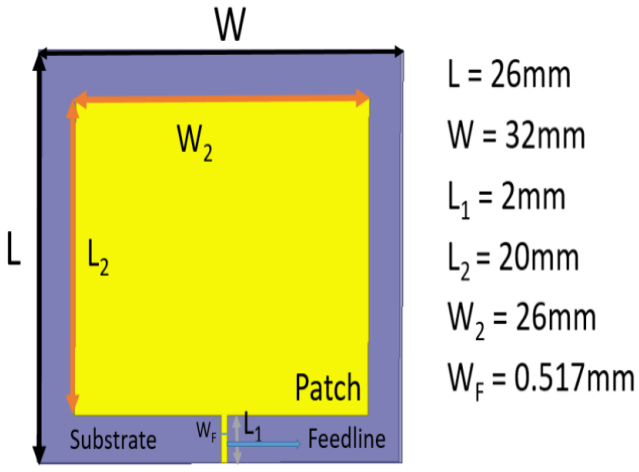


Fig3: Antenna without slot

III. RESULTS

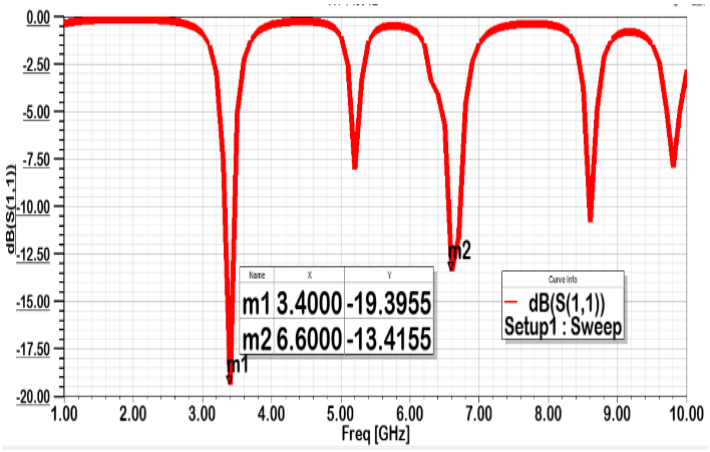


Fig4: Return loss vs. Frequency without slot

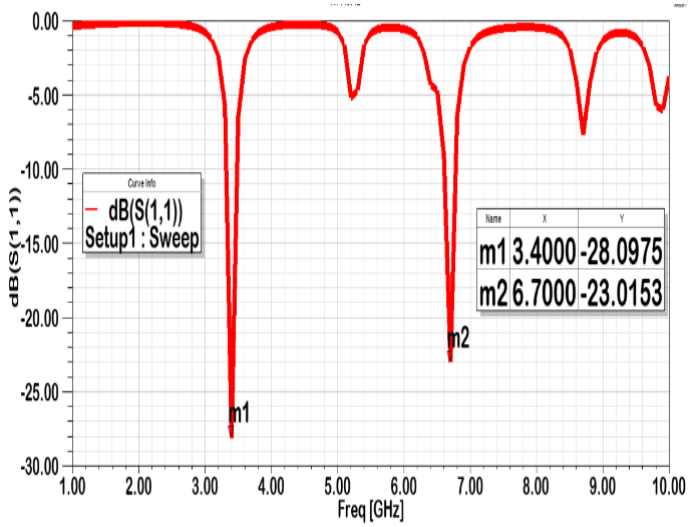


Fig5: Return loss Vs. Frequency with slot

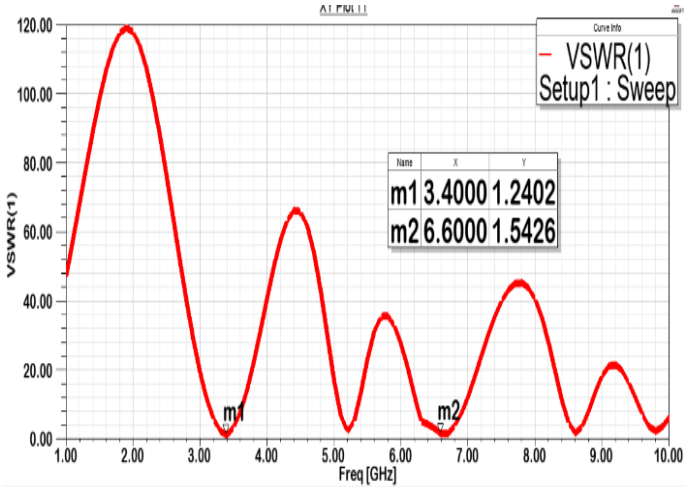


Fig6: VSWR without slot

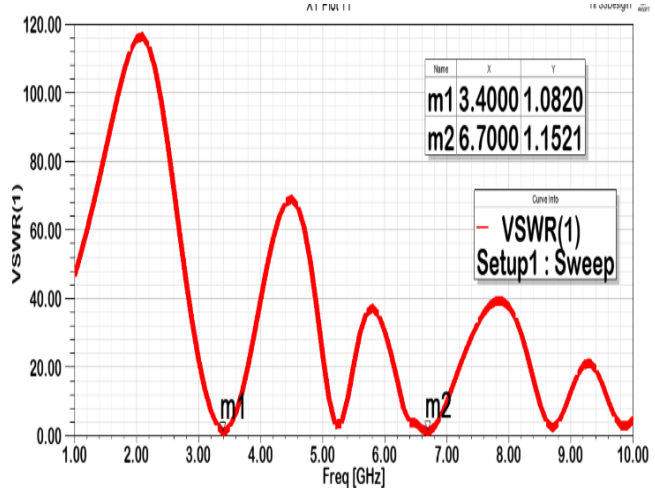


Fig7: VSWR with slot

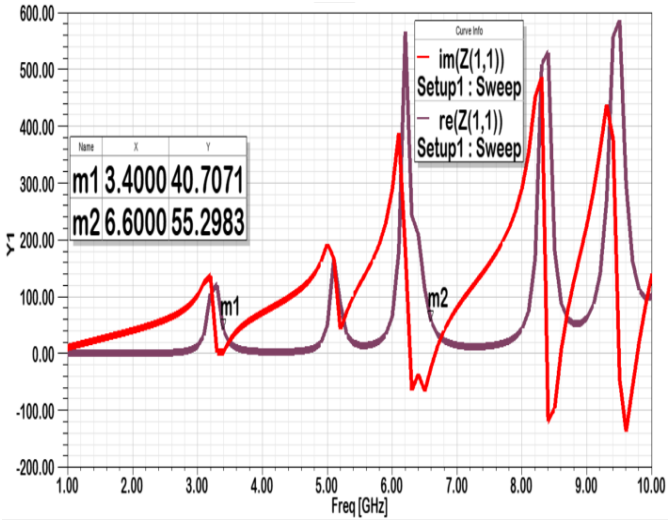


Fig8: Impedance Curve without slot

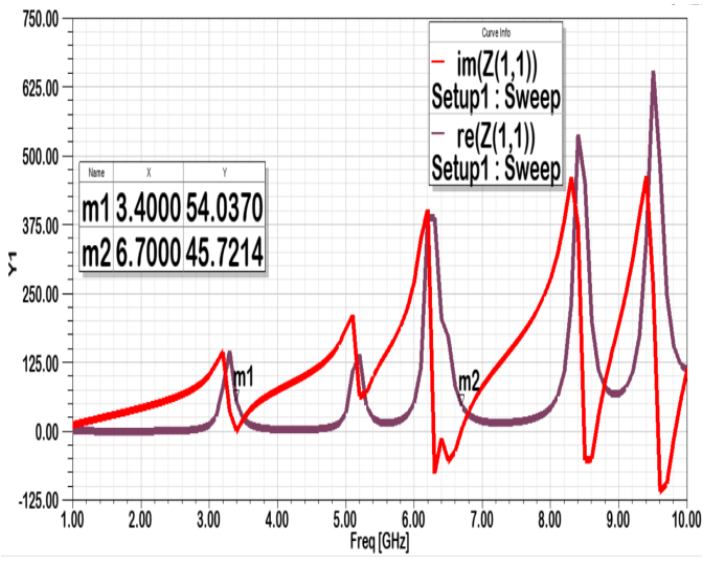


Fig9: Impedance Curve with slot

GAIN

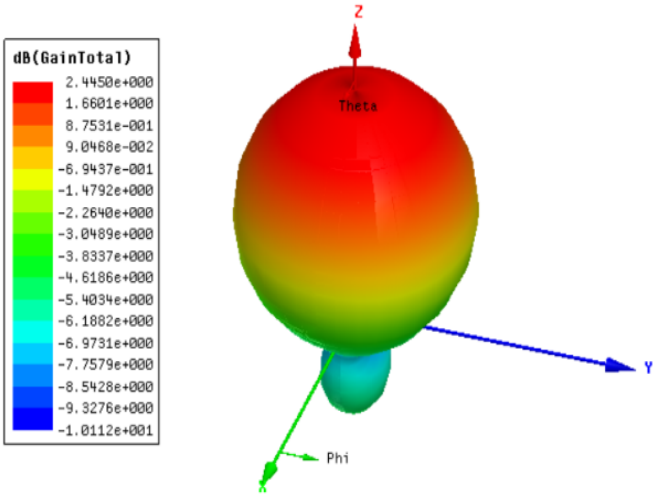


Fig10: For 3.4 GHz frequency without slot

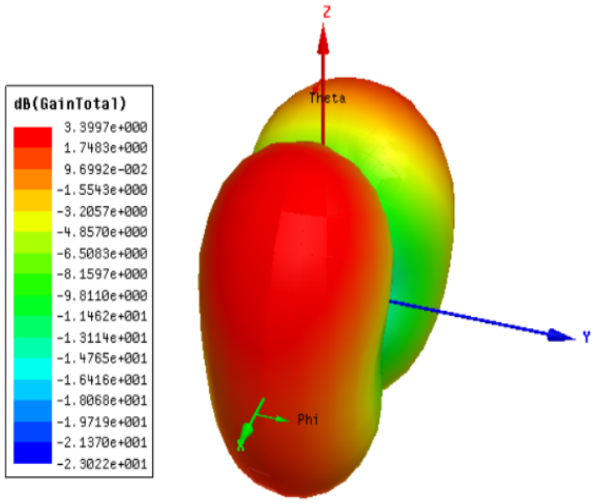


Fig11: For 6.6GHz frequency without slot

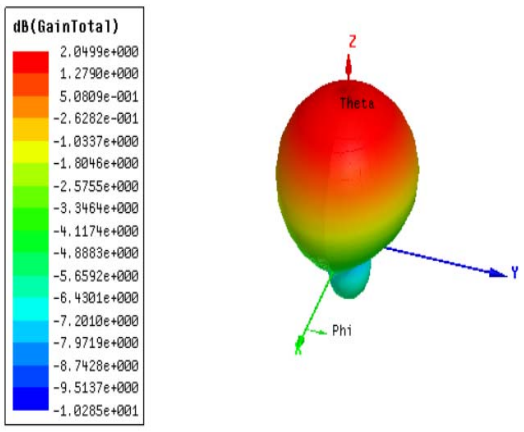


Fig12: For 3.4 GHz frequency with slot

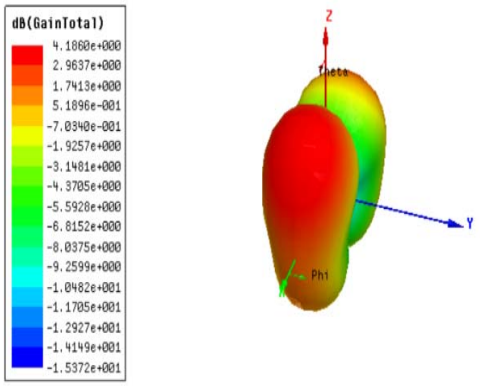


Fig13: For 6.7GHz frequency with slot

RADIATION PATTERNS:

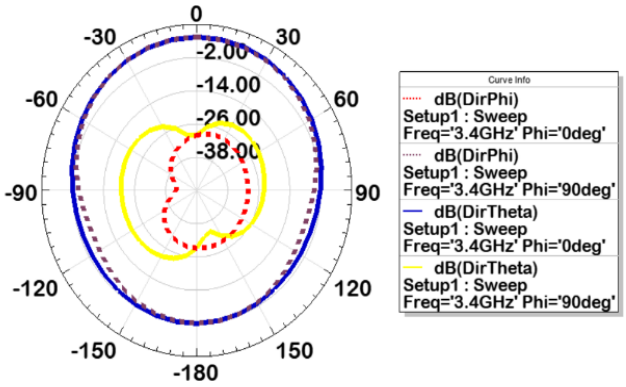


Fig 14: For 3.4 GHz frequency

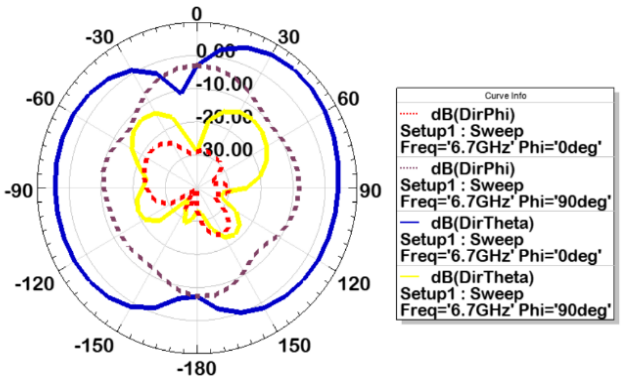


Fig15: For 6.7 GHz frequency

Results table:

Without slots:

Serial number	Frequency generated	Return loss	VSWR	Impedance	Gain
1	3.4Ghz	-19.39	1.2	40	2.44
2	6.6Ghz	-13.41	1.5	55.29	3.39

With slots:

Serial number	Frequency generated	Return loss	VSWR	Impedance	Gain
1	3.4Ghz	-28.29	1.08	54.03	2.04
2	6.7Ghz	-23.01	1.15	45.72	4.19

Comparison Table

Reference	Antenna volume (mm^3)	Frequency (GHz)	VSWR	Gain dB
[14]	4000	2.3 5.3 6.7	1.1 1.1 1.2	4.11 -11.17 -1.6
[5]	6400	0.9 3.5	1.3 1.1	6.7 8.42
[6]	3200	3.4 5.6	1.22 1.56	3.43 7.25
Proposed antenna	1331.2	3.4 6.7	1.08 1.15	2.44 4.18

CONCLUSION:

The purpose of this design is to achieve dual band frequencies with good gain for a compact and simple microstrip patch antenna. A small rectangular slot is made on the patch for impedance matching. The designed Multiband microstrip patch antenna produces two frequencies 3.4GHz and 6.7GHz with a gain of 2.44dB, and 4.18 dB respectively. Which are well suited for Wi-Max, radio navigation applications.

REFERENCES

1. Banuprakash.R, Hariprasad.S.A.”A Compact Multi-band Rectangular Slot Microstrip Antenna for WiMAX, WLAN and X-band Applications.”In Internstional Journal of Engineering &Technology,2018.
2. Banuprakash.R, GSPN Amith, Gagana N, Ravi AG, Pavanashree C.” Design of Multiband Antenna for Wimax and WLAN Applications Using DGS.”In IJET,2018.
3. Design and Performance Analysis of Microstrip Array Antennas with Optimum Parameters for X-band Applications in (IJACSA) International Journal of Advanced Computer Science and Applications, Vol. 2, o.4, 2011.
4. Chen, Zhouyun, Xiwang Dai, and Guoqing Luo. "A new H-slot coupled microstrip filter-antenna for modern wireless communication systems." In 2018 International Workshop on Antenna Technology (iWAT), pp. 1-3. IEEE, 2018.

5. Nurjihan, Shitha Fitria, and Achmad Munir. "Effect Of DGS incorporation for bandwidth enhancement of UWB microstrip BPF."In Wireless and Telematics (ICWT), 2017 3rd International Conference on, pp. 39-42. IEEE, 2017.
6. Thatere, Ajay, Dwejendra Arya, and P. L. Zade. "Wi-Fi microstrip antenna with DGS." In Power and Advanced Computing Technologies (i-PACT), 2017 Innovations in, pp. 1-6. IEEE, 2017.
7. Zahran, Ahmed E., Mahmoud A. Abdalla, and MH Abd El-Azeem. "Single/dual band reconfigurable metamaterial dipole loaded antenna for wireless applications." In Antennas and Propagation 2016 IEEE International Symposium (APSURSI), pp. 457-458..
8. Aggarwal, Ishita, Malay Ranjan Tripathy, and Sujata Pandey. "Metamaterial inspired multiband slotted antenna for application in IOT band." International Conference on Green Engineering and Technologies (IC-GET), 2016 Online, pp. 1-4.
9. S. Karvekar, S. Deosarkar, and V. Deshmukh. "Design of compact probe fed slot loaded microstrip antenna." International Conference on Communications and Signal Processing (ICCSP), 2014. IEEE.
10. V. Mathur, and M.Gupta,"Comparison of performance characteristics of rectangular, square and hexagonal microstrip patch antennas", In Reliability, Infocom Technologies and Optimization ,2014, October.
11. Maci. S., Gentili, G.B,. Piazzessi, P., & Salvador, C. “Dual band slot loaded patch antenna”, IEEE Proceedings of Microwaves Antennas and Propagation, 142,225, 1991.
12. P. Bhartia, P. Rao, K.V.S and R.S. Tomar, “Millimeter wave microstrip and printed circuit antennas,” Norwood, MA: Artech House, 1991.

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Centroid and Gateway based Hierarchical Routing Protocol for Wireless Sensor Network

Raghunandan G H[1]
Department of Telecommunication Engineering
BMS Institute of Technology and Management,
Bangalore, India
raghunandangh@bmsit.in

Dr. A. Shobha Rani[2],
Department of ECE,
BMS Institute of Technology and Management,
Bangalore, India

Aishwarya Varma[3]
Department of Telecommunication Engineering,
BMS Institute of Technology and Management
Bangalore, India

Monisha S Reddy[4]
Department of Telecommunication Engineering
BMS Institute of Technology and Management
Bangalore, India

Pavithra Regina Dennis[5]
Department of Telecommunication Engineering
BMS Institute of Technology and Management
Bangalore, India

Rohanti Vasanth Kumar[6]
Department of Telecommunication Engineering
BMS Institute of Technology and Management
Bangalore, India

***Abstract*— Wireless Sensor Network's composition at thqae foundation level is sensors. These battery-powered, efficient sensors are deployed over a particular region under consideration for the application that they are sought out for. These sensor nodes are not only used for their obvious sensing capabilities, but are also used to compute and communicate with other nodes using radio signals. However, as economical and efficient as these sensors are, they still have a lot of constraints such as power, bandwidth, network lifetime and variance. It thus, becomes extremely important to make sure that all these constraints are optimized while routing data through the sensors. Thus, efficient routing, to some extent can be provided if an centroidal agglomerative approach is used. This ensures that data is aggregated at different levels which in turn lead to a simple yet efficient network. In this paper, we propose a method to route the data hierarchically and at the same time, optimize the objectives and constraints put forth by other routing protocols. The simulation results of the proposed algorithm shows improvement in efficiency compared to existing protocols.**

Keywords — sensor nodes, efficiency, wireless sensor network, agglomerative, hierarchical routing.

I. INTRODUCTION

Wireless Sensor Nodes were initially introduced as a small portable object, which when coupled with the knowledge to handle them can prove to be beneficial to so many different applications. When integrated into machinery, these sensors helped improve the manufacturing productivity and also improved efficiency of the machinery. Another advantage of including these sensors was the fact that there was no need of bulky wires and cables as it was a completely wireless setup. Apart from this, it was also found to be extremely smart in terms of response time which in turn led to faster data acquisition. The machinery thus developed exhibited reliability and accuracy when tested over a longer period of time as well. However, with increase in scalability and lifetime of a machine come some disadvantages as well.

One major disadvantage was that the sensor nodes used are battery operated which means that they have a finite lifetime. This directly translates to the sensors providing only little or limited energy for the working of the machine which in turn leads to a modest amount of processing power. Thus, the need of the hour was to, in some way; optimize all these drawbacks so that the lifetime of the sensor nodes as well as its range can be improved.

A wireless sensor network is thus a collection of many such sensor nodes, unique to each application. These sensors communicate with each other through transmission and reception of data and finally provide the designated output at par with the application.

While considering applications where sensor nodes are used for data acquisition and transmission, these drawbacks can somewhat be minimized by efficient routing. Routing of data makes sure that data is delivered to the destination, keeping in mind parameters such as delay, failure of links and throughput. [1] Though routing in any network is important, routing in a WSN plays a crucial role. This is because the tasks of transmission, reception, processing and storing must be done using the minimum power available. If not, it will not only lead to the network being redundant, but is also a waste of bandwidth. Keeping the removal of redundancy as the major priority, aggregation of data is the best possible solution.

The major advantages of using data aggregation are [2]:

1) Since clustering or aggregating of data reduces the size of the routing topology per se, it is much easier to scale as opposed to that of a flat topology.
2) Fusion or aggregation of data leads to less load being introduced on the sensors. In a cluster, the cluster head aggregates the data, thus reducing the load on all the sensors to transmit to the receiver.
3) Since aggregation occurs at every level, transmission is done using minimum energy as the number of sensor nodes that transmit is reduced.
4) The cluster head in each cluster is the only node that transmits to the receiver. This, in turn, reduces the possibility of collision of data between sensors.
5) Since less energy is being used, the sensors can operate for a longer period of time. Thus, the lifetime of the network is enhanced.

The remaining sections of this paper are: In Section II, we talk about the existing systems, their limitations which are the

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objectives for our proposed system. Section III highlights our system model. Section IV focuses in depth about proposed system. Section V is the implementation of the system and results and Section VI concludes the paper.

II. Existing Systems

The many varied applications of wireless sensor networks over the years has made it imperative that different routing techniques and system models are to be used in order to maximize the objectives and minimize any drawbacks and limitations.

Routing in current existing systems has been divided into a number of categories such as flat based routing, hierarchical and location based routing. [3] These routing protocols are simply used to determine how best to route the data with maximum efficiency. In the flat based routing, information is relayed from one sensor node to another. Thus, there is no aggregation of data. Whereas, in the hierarchical routing protocols, data is aggregated at every level until it reaches the sink node or the base station depending on the application of the wireless sensor network. Location routing on the other hand does not focus on aggregation of the data but rather on the location of the individual sensors.

All the above mentioned routing protocols have their own advantages and disadvantages. However, a good routing protocol should satisfy the basic objectives such as energy efficiency, increased lifetime and minimum delay. At the same time, the existing systems have a number of limitations. By means of this paper, we attempt to propose a system model that would minimize the basic limitations of a wireless sensor node as mentioned below [4]:

1) Since the deployment of wireless sensors are completely application based, the environmental conditions of the area under consideration can affect the overall efficiency of the network. Thus, sensing is greatly compromised by environmental factors such as climate, physical obstacles and real-time unpredictable errors.

2) Transmission, reception as well as computation of the data use the energy that is inherent in the sensor nodes. Thus, there is already a loss of energy. However, aggregating data can also contribute to further loss which is undesirable in the wireless sensor network.

3) Sensor nodes are capable of communicating only a sizeable amount of data. Often, the load on the sensors become much more than that which the sensor node can handle. This leads to significant congestion, delay and also loss of the data in some cases.

4) Excess load on the sensors can cause path breaks during routing. Thus, alternate paths have to be determined. However, this leads to bandwidth limitation as well as path delays which further reduce the efficiency of a system.

5) The rate at which one sensor node loses energy might not be the same rate at which another sensor node loses its energy. Thus, there is a variance created in the network. This, in turn, contributes to uneven distribution of energy in the system, thus posing as a limitation.

III. Proposed System

As seen in the fig.1, the proposed system model follows the principle of hierarchical routing wherein data is aggregated into clusters. The circles denote the individual sensor nodes while the squares depict the elected cluster head for that respective cluster. The nodes that are marked in green depict gateway nodes which are also sensors that are used to route data. Finally, the triangle depicts the gateway node. Clusters are nothing but groups of sensor nodes. Here, clustering can either be:

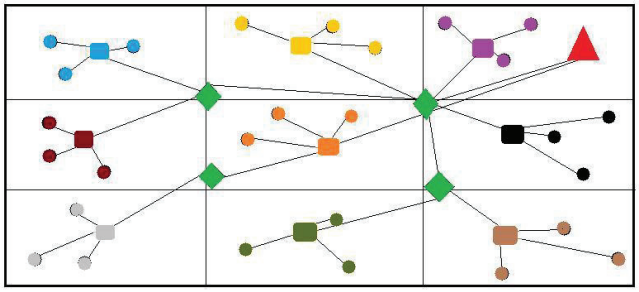

Fig. 1: Proposed System Model

(i) Intra-clustering where sensor nodes of a particular cluster aggregate their data to the cluster head which is elected.

(ii) Inter-clustering where data aggregation happens between two or more clusters i.e. the data from all the cluster heads are aggregated together.

Thus, the entire operation of the system proposed is divided into two phases:

(i) The set-up phase: This phase involves the election of the cluster head. This can be done using either deterministic probability or based on the centrality approach depending on the base protocol that is being used such as LEACH, TEEN, DEEC etc. to name a few. This cluster head is responsible for aggregating all the data that needs to be relayed by the sensor nodes to the base station.

(ii) The steady phase: This is the phase where actual transmission takes place. Thus, data is routed using the hierarchical agglomerative approach in this phase.

IV. System Model

The proposed model is used to route the data. However, there are certain assumptions with respect to the model and network in general that are considered. These include:

1. Deployed sensor nodes and gateway/ intermediate nodes are homogenous in nature. This simply means that initially, when deployed, all the sensor nodes are said to have approximately equal energy levels.
2. The sensor nodes, gateway nodes as well as the base station is said to be stationary.
3. The idea behind deploying these sensors is for applications where the location of the sensors is of little or no concern. Thus, the sensor nodes are location unaware and are not connected to any GPS system whatsoever.
4. The base station is continuously powered as opposed to the battery operated sensors. Thus, power supply to the base station is not a concern.
5. Node failure can occur in case of complete energy depletion.

The entire system model can briefly be classified into five main functions. These functions are crucial to the working of the routing protocol. They include:

(1) Division of the area into clusters:

The entire area under consideration must first and foremost be divided into approximately equal smaller areas. These areas are known as clusters and these clusters contain a number of sensor nodes.

(2) Election of the cluster head:

In order to route data using an agglomerative approach, aggregation of data must start from the lowest level i.e. the clusters. Thus, each cluster elects its own cluster head whose main function is to collect all the data from the sensor nodes of the cluster and successfully route it to the higher levels in the hierarchical approach. The cluster head is elected using the centrality based approach that focuses on the receive signal strength (RSS) of the sensor nodes.

(3) Aggregated data communication:

After the data from the sensor nodes are aggregated to the cluster head, routing of that data from the cluster head to the gateway nodes need to be considered. As mentioned earlier, gateway nodes are simply intermediate nodes that help route the data to the base station. The data is then transmitted between the gateways and finally reaches the base station of the network. The main reason of incorporating these gateways is to reduce transmission distance between the cluster heads and the base station, thus improving overall efficiency.

(4) Eliminate dead sensor nodes:

After each round of transmission and reception, the energy levels of the individual sensor nodes are monitored. If, at any point, the energy of the sensor node falls below the threshold level, that sensor is said to be a dead sensor and the node is eliminated in terms of transmitting any more information.

V. Implementation And Results

The implementation of the proposed system is carried out using Matlab version 8.1. First, sensors are deployed at random in a 100*100 area. After the deployment of sensors, the entire area under consideration is divided into clusters which are identical to one another. The cluster head is selected on the basis of the centrality approach that calculates the distance between sensor nodes to determine the best fit cluster head. Then, intermediate gateway nodes are deployed at intersections of clusters. These gateway nodes are further connected to each other and then routed to the base station.

Once the successful completion of a round or iteration occurs, the energy of all the sensor nodes are calculated. Thesensor nodes whose energy falls below the threshold are removed and the cluster head selection process is done again.

As seen in Fig3, a graph of the number of alive sensor nodes vs. the number of rounds is plotted. As compared to the LEACH protocol, it can be observed that the number of alive nodes at any given point for the proposed system is more than that of the LEACH protocol. Thus, the lifetime of the sensors is increased which is directly proportional to the lifetime of the network.

In Fig4, the residual energy of the sensor node after each round vs. the number of rounds is plotted. As compared to LEACH, it is seen that the energy contained in the sensor nodes for the proposed system is much higher after each round. Thus, the energy consumed for communication is less. This means that the energy efficiency is improved.

In Fig 5, the variance of the network in the proposed system against the number of rounds is plotted. While compared with the results of the LEACH protocol, it is observed that the variance is a constant slope with no sharp peaks or drops. This means that the sensor nodes in the network have little to no variance and the energy loss across the sensors is happening at a constant rate, thus improving the network efficiency.

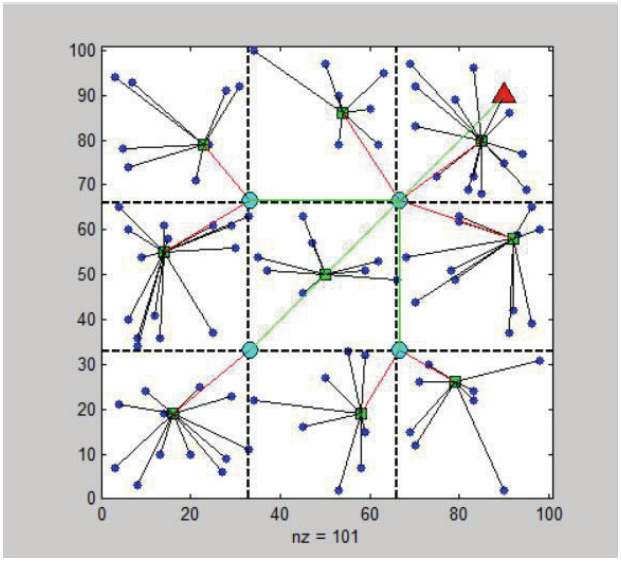

Fig. 2:Topology of network when sensors are initially deployed

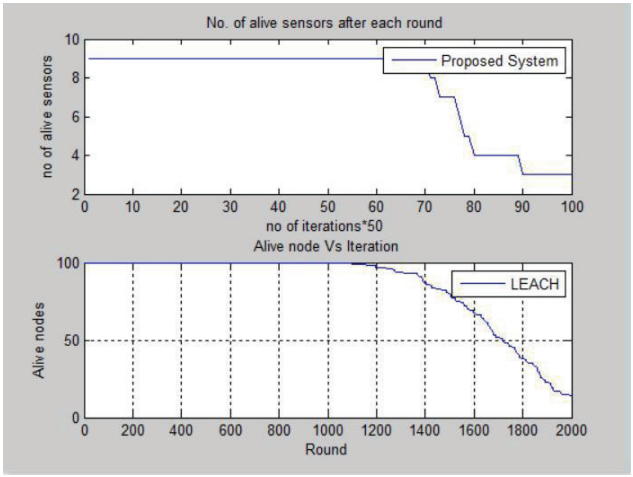

Fig. 3:Number of alve sensors after 2000 rounds as compared to LEACH

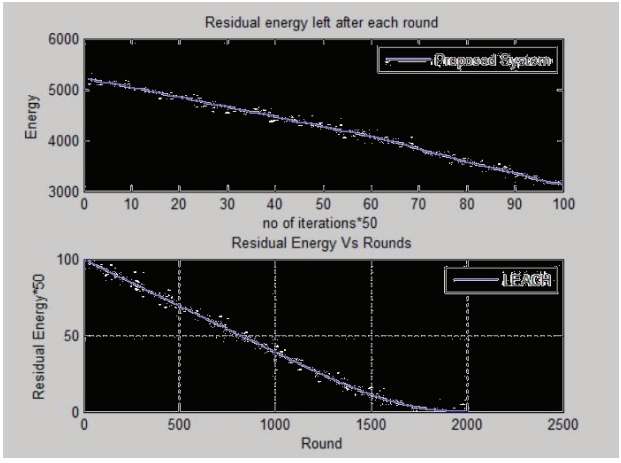

Fig. 4:Residual energy after 2000 rounds as compared to LEACH

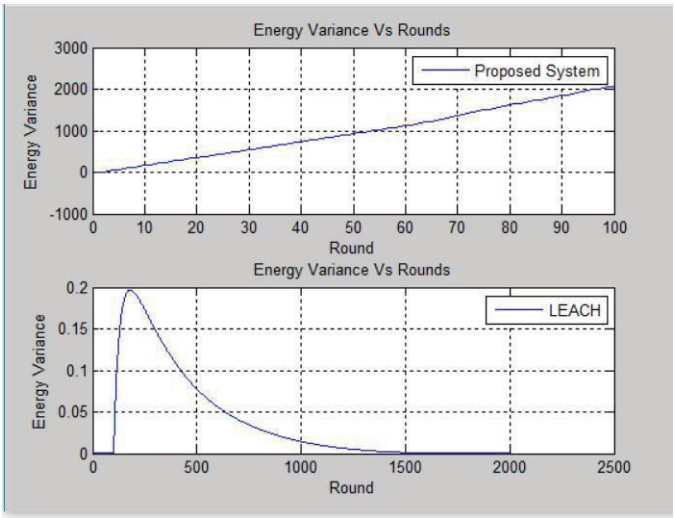

Fig. 5:Energy Variance after 2000 rounds as compared to LEACH

VI. Conclusion

It is thus observed from our analysis that the main principle of working of the protocol is cluster based centrality approach. Thus, the wireless sensor nodes transfer data by aggregation which is one of the major advantages of the proposed system. By using the system model above, the efficiency and network lifetime of the network is considerably enhanced. By means of assigning sensor nodes at every level to collect all the data to be transmitted, the load on the sensors is reduced. The clustering and aggregation of data goes a long way in simplifying the routing of the wireless sensor network. Furthermore, introduction of the gateway nodes reduces transmission distance of data from the cluster heads to the base station.

REFERENCES

[1] Sukhchandan Randhawa, Comparative analysis of Flat Routing Protocols in Wireless Sensor Networks: Which one is better? 2017 International Conference on Intelligent Computing and Control (I2C2)

[2] Xuxun Liu, A Survey on Clustering Routing Protocols in Wireless Sensor Networks, Sensors (Basel) 2012;

[3] Raghunandan.G.H, Sagar Metri, “A novel approach to increase overall efficiency in wireless sensor networks”, International Conference on Computing, Electronics and Electrical Technologies [ICCEET]-2012

[4] Raghunandan.G.H, Dr.A.Shobha Rani, Nanditha.S.Y, Swathi.G, “Hierarchical agglomerative clustering based routing algorithm for overall efficiency of wireless sensor network”, International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT)-2017.

[5] Raghunandan G.H, “An Adaptive Cluster Based Routing Protocol for WSN”, Int. Journal Advanced Networking and Applications Volume: 07 Issue: 01, 2015.

[6] Hamza Fahim, Nadeem Javaid, Zahoor Ali Khan, Umar Qasim,Shumaila Javed, Danish Mahmood, Zafar Iqbal, “ Multilevel Routing Protocol for Energy Optimization in Wireless Sensor Networks, 2015 9th International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing, 2015.

[7] Amanjot Singh Toor, Dr. A.K. Jain, “A Survey of Routing Protocols in Wireless Sensor Networks: Hierarchical Routing”,IEEE Conference on the Recent Advances and Innovation in Engineering at Jaipur, 2016.

[8] Jaya Lakshmy V, Sindhu V, “ A Structural Analysis of a few Energy Efficient Hierarchical Routing Protocols in WSN”, 2017 International Conference on Innovations in Information, Embedded and Communication Systems, 2017.

[9] Raghunandan.G.H, “Comparative Analysis of Routing Techniques for Wireless Sensor Networks”, Proceedings of the IEEE National Conference on Innovations in Emerging Technology, IEEE Conference Proceedings, February 2011

[10] Amit Rathee, Randeep Singh, Abhishilpa Nandini “Wireless Sensor Network – Challenges and Possibilities”, International Journal of computer Applications(0975-8887) volume 140-no 2,April 2016.

[11] JaeHyun Kim, MyungJune Youn, HahnEarl Jeon and Jaiyong Lee/ Yonsei Univ, “Comparison of traffic dependant wireless sensor network protocols”, 2010

[12] W. Heinzelman, A. Chandrakasan and H. Balakrishnan, "Energy-Efficient Communication Protocol for Wireless Micro sensor Networks," In proceedings of the 33rd Hawaii International Conference on System Sciences (HICSS '00), January 2000

[13] L. Yadav, C. Sunitha, “Low Energy Adaptive Clustering Hierarchy in Wireless Sensor Network (LEACH)”, SGT Institute of Engineering & technology, Gurgaon, Haryana-122505,INDIA, International Journal of Computer Science and Information Technologies, Vol. 5 (3),2014.

[14] N. Sindhwani, R. Vaid, “V Leach: An Energy Efficient Communication Protocol for WSN”, Vol. 2, No. 2, February-March 2013.

[15] Rupika Goyal, Shashikant Gupta, Pallavi Khatri, “Energy Aware Routing Protocol Over Leach on Wireless Sensor

[16] Network”, International Conference on Computing, Communication and Automation (ICCCA2016).

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PERFORMANCE EVALUATION OF SOLAR TRACKING SYSTEM WITH REFLECTORS

MADHU MC[1], C S MALA[2] & K. BADARI NARAYANA[3]

[1]*Assistant Professor, Mechanical Engineering, Bmsit&M, Bengaluru, India*

[2]*Associate Professor, Telecommunication Engineering, Bmsit&M, Bengaluru, India*

[3] *Principal Consultant, COE Aerospace & Defence, VTU Nagarabhavi, Bengaluru, India*

ABSTRACT

An automatic solar panel orientation system has been designed to achieve high performance by tracking the sun rays throughout the day. The solar tracking system was connected to the DC motor which is driven by the shaft and the shaft in turn is connected to the solar panel. The main panel rotates to harvest the maximum sunlight. Two reflectors fixed on each side of the panel ensure that the light radiation is directed on to the panel. A bearing was mounted on the column shaft to facilitate the rotation to the tracker. A motor is provided to drive the shaft and it tracks the motion of the sun across the sky and ensures the maximum amount of radiation to fall on the panels. The efficiency of the system was found to be higher using the solar tracking system with reflectors, when compared to the system without reflectors. To achieve this, the solar tracking system was implemented using a DC geared motor, solar photovoltaic panels and geared wheel arrangement.

KEYWORDS: Photo Voltaic Cell, Reflectors, Solar Panel, Solar Panel Efficiency & Solar Tracking System

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Original Article

INTRODUCTION

Solar energy is one of the most promising renewable energy sources. There is a huge conversion potential of solar energy into electrical power. The conversion of solar radiation into electrical energy using Photovoltaic (PV) effect is a very promising technology since it is a clean, silent and reliable technology. The maintenance cost of Solar Photovoltaic Cells is very low. It has been found that this technology has a very small ecological impact. Performance of a photovoltaic array depends primarily on sunlight. Climatic conditions like clouds and fog significantly affect the amount of solar energy that is received by the PV array and therefore impacts its performance.

Literature Review

An extensive literature survey has been carried out. Different types of sun-tracking systems and their merits and demerits have been discussed by Hossein Mousazadeh [1]. The author finds that the most efficient and popular sun-tracking device to be the polar-axis and azimuth/elevation type tracking system.

Ahmed Abu Hanieh [2] explains that two degrees of freedom can be done using part of the power output of the solar panel. In his project, the kinematics of the system used is simple and can easily be controlled using astronomic geometric calculations taking into account the symmetry of the system.

Nader Barsoum [3] has developed and implemented a solar tracking system with two degrees of freedom and it also detects the sunlight using sensors. This Peripheral Interface Controller was the brain of the entire tracking system,

and it was programmed to detect the sunlight through the sensors and then actuate the motor to the position.

Some work has been carried out on the solar radiation falling perpendicular to the Photovoltaic panel. It was found that [4] a system which implemented tracking produced an average of 1.4 times more heat energy in comparison with the stationary collector of the same size.

Methodology

The photovoltaic cell is the basic building block of a photovoltaic system. The individual cells varies from 0.5 inches to 4inches. One cell produces an electrical power between 1 to 2 watts. The PV Panels are fabricated using these cells. The PV panels are connected in series to increase the total power generated. These panels produce electricity as the sun rays fall on them by converting solar radiation into electrical power. Each PV panel produces an approximate of 75 watts of power with an efficiency of around 18%. In order to increase the efficiency of the panels, various methods are adopted. One such method is the automatic solar tracking system. This system facilitates the run rays to fall on the PV panels for the longer duration of time thus enabling higher electrical power generation, which in turn increases the efficiency of the panels.

A solar tracking system basically consists of a DC gear motor to turn the panels in the direction of sunlight**.** In our work, a DC gear motor, two solar cells, and a gear wheel arrangement are being used for the tracking system. Two reflectors are fixed on each side of the panel. This ensures that the sunlight falling is directed on the panel. A motor is driven by the shaft. The shaft is connected to a solar panel.

It tracks the motion of the sun across the sky and ensures the maximum amount of radiation falls on the panels. The solar panels are positioned to receive sufficient amounts of airflow. This induces natural cooling, which help to keep the efficiency rate high.

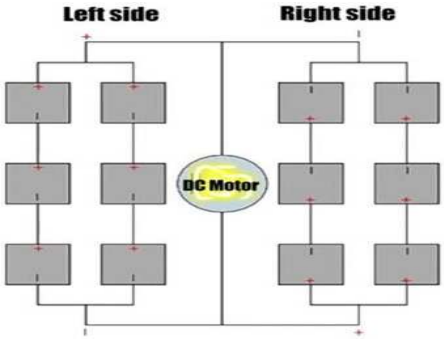


Figure 1: Circuit Diagram For The Solar Tracker Reflectors

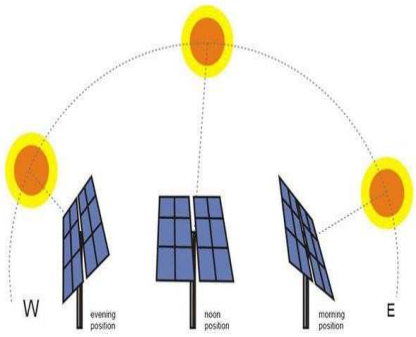


Figure 2: Sun Tracking System

Aluminium foil is prepared in thin metal leaves with a thickness less than 0.2 mm (7.9 mils); The foil is pliable and can be readily bent or wrapped around objects. It has 87-89% reflectivity.

Bevel gears are useful when the direction of a shaft's rotation needs to be changed. They are usually mounted on shafts that are 90 degrees apart but can be designed to work at other angles as well.

Figure 3: Sun Tracking with Reflectors

Experimentation

Experiments were carried out to investigate the performance improvement in the efficiency of solar PV panels. The entire set up for tracking the sunlight falling on the solar PV panels is represented in the Figure 2. Generally, a sun tracker is employed to increase the efficiency of the panel. In our work, a reflector is employed along with the sun tracker, in order to increase the efficiency further.

Experiments were conducted without the reflectors first. The set up of the same is shown in Figure 3. The experimentation results were obtained and the same experiment was conducted with reflectors and the results were noted. It was observed that the efficiency of the panel greatly improved with the addition of the reflectors.

Efficiency of Solar Panel without Reflectors

Solar panels are fixed at an angle of the latitude of the location. The latitude for Bangalore is 12.8^0 and hence the solar panels are inclined at 13^0. This enables maximum rays to fall on the panel, which generally is from 9 am to 3 pm.

Efficiency of Solar Panel with Reflectors

A solar tracker is a device which is fitted on to the solar panels that track the motion of the sun across the sky and ensures the maximum amount of radiation fall on the panels. A bearing is mounted on the column shaft to provide rotation to the tracker. A motor is provided to drive the shaft.

Solar Panel Conversion Efficiency Calculation

Solar panel conversion efficiency is the ratio of the electrical output of a solar cell to the incident energy (falling on the cell) in the form of sunlight.

The energy conversion efficiency (η) of a solar cell is the percentage of the solar energy that is converted into electrical energy. This is calculated by dividing a cell's power output (watts) at its maximum power (P) by the input light (W/m2) and the surface area of the solar cell (m^2).

Solar Conversion Efficiency = P /(E *A) * 100 (1)

Solar cells power output is calculated by P(W)= V*I (2)

Area of solar panel = 0.133 m^2

Energy input = 1000 W/m^2

RESULTS AND DISCUSSIONS

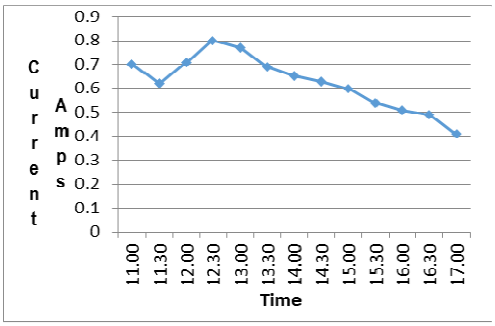
Results for Solar Panels without Reflectors

An extensive research has been carried out to explore the conversion efficiency with and without reflectors for the photovoltaic solar panels.

The observations of the experiments are presented in the tables and graphs. Table 1 presents the results of experiments conducted without reflectors. It is seen that the voltage is at a peak at 16.00. hours and the current measured at that point of time was 0.51 amps, which resulted in yielding a power of 10.618watts with an efficiency of 7.96%. The least voltage observed was in the range 14.00 hours to 14.30hours, at which points the current measured was 0.65Amps and 0.63Amps, yielding a power of 12.62watts and 12.42watts yielding an efficiency of 9.75 and 9.45% respectively. It is observed that at 12.30 hours, the voltage it measured was 20.41Volts and a current of 0.8A which has generated a power of 16.328watts yielding an efficiency of 12.24% which is the maximum recorded during the course of the experiment. The point to be noted here is that at 12.30hours not only is the efficiency the highest but the peak current of 0.8 A is observed. The results of Table 1 is plotted as a graph of current versus time and is presented in Graph 1. and the efficiency versus Time is presented in Graph 2.

Table 1: Experimentation Results for Solar Panels without Reflectors

Time	Voltage (V)	Current (A)	Power (W)	Efficiency (%)
11.00	20.6	0.7	14.42	10.81
11.30	20.7	0.62	12.834	9.62
12.00	20.5	0.71	14.555	10.91
12.30	20.41	0.8	16.328	12.24
13.00	20.03	0.77	15.631	11.72
13.30	20.02	0.69	13.81	10.35
14.00	20	0.65	13	9.75
14.30	20	0.63	12.6	9.45
15.00	20.7	0.6	12.42	9.31
15.30	20.7	0.54	11.178	8.38
16.00	20.82	0.51	10.618	7.96
16.30	20.6	0.49	10.094	7.57
17.00	20.6	0.41	8.446	6.33



Graph 1: Current vs Time for Solar Panels without Reflectors

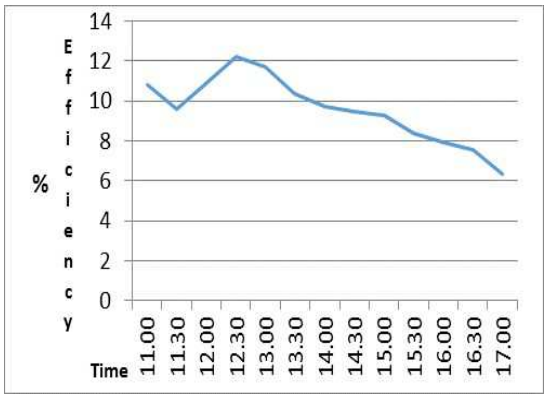
Results for Solar Panels with Reflectors

The results for the experimentation of the Solar Panels with reflectors are presented in Table 2. The experiment observation reveals that the voltage measured is maximum at 11.00hours measuring a current of 0.8 Amps giving a power of 16.64 watts yielding an efficiency of 12.48. It was observed from the Table.2 that the minimum voltage measured at

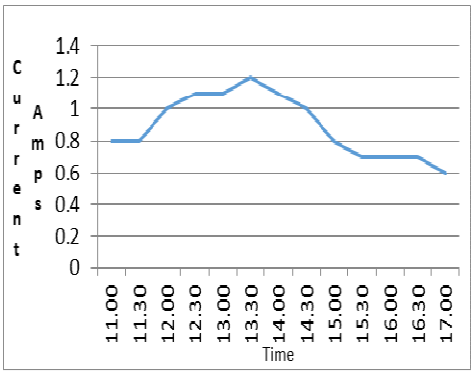
14.00 Hours and at that time the current measured was 1.1amps and power was 22W and an efficiency of 16.5%. The maximum efficiency yielded was at 13.30hours, when the voltage was 20.2 volts and a current of 1.2Amps, generating power of 24W yielding an efficiency of 18.18%. It was also observed that the peak current was obtained at 13.30 hours. The least efficiency and current were seen from 16.00 Hours onwards. The least observed efficiency was 9.27% at 17.00 hours. The graph of current versus time is presented in Graph.3. It was observed from the graph that the current is maximum at 13.30 hours. Graph.4 represents the relationship between time and efficiency.

Table 2: Experimentation Results for Solar Panels with Reflectors

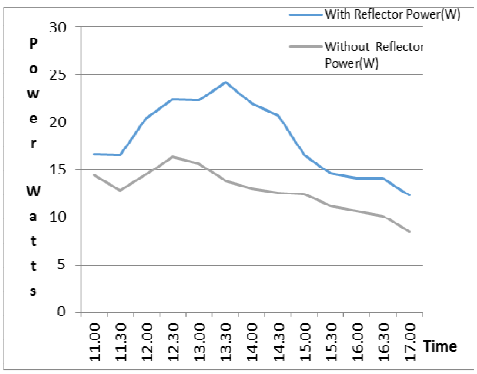
Time	Voltage (V)	Current (A)	Power (W)	Efficiency (%)
11.00	20.8	0.8	16.64	12.48
11.30	20.7	0.8	16.56	12.42
12.00	20.5	1	20.5	15.37
12.30	20.4	1.1	22.44	16.83
13.00	20.3	1.1	22.33	16.74
13.30	20.2	1.2	24.24	18.18
14.00	20	1.1	22	16.5
14.30	20.7	1	20.7	15.52
15.00	20.7	0.8	16.56	12.42
15.30	20.8	0.7	14.56	10.92
16.00	20.6	0.7	14.04	10.53
16.30	20.6	0.7	14.04	10.53
17.00	20.6	0.6	12.36	9.27



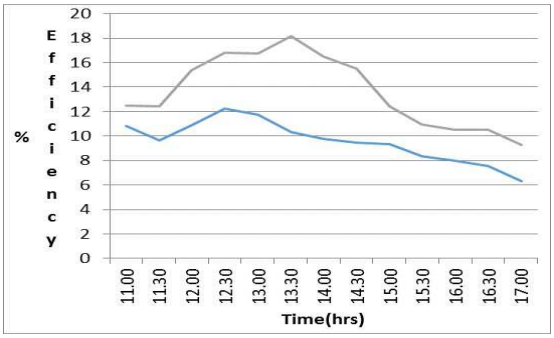
Graph 2: Efficiency vs Time for Solar Panels without Reflectors



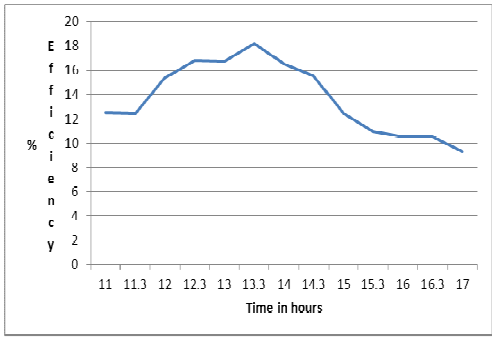
Graph 3: Current vs. Time for Solar Panels with Reflectors



Graph 4: Efficiency vs Time for Solar Panels with Reflectors



Graph 5: Comparison of the Output Power Without Efficiency with and Without Reflectors



Graph 6: Comparison of Solar PV Panel with and Reflectors

After obtaining the results for power generation and efficiency for Solar PV panels with reflectors and without reflectors, a comparison was made and inferences were drawn. Comparisons of the output power is presented in Graph 5 and comparison of efficiencies with and without reflectors are presented in Graph 6.

It was observed from graph 5 that the maximum power generated is 16.328watts for solar panel without reflector, whereas with reflectors the maximum power generated was 24.24W. Table 1 and Table 2 indicate that the efficiency without reflectors was 2.24%, whereas with reflectors was 18.18%

The above results clearly indicated that the power generation in Solar PV Panels has greatly increased by7.912W by interfacing reflectors to the solar panels. It also indicated the rise in efficiency by 5.94 % due to the introduction of reflectors.

For solar PV panels, an increase in conversion efficiency even by 1% is a significant achievement, as a large number of panels are always connected for higher power generation. For a power generation of 10kW, on an average of 100 solar panels are required. Therefore it was clear that a small increase in efficiency would result in a significant increase when used for larger scale power generation.

We compared the solar tracking system by the use of a solar cell with a fixed solar panel system and found that the efficiency of tracker-based solar tracking system was improved by 23%.

CONCLUSIONS

By using reflectors, it was observed that efficiency of solar panel increased by 8% for a fixed interval of time over a day. Also, a solar cell with the tracking system was more efficient than a fixed solar panel system. This system was found to be more efficient and cost-effective in the long run. From the results, it was found that, by automatic tracking system and reflectors, there was the improvement in efficiency when compared with a non-tracking system.

REFERENCES

1. *Hossein Mousazadeh, "A review of principle and sun tracking methods of maximising solar system output," Renewable and sustainable energy reviews, Elsevier, Pergamon vol 13(2009), pp1800-1818.*
2. *Ahmed Abu Hanieh," Solar Photovoltaic panels tracking system," Advances in Dynamical systems and control, Birzeit univ., 15January 2015, pp 30-37.*
3. *Nader Barsoum, "Fabrication of dual –axis solar tracking controller project", Intelligent control and automation, Vol 2, No 2, pp.265-273*

4. *L. Kancevica et al, "Renewable Energy and Energy Efficiency" Proceedings of the international scientific conference, Jelgava- 2012.*
5. *R. Condit and D. W. Jones, "Simple DC motor fundamentals," Texas Instruments. Publication AN907, pp. 1 – 22, 2004.*
6. *S. J. Hamilton, "Sun-tracking solar cell array system," University of Queensland Department of Computer Science and Electrical Engineering, Bachelors Thesis, 1999.*
7. *M. F. Khan and R. L. Ali, "Automatic sun tracking system," presented at the Engineering Conference,*
8. *Nader Barsoum, "Fabrication of Dual-Axis Solar Tracking Controller Project", Curtin University, Sarawak, Malaysia, Intelligent Control and Automation, 2011, Vol2, pp. 57-68.*
9. *Antonio L. Luque; Viacheslav M. Andreev "Concentrator Photovoltaics". Springer Verlag. (2007).*
10. *David Cooke, "Single vs. Dual Axis Solar Tracking", Alternate Energy eMagazine, April 2011*
11. *Prof. Pooja K. Chhatwani, Prof. Jayashree Somani, "Intelligent solar tracker system implemented on 8051 microcontroller". International Journal of Engineering Trends and Technology, Vol.4, Issue 9, pp 4267-4271, Sep.2013*
12. *http://www.nrel.gov/learning/re_photovoltaics.ht ml?print*
13. *http://www.solar-facts.com/panels/paneltypes.php.*
14. *S. P. Sukhatme, J. K. Nayak, " Solar Energy- Principles of thermal collection and storage", Third Edition, pp.1-460*
15. *Optimal design of orientation of PV collector with reflectors (http:/www.sciencedirect.com/science/ article/pii/S0306261910000462)*
16. *A. K. Saxena and V. Dutta, "A versatile microprocessor based controller for solar tracking," in Proc. IEEE, 1990, pp. 1105 – 1109.*
17. *T. A. Papalias and M. Wong, "Making sense of light sensors," http://www.embedded.com, 2006.*

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A NEW CHANNEL ASSIGNMENT METHOD IN COGNITIVE RADIO SYSTEM

C.P. Mallikarjuna Gowda[1] and T. Vijayakumar[2]

[1]*Department of Telecommunication Engineering, B.M.S. Institute of Technology and Management, India*
[2]*Department of Electronics and Communication Engineering, SJB Institute of Technology, India*

Abstract

In this paper, a novel method to estimate the unsuccessful probability is proposed by combining the unnecessary probability and the blocking probability. The Unnecessary probability is the probability when the mobile node is unnecessarily handed over and the blocking probability is the one when the network is not able to assign the channel to the mobile now. A new design of new channel assignment method for cognitive radio system is presented. The first fit method and the random assignment methods are also implemented for the cognitive radio application as a baseline. The PU and SU call blocking are modeled for all the three methods. It is shown that advantages of first fit method and the random assignment methods are combined into the new method, namely, selective assignment method. Simulation are conducted for the various network parameters like number of channels, number of links, load on each link, percentage of the PU versus SU calls etc. It is shown that selective assignment method yields better results than that of the first fit method and the random assignment methods. Finally, the blocking probabilities are combined with the unnecessary handover probabilities of a three-node network to determine the unsuccessful handover probabilities of the first fit, random assignment and selective assignment methods.

Keywords:

Cognitive Radio, Random Assignment, First Fit Assignment, Selective Assignment, Unnecessary Probability, Blocking Probability, Unsuccessful Handover Probability

1. INTRODUCTION

Quality of service (QoS) is very important to ensure that the calls get transmitted from one point to other point. The QoS is not just necessary but it should be optimum enough to guarantee high throughput. The resources of the network should be effectively used with optimum QoS. The QoS can be optimized with the call arrival rate, call termination rate, holding time of the calls, blocking probability etc. In a cognitive radio world, there are licensed users and unlicensed users. The licensed users are known as Primary Users (PU) and the unlicensed users are known as Secondary Users (SU). In order to guarantee the interference free communication, the SU must not occupy the channels assigned for the PU. The Cognitive radio base station (CRBS) assigns the vacant channels to the PU and SU whenever the calls arrive.

The SUs are allocated the channels meant for the PUs. While allocating the SU in the channels of PU, it requires dynamically detecting and identifying the channels that are not in use by the PU. While performing this task of dynamic detection, there is a considerable amount of energy consumption. Ahmed et al. [1] and Elias et al. [2], authors discussed a comprehensive survey on the state-of-the-art channel assignment algorithms and spectrum assignment in cognitive radio networks, respectively. Usman et al. [3] [4] demonstrated channel assignment models for high priority users in wireless cellular network. The increase in blocking probability of newly originated calls is the tradeoff in using these models, which leads to bad QoS. Zafer et al. [5] developed a blocking probability analysis for a multi-hop wireless line and grid networks. The authors focused on the effect of transmission radius of the nodes and dynamic channel assignment algorithm. Xiukui et al. [6] demonstrated that the PU and SU can coexist in a network and the SU can directly access the channels allocated for the PU. The calls of the PU are closely monitored by the SU. A prediction technique has been proposed by the authors to guess the arrival of PU. However, this model lacks the channel updating scheme. The optimum architecture for the CRBS is discussed in detail by the authors in ref [7]. Bajpai et al. [8], authors discussed a spectrum allocation scheme for a Cooperative Cognitive Radio Network (CCRN). The scheme involved leasing out of the spectrum reserved for the PU to SU. However, this work does not cover the spectrum sensing methods.

Xiukui et al. [9] developed a prediction algorithm to predict the PU traffic and SU traffic. The prediction of the traffic was based on the spectrum sharing. The accessibility of the channels meant for the PU was estimated in terms of the probability for the SU allocation. The methods developed in this work are computationally expensive and it was difficult to implement this scheme practically. Authors of another similar research work [10] also performed analysis and developed a predictive algorithm to estimate the PU traffic. Cooperative spectrum sharing by means of static cognitive radio nodes over different service providers have been proposed by Kaniezhil et al. [11]. Centralized channel allocation was discussed in detail in [12]-[15]. A mobile switching center allocates the channels to the calls in centralized channel allocation since only mobile switching center has the information about the channel usage information. Mobile switching center allocates the channels in such way that there would be no interference of the channels. Whenever, each cell releases or allocates channels, it immediately notifies the mobile switching center and hence the later has all the information about the status of channels in all the cells. However, the centralized channel allocation system suffers a drawback. It suffers from the single point failure and the whole network system comes to halt when the mobile switching center fails. This scheme is not only scalable, but also not reliable.

The distributed channel allocation schemes [16]-[20] are more versatile and reliable than that of the centralized channel allocation schemes. There is no mobile switching center in the distributed channel allocation system and each cell has a base station to assign the channels. Each station takes the decision based on the local information and does not depend on the neighboring cells or base stations. However, the base station which allocates the channels, communicates with all other base stations about its decision so that the channel is not reserved or allocated by the other base stations.

The channel allocation algorithms by the base station can be based on the first fit or random assignment. In this work, the drawbacks of the first fit and random assignment are discussed

and new selective assignment scheme is presented. The selective assignment method is designed to handle the calls of PU and SU.

Based on the literature review conducted, it is observed that the channel assignment methods are first fit and random assignment both for PU and SUs for same sequence of channels. When a new PU arrives, if the channel is already occupied by a PU or SU, then it results in blocking. Same thing happens for SU as well. Hence the blocking probabilities are high with first fit and random assignment. In order to overcome this, a new channel assignment that treats PUs and SUs separately is required to be designed.

Also, when a mobile node is transferred from one network to another network due to lack of enough bandwidth, if it results in unnecessary handover along with call blocking in the new network, then it is much more inefficient than being in the first network. Hence it is required to determine the total probabilities considering the unnecessary probability and blocking probability in a two or three network system, for example. An effort is made in this research work to determine the total unsuccessful probability considering both unnecessary handover probability and blocking probability for a three- network system. The literature for the methods to estimate the unnecessary handover can be found from [21]-[23].

In this paper, a new channel assignment method is proposed in order to reduce the blocking probabilities as low as possible. In the selective channel assignment, a window of channels can be reserved for the calls. Same window can be used both for PU and SU or separate windows can be reserved. When separate windows are reserved at two extreme ends of the channel sequence, the blocking probabilities are very least. When first fit or random assignment is used, the same channels will be allocated to the new PU or SU, but if they are occupied PU already then it results in blocking. In the new channel assignment method, the PU channels are reserved at one end of the sequence and the channels at the other end which are unused by PU, are reserved for the SUs. Hence the blocking probabilities are very less in such an arrangement. In this paper the selective channel assignment method is presented for different scenarios. Also, a method to estimate the total unsuccessful probability considering unnecessary handover probability and blocking probability is presented.

In section 2, the probability equations derived and the channel selection methods first fit, random assignment and selective assignment methods are discussed in detail. Also, the probability equations are presented for the unnecessary handovers in a three-node network. In section 3, the simulation results for various cases are presented. Finally, the conclusions are given in the last section.

2. PROBABILITY MODEL

Let the Markov chain be represented as $M/M/\infty$. The arrival rate of the call is represented by λ and termination rate by μ. The states of the process are defined by no calls, one call, two calls, or n calls. As per the Markov condition, the probability of entering into a state depends only on the previous last state, but not on the previous state states of the last state. If the present state of the system is P_i, then the probability of transition is from P_i to P_{i+1}. The state of any system is given by the Poisson distribution as:

$$P(L,C) = \frac{L^C}{C!} e^{-L} \tag{1}$$

where, L is the load and the C is the number of channels in the system. The Poisson's distribution is applicable for the number of calls being infinite, but practically, the number of channels is finite. If the N is the number of infinite calls and n is the number of finite calls then by approximating the Poisson's distribution to finite number of calls, any call that is beyond n will not get service and assumed to be a NULL. Therefore, the Poisson's distribution now become,

$$P(L,C) = \frac{\frac{L^C}{C!}}{\sum_{i=0}^{n} \frac{L^i}{i!}} \tag{2}$$

where, $P_e(L,C)$ is known as the Erlangs probability density function. The blocking probability can be defined as:

$$P_{b,p} = \frac{\frac{L^n}{n!}}{\sum_{i=0}^{n} \frac{L^i}{i!}} \tag{3}$$

A network has the channels and the links. The number of links and channels are finite in a network. Each link may be considered as the connection between one base stations to another base station. Each base station can assign a call to a particular frequency range or channel and the call gets transmitted from one base station to the target end base station, to which the receiving call is connected to. In a cognitive radio networks, the type of calls can be primary or secondary. Hence each type of call can be through these channels and links. When the PU calls get the priority in transmission, SU calls also keep arriving at base station which must be given the secondary priority. Hence, when the PU calls are not scheduled, the SU are allocated in those channels and links. But as soon as the SU call is allocated, a PU call may arrive which leads to the blocking of the PU call.

Let the arrival rate of the PU call is λ_p and that of the secondary call is λ_s similarly μ_p and μ_s are the termination rates of PU and SU respectively. Let the states are represented by x_p and x_s.

$$\lambda_p P_{0xs} = P_{1xs}\mu_p \tag{4}$$

This can be written as

$$P_{1xs} = \frac{\lambda_p}{\mu_p} P_{0xs}$$

$$P_{1xs} = A_p P_{0xs} \tag{5}$$

Similarly, from second state to third state

$$\lambda_p P_{1xs} = P_{2xs} 2\mu_p \tag{6}$$

$$P_{2xs} = \frac{\lambda_p}{2\mu_p} P_{0xs} \tag{7}$$

$$P_{2xs} = A_p P_{0xs} \tag{8}$$

This can also be written as

$$P_{2xs} = \frac{A_p^2}{2!} P_{0xs} \tag{9}$$

The generalized form of Eq.(9) is

$$P_{xp,xs} = \frac{A_p^{xp}}{xp!} P_{0,xs} \quad (10)$$

$$P_{xp,xs} = \frac{A_s^{xs}}{xs!} P_{xp,0} \quad (11)$$

Let $x_s = 0$, then

$$P_{xp,0} = \frac{A_p^{xp}}{xp!} P_{0,0} \quad (12)$$

Combining both Eq.(11) and Eq.(12),

$$P_{xp,0} = \frac{A_p^{xp}}{xp!} \frac{A_s^{xs}}{xs!} P_{0,0} \quad (13)$$

Considering entire set of all the states,

$$P_{xp,xs} = \frac{A_p^{xp}}{xp!} \frac{A_s^{xs}}{xs!} e^{\left[A_p + A_s\right]} \quad (14)$$

The assignment of channels can be done in any of the two methods:

- First fit method
- Random assignment method

In First fit method, when a PU call or SU call arrives, the first link of first channel is assigned with that call. The call will move forwards in the chain of links. When the next call arrives, again the first link of the first channel is assigned. In this method, the main disadvantage is the channels at the farther end of the sequence of the channels are unutilized.

In the random assignment method, the channels are selected randomly; hence all the channels may get equal chance to service the calls. But there is a high chance that the calls get blocked since the calls are assigned randomly. There is a possibility that two consecutive calls may get assigned to the same channel. The advantage of using random assignment is all the channels are utilized uniformly.

In this paper, a new method is proposed, to assign both primary calls and secondary calls in a wireless network, the advantages of both the above methods are leveraged. This method is known as selective approach method. The channels can be assigned randomly but at the specific window of channels in the sequence. For examples, when the channels near the start of the sequence is selected in the window as priority channels, it becomes equivalent to First fit method. The window can be chosen randomly at any location; hence it has the advantage like a random assignment method. The location of the window is the key in this method to achieve the best performance. More importantly, the two windows can be chosen as priority for PU and SU separately. This particular feature is absent in the first fit and random assignment methods.

In some cases, the handover probabilities need to be considered along with the blocking probabilities for successful handover of the mobile unit. If the mobile units are handed over unnecessarily then if the calls get blocked, it results in a very severe situation and network will start losing its credibility. Hence before handing over, the unnecessary handovers are to be calculated so that risk can be estimated. In the present work, a three-node network simulated for the unnecessary handovers.

Consider there are three networks A, B and C as shown in Fig.1. For mathematical purpose, it can be denoted as nodes n_1, n_2 and n_3. Let the maximum number of channels in the network nodes are B_1, B_2 and B_3. Let the occupied bandwidth in the network nodes can be denoted as b_1, b_2 and b_3. $P_{nj/ni}$ denotes the probability of mobile node moving from node n_i to n_j and $P_{ni/ni}$ denotes the probability of mobile node continue to stay in n_i after a time interval D. The mobile node will be transferred from node n_1 to n_2 when $b_2 - b_1 \geq L$, where L is the minimum gap of number of channels that should be maintained to take the decision for handover. More details can be found about wrong decision probabilities in [22].

Hence,

$$P_{n2/n1} = P\{b_2 - b_1 \geq L\},$$
$$P_{n1/n2} = P\{b_1 - b_2 \geq L\},$$
$$P_{n3/n2} = P\{b_3 - b_2 \geq L\},$$
$$P_{n2/n3} = P\{b_2 - b_3 \geq L\},$$
$$P_{n3/n1} = P\{b_3 - b_1 \geq L\}, \text{ and}$$
$$P_3 = P\{b1 - b_3 \geq L\} \quad (15)$$

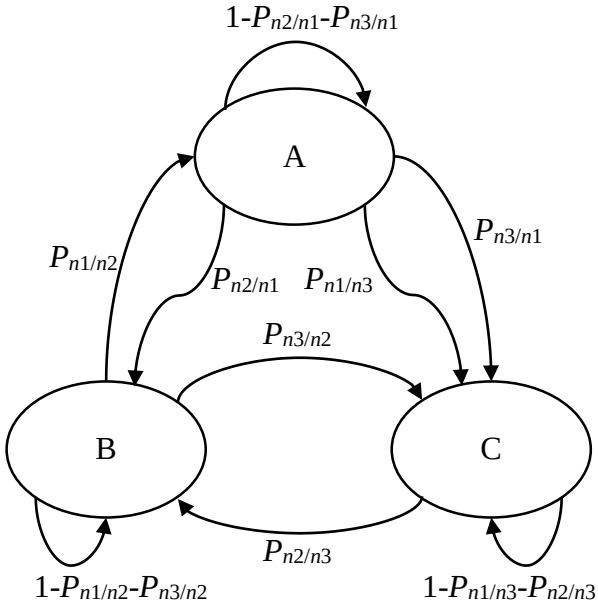

Fig.1. Three-Node Network

Unnecessary handover probability can be expressed as

$$UHP = P_{n1}P_{n2/n1}\sum_{j=L}^{B_2}\prod_{2,B_2-j}\sum_{k=0}^{j-L}\prod_{1,B_1-k}\xi_1(k,r,D)\cdot\sum_{i=0}^{B_1}\prod_{1,B_1-i}\sum_{k=i+L}^{B_2}\prod_{2,B_2-k}\psi_2(k,r,D)$$
$$+P_{n1}P_{n3/n1}\sum_{m=L}^{B_3}\prod_{3,B_3-m}\sum_{k=0}^{m-L}\prod_{1,B_1-k}\xi_1(k,r,D)\cdot\sum_{i=0}^{B_1}\prod_{1,B_1-i}\sum_{k=i+L}^{B_3}\prod_{3,B_3-k}\psi_3(k,r,D)$$
$$+P_{n2}P_{n1/n2}\sum_{j=L}^{B_1}\prod_{1,B_1-j}\sum_{k=j-L+2}^{B_1}\prod_{1,B_1-k}\psi_1(k,r,D)\cdot\sum_{i=0}^{B_2}\prod_{2,B_2-i}\sum_{k=0}^{i+L-2}\prod_{2,B_2-k}\xi_2(k,r,D)$$

$$+P_{n2}P_{n3/n2}\sum_{j=L}^{B_3}\prod_{1,B_3-j}\sum_{k=j-L+2}^{B_3}\prod_{3,B_3-k}\psi_3(k,r,D)\cdot\sum_{m=0}^{B_2}\prod_{2,B_2-m}\sum_{k=0}^{m+L-2}\prod_{2,B_2-k}\xi_2(k,r,D)$$

$$+P_{n3}P_{n1/n3}\sum_{m=L}^{B_1}\prod_{1,B_1-m}\sum_{k=m-L+1}^{B_1}\prod_{1,B_1-k}\psi_1(k,r,D)\cdot\sum_{i=0}^{B_3}\prod_{3,B_3-i}\sum_{k=0}^{i+L-2}\prod_{3,B_3-k}\xi_3(k,r,D)$$

$$+P_{n3}P_{n2/n3}\sum_{j=L}^{B_2}\prod_{2,B_2-j}\sum_{k=0}^{j-L}\prod_{3,B_3-k}\xi_3(k,r,D)\cdot\sum_{m=0}^{B_3}\prod_{3,B_3-m}\sum_{k=m+L}^{B_2}\prod_{2,B_2-k}\psi_2(k,r,D) \quad (16)$$

where, $\prod_{i,k}$ is the probability of occupied bandwidth k and ρ_i is the traffic load in channel i.

$$P_{n1}=\frac{P_{n1/n2}+P_{n1/n3}}{P_{n1/n2}+P_{n2/n1}+P_{n1/n3}+P_{n3/n1}} \quad (17)$$

$$P_{n2}=\frac{P_{n2/n1}+P_{n2/n3}}{P_{n1/n2}+P_{n2/n1}+P_{n2/n3}+P_{n3/n2}} \quad (18)$$

$$P_{n3}=\frac{P_{n3/n1}+P_{n3/n2}}{P_{n1/n3}+P_{n3/n1}+P_{n2/n3}+P_{n3/n2}} \quad (19)$$

$$\prod_{i,k}=\frac{\rho_i^k}{k!\sum_{j=0}^{B_i}\frac{\rho_i^j}{j!}} \quad (20)$$

$$\xi_i(r,k,D)=\sum_{m=0}^{B_i-k}\frac{(\Lambda_i D)^m}{m!}e^{-\Lambda_i D}\cdot\sum_{s=0}^{m+k-r}\frac{(\lambda_i D)^s}{s!}e^{-\lambda_i D} \quad (21)$$

$$\psi_i(r,k,D)=\sum_{m=0}^{B_i-k}\frac{(\Lambda_i D)^m}{m!}e^{-\Lambda_i D}\cdot\left[1-\sum_{s=0}^{m+k-r}\frac{(\lambda_i D)^s}{s!}e^{-\lambda_i D}\right] \quad (22)$$

$$\Lambda_i=\lambda_i(B_i-k)/B_i \quad (23)$$

The unsuccessful handover probability can be expressed as

$$P_{unsuccessful}=UHP\times P_{blocking} \quad (24)$$

The blocking probabilities are estimated based on the type of channel allocation method, i.e. first fit, random assignment or selective assignment.

3. SIMULATION RESULTS

In this section, simulation results are presented for algorithms based on first fit, random assignment and selective assignment methods for primary unit's allocation and secondary unit's allocation. In the first part only two existing methods, namely, first fit, random assignment is verified for performance. The models are simulated for a tandem - networks that has the 10 nodes, 10 channels with 3 Erlangs of load per link and 20 nodes, 11 channels with 5 Erlangs of load per link. In both the cases, the number of PU calls are 80% of the total calls received. That means, for 2000 iterations, there are 2000 calls received, of which 1600 calls are PU calls and the remaining 400 calls are SU calls.

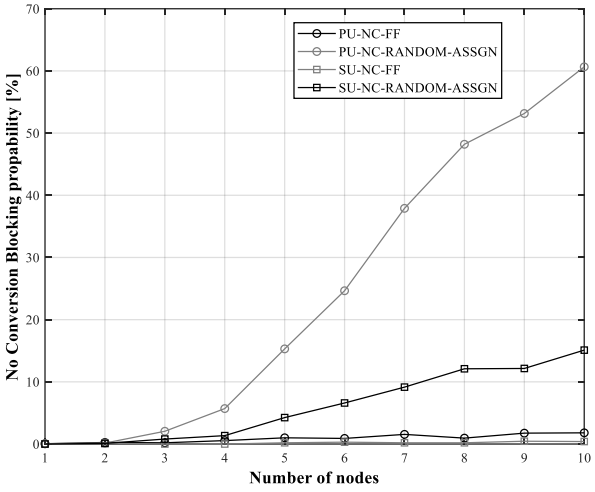

Fig.2. Blocking Probability of First Fit and Random Distribution for a load 3 Erlangs per link and with 10 Channels, 10 Links (nodes) and 2000 iterations

The Fig.2 shows the blocking probability of the PU and SU assignment with first fit and random assignments. The network has 10 Channels, 10 links and there was a load of 3 Erlangs per link. It can be concluded from Fig.2 that the random assignment has higher blocking probability than that of the first fit method both for the PU and SU. However, the problem with first fit method is, the channels in the tail end of the frequencies are not utilized to its capacity. There is always more utilization on the channels near the head end of the sequence of channels.

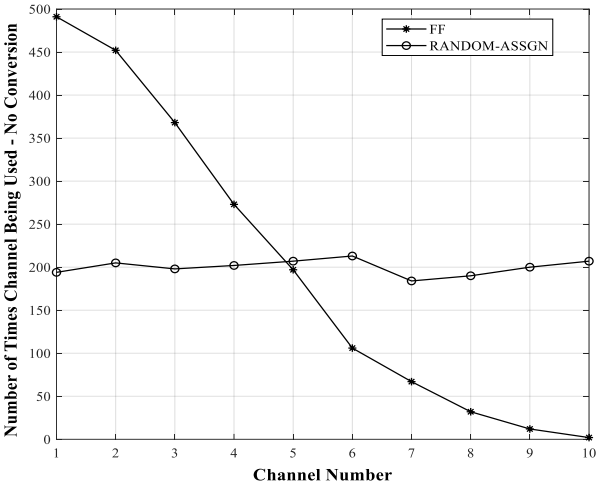

Fig.3. Frequency of channel usage by First Fit, Random Distribution for a load 3 Erlangs per link and with 10 Channels, 10 Links (nodes) and 2000 iterations

It can be observed from Fig.3 that with first fit method, channel 1 is used 485 times for assignment and Channel 2 is used 450 times, whereas the channels 7, 8, 9 and 10 are used less than 100 times. In case of the random assignment, all channels are used approximately 200 times, but the blocking probabilities are high as shown in Fig.2, i.e. 61% for PU and 16% for SU. In case for First fit, it is 3% and 1.5% respectively for PU and SU.

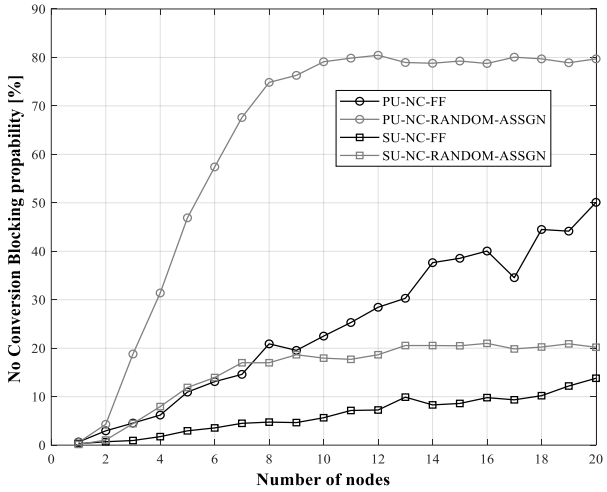

Fig.4. Blocking Probability of First Fit and Random Distribution for a load 5 Erlangs per link and with 20 Link (nodes), 11 Channels and 2000 iterations

When the load is increased to 5 Erlangs per link in a 20 links and 11 channel networks, the blocking probabilities are very high with 80% for PU and 20% for SU, as shown in Fig.4, when the random assignment was used. In case of first fit assignment, it is 50% for PU and 13% for SU. The increase in the blocking probabilities can be attributed to the high load on each link. The frequency distribution of channel assignment is provided in the Fig.5.

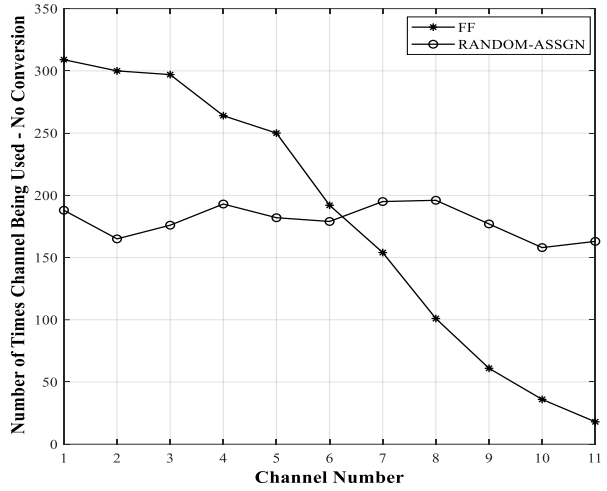

Fig.5. Frequency of channel usage by First Fit, Random Distribution for a load 5 Erlangs per link and with 20 Links (nodes), 11 Channels and 2000 iterations

As a next step, a selective assignment method has been developed as part of this research work. In this method, the channels are not selected based on the sequence, but based on the priority set. For example, the channels in the middle are given priority while assigning the calls or the channels at the end may be given the preference. This flexibility is not possible when the first fit method is used. The random assignment method does not have the flexibility to give the priority either at the beginning of the sequence or at any desired location. Hence the proposed selective assignment method has the advantage of the random assignment and the priority assignment similar to first fit method. Hence the selective assignment method may be treated as a combined method of first fit method and the random assignment method.

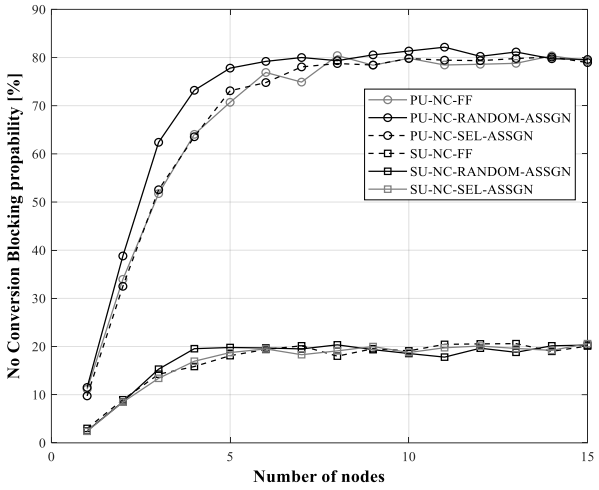

Fig.6. Blocking Probability of First Fit, Random Distribution and Selective Assignment methods for a load 8 Erlangs per link and with 15 Links (nodes), 10 Channels and 2000 iterations

The Fig.6 shows the blocking probability for the First Fit, Random Distribution and Selective Assignment methods with priority near the start of the channel sequence for a load 8 Erlangs per link and with 15 Links (nodes), 10 Channels and 2000 iterations. The simulations are performed both for PU and SU. Of the total 2000 calls, 80% of the calls are PU and the remaining 20% are SUs. It can be observed from the Fig.6 that selective assignment methods have better blocking probability than the first fit or random assignment. For example, at link 2, selective assignment has 32% blocking probability for PU, random assignment has 39% and first fit has 34%. After link 4, random assignment and selective assignment both have almost similar blocking probabilities. In case of SUs, the blocking probabilities are better in case of selective assignments up to the link 5. Since the number of SU calls are less than that of the PU calls, the blocking probabilities are much lower in case of SUs for all the three methods of assignment.

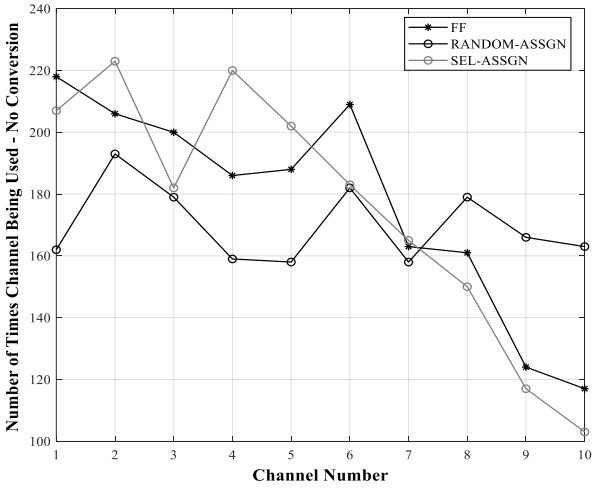

Fig.7. Frequency of channel usage by First Fit, Random Distribution and Selective Assignment methods for a load 8 Erlangs per link and with 15 Links (nodes), 10 Channels and 2000 iterations

From Fig.7, it can be observed that the number of times channels near the start of the sequence is random up to channel 5 and then the frequency of channel usage is similar to first fit assignment. In both these cases, the cannels were not properly used.

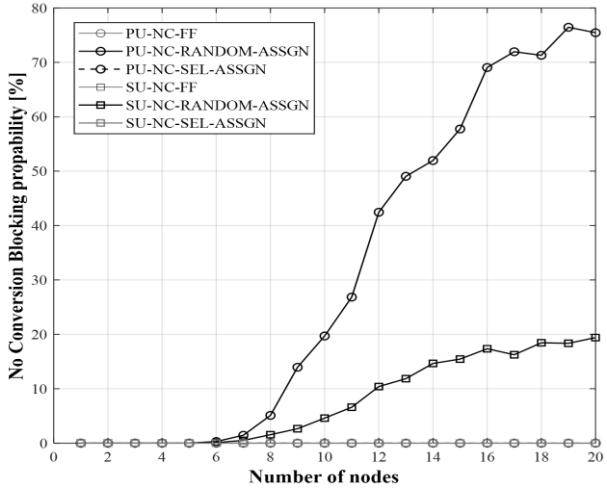

Fig.8. Blocking Probability of First Fit, Random Distribution and Selective Assignment methods for a load 15 Erlangs per link and with 20 Links (nodes), 50 Channels and 2000 iterations

The Fig.8 shows the blocking probability for the First Fit, Random Distribution and Selective Assignment methods with priority at the middle of the sequence of channels for a load 15 Erlangs per link and with 20 Links (nodes), 50 Channels and 2000 iterations. The Selective assignment and first fit methods both yielded almost zero blocking probability. This zero blocking probability was due to the reason that there are 50 channels available to accommodate 2000 calls. This is true both in cases of PU and SU.

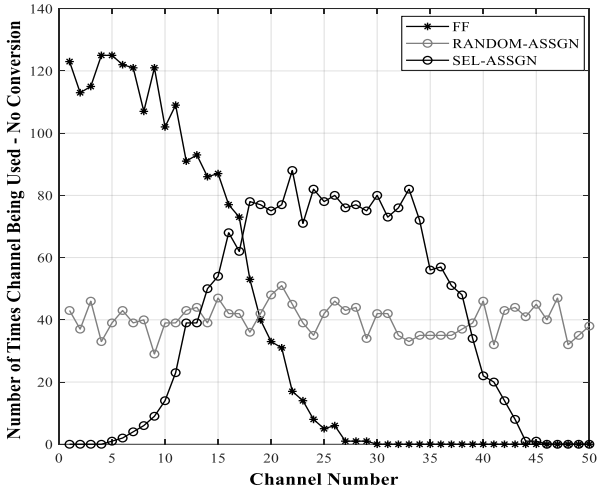

Fig.9. Frequency of channel usage by First Fit, Random Distribution and Selective Assignment methods for a load 15 Erlangs per link and with 20 Links (nodes), 50 Channels and 2000 iterations

The Fig.9 shows an interesting plot about the distribution of the utilization of the channels by the selective assignment. Since the method has the flexibility to provide priority to any window, in this simulation, the channels at the middle of the sequence were given priority both for PU and SU. The frequency of utilization is high near channel 25.

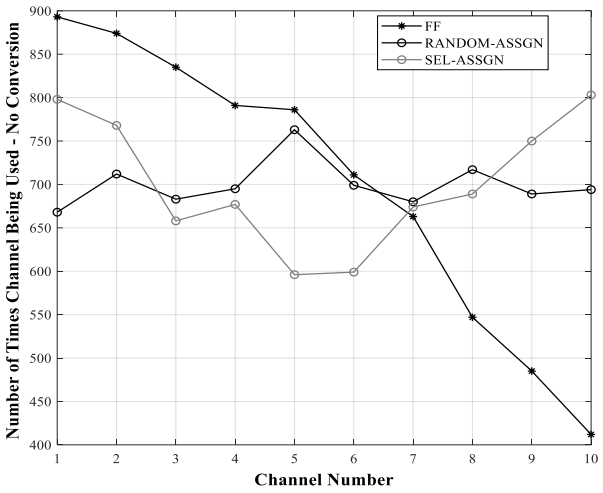

Fig.10. Frequency of channel usage by First Fit, Random Distribution and Selective Assignment methods for a load 8 Erlangs per link and with 15 Links (nodes), 10 Channels and 8000 iterations

An interesting feature of the proposed method can be observed in Fig.10, where the channels near the beginning of the sequences are reserved for the PUs and the channels near the end of the sequence are reserved for the SUs in case of selective assignment method. With this approach, the blocking probabilities can be significantly reduced in case of the selective assignment method. The feature of assigning different priority channels is not possible in case of first fit assignment and the random assignment method.

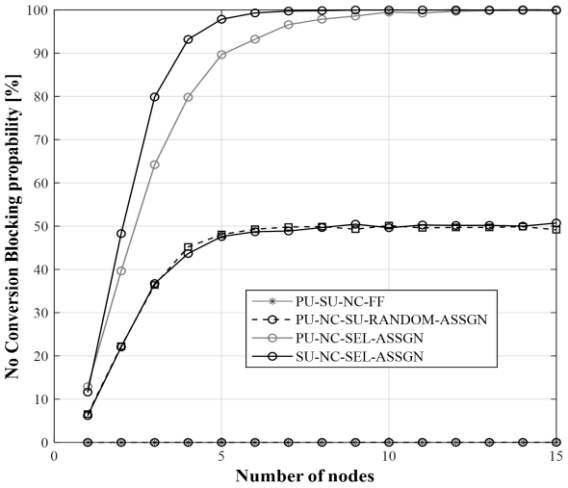

Fig.11. Blocking Probability of First Fit, Random Distribution and Selective Assignment methods for a load 8 Erlangs per link and with 15 Links (nodes), 10 Channels and 8000 iterations

In yet another simulation with the priority given near the start of the sequence for PU and the near the end of the sequence for SU, with equal probabilities of arrival of PU and SUs, the Fig.11 shows that there is significant improvement in the blocking probability for the selective assignment method. The reason behind the significant improvement is in case of first fit and the random assignment methods, the same set of channels are

repeated channels both for PU and SU. With selective assignment method, the PU and SU can be reserved with a set of channels and hence there is significant reduction in the blocking probability. The blocking probability is maximum when the reserved channels in the selective channels are as distant apart as possible between PUs and SUs.

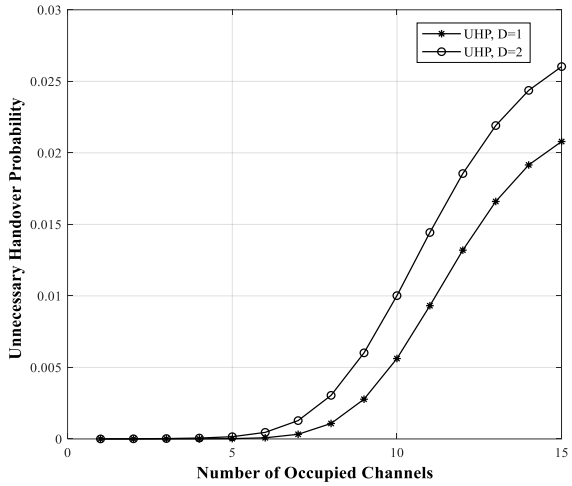

Fig.12. Unnecessary Handover Probability vs. number of occupied channels for B_1 = 15, B_2 = 15 and B_3 = 15.

From Fig.12, the UHP for different decision times can be read and it can be used along with the blocking probabilities of Fig.10 to determine the unsuccessful probability of handover of first fit, random assignment and selective assignment methods.

4. CONCLUSIONS

In this work, the channel assignment algorithms are implemented in MATLAB. The summary of results is presented in Table.1. The first fit method and random assignment method are used to estimate the blocking probabilities. The First fit method yielded lower blocking probabilities than the random assignment method, however random assignment method has the advantage of the utilizing all the channels randomly and efficiently. The advantages of the first fit method and random assignment are combined and a new assignment method, namely selective assignment is proposed. In this method, a window for selective channels for maximum assignment is randomly selected. The window can be selected anywhere in the sequence of the channels. Also when this assignment is applied to PU and SU together, the first fit and random and selective assignment methods will repeatedly use the same channels or channels in the same window for assignment. As future work, total unsuccessful probabilities need to be estimated when a PU gets blocked in the window reserved for PU, it can be assigned in the window of SU so that blocking probabilities can further be reduced for PUs.

Hence the first fit method and selective assignment methods yielded almost same blocking probability. However, in selective assignment method, there is a flexibility to choose multiple windows separately for PU and SU. It is shown in the results that as the distance between the window of PU and window of SU increases, the blocking probabilities become much better than the first fit and random assignment. When the distance is maximum, the blocking probability drops by 50% in case of selective assignment method. Hence, the selective assignment proposed in this paper is more efficient than that of the first fit and the random assignment methods. The blocking probabilities are combined with the unnecessary handover probabilities to determine the unsuccessful handover probabilities of the first fit, random assignment and selective assignment methods.

Table.1. Summary of all Simulations

Number of Channels	Number of Nodes	Load in Erlangs	Ref	Best Assignment method
10	10	3	Fig.2	First Fit
11	20	5	Fig.4	First Fit
10	15	8	Fig.6	Selective Assignment and First Fit
50	20	15	Fig.8	Selective Assignment
10	15	8	Fig.11	Selective Assignment

REFERENCES

[1] Ejaz Ahmed, Abdullah Gani, Saeid Abolfazli, Liu Jie Yao and Samee U. Khan, "Channel Assignment Algorithms in Cognitive Radio Networks: Taxonomy, Open Issues, and Challenges", *IEEE Communications Surveys and Tutorials*, Vol. 18, No. 1, pp. 795-823, 2016.

[2] Elias Z, Tragos, Sherali Zeadally, Alexandros G, Fragkiadakis and Vasilios A. Siris, "Spectrum Assignment in Cognitive Radio Networks: A Comprehensive Survey", *IEEE Communications Survey and Tutorials*, Vol. 15, No. 3, pp. 1108-1135, 2013.

[3] Muhammad Rehan Usman and Soo Young Shin, "Channel Allocation Schemes for Permanent User Channel Assignment in Wireless Cellular Networks", *IETE Journal of Research*, Vol. 62, No. 2, pp. 189-197, 2016.

[4] Muhammad Rehan Usman and Soo Young Shin, "Channel Blocking Analysis and Availability Prediction in Cognitive Radio Networks", *Proceedings of IEEE Workshop on Computing, Networking and Communications*, pp. 1-6, 2017.

[5] Murtaza Zafer and Eytan Modiano, "Blocking Probability and Channel Assignment in Wireless Networks", *IEEE Transactions on Wireless Communications*, Vol. 5, No. 4, pp. 233-245, 2006.

[6] Xiukui Li and S.A. Reza Zekavat, "Cognitive Radio Based Spectrum Sharing: Evaluating Channel Availability via Traffic Pattern Prediction", *Journal of Communications and Networks*, Vol. 11, No. 2, pp. 104-114, 2009.

[7] Berk Canberk, Ian F. Akyildiz and Sema Oktug, "Primary User Activity Modeling using First-Difference Filter Clustering and Correlation in Cognitive Radio Networks", *IEEE/ACM Transactions on Networking*, Vol. 19, No. 1, pp. 170-183, 2011.

[8] Rahul Bajpai and Aditya Trivedi, "Joint Power and Spectrum Allocation for Cooperative Cognitive Radio Network with End User Mobility", *Proceedings of 11th*

International Conference on Wireless and Optical Communications Networks, pp. 1-5, 2014.

[9] Xiukui Li and S.A. Reza Zekavat, "Traffic Pattern Prediction Based Spectrum Sharing for Cognitive Radios", *Proceedings of International conference on Electrical and Electronic Engineering*, pp. 1-5, 2009.

[10] X. Li and S.A. Reza Zekavat, "Spectrum Sharing Across Multiple Service Providers via Cognitive Radio Nodes", *IET Communication*, Vol. 4, No. 5, pp. 551-5661, 2010.

[11] R. Kaniezhil and C. Chandrasekar, "Multiple Service providers sharing Spectrum using Cognitive Radio", *International Journal of Scientific and Engineering Research*, Vol. 3, No. 3, pp. 1-7, 2012.

[12] H. Jiang and S. Rappaport, "Prioritized Channel Borrowing without Locking: A Channel Sharing Strategy for Cellular Communications", *IEEE/ACM Transactions on Networking*, Vol. 4, No. 2, pp. 163-172, 1996.

[13] J.C.I. Chuang, "Performance Issues and Algorithms for Dynamic Channel Assignment", *IEEE Journal on Selected Areas in Communications*, Vol. 11, No. 6, pp. 955-963, 1993.

[14] R. Mathar and J. Mattfeldt, "Channel Assignment in Cellular Radio Networks", *IEEE Transactions on Vehicular Technology*, Vol. 42, No. 4, pp. 647-656, 1993

[15] G. Cao and M. Singhal, "Distributed Fault-Tolerant Channel Allocation for Cellular Networks", *IEEE Journal of Selected Areas in Communications*, Vol. 18, No. 7, pp. 1326-1337, 2000.

[16] J. Yang, D. Manivannan and M. Singhal, "A Fault-Tolerant Dynamic Channel Allocation Scheme for Enhancing QoS in Cellular Networks", *Proceedings of IEEE 36th International Conference on System Sciences*, pp. 306-315, 2003.

[17] T.H. Lai, J. Jiang and T. Ma, "A Relaxed Mutual Exclusion Problem with Application to Channel Allocation in Mobile Cellular Networks", *Proceedings of IEEE 20th International Conference on Distributed Computing Systems*, pp. 592-599, 2000.

[18] X. Dong and T.H. Lai, "Distributed Dynamic Carrier Allocation in Mobile Cellular Networks: Search vs. Update", *Proceedings of International Conference on Distributed Computing Systems*, pp. 108-115, 1997.

[19] R. Prakash, N. Shivaratri and M. Singhal, "Distributed Dynamic Channel Allocation for Mobile Computing", *Proceedings of 14th International Symposium on Principles of Distributed Computing*, pp. 47-56, 1995.

[20] Jian Chang Yang and D. Manivannan, "Performance Comparison of Two Channel Allocation Approaches: Channel Pre-allocation vs. Non-Pre-allocation", *Proceedings of 3rd International Conference on Wireless and Mobile Communications*, pp. 191-195, 2007.

[21] C. Chi, X. Cai, R. Hao and F. Liu, "Modeling and Analysis of Handover Algorithms", *Proceedings of IEEE Global Telecommunications Conference*, pp. 4473-4477, 2007.

[22] S. Akhila and S. Kumar, "Analysis of Handover Algorithms based on Wrong Decision Probability Model", *International Journal of Wireless Networks and Communications*, Vol. 2, No. 1, pp. 165-173, 2010.

[23] Suresh R. Halhalli, Subhash Kulkarni, K.S.R. Anjaneyulu and S. Akhila, "Probability Modeling of Multi Node Wireless Networks", *International Journal of Computer Applications*, Vol. 51, No. 1, pp. 22-27, 2012.

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Effect of Block Size on the Performance of a new Algorithm to Compress an Image using 3D DCT

Surekha R Gondkar[1], Dr.Girish V Attimarad[2], Dr.B Chandrasekhar[3]

[1]*Dept. of TE, BMS Institute of Technology and Management,Bengaluru-560064, India*
[2]*Dept. of ECE, KS School of Engineering and Management, Bengaluru-560109, India*
[3]*Dept. of CSE, RR Institute of Technology, Bengaluru, 560 090, India*
**Corresponding Authors and E-mails:*
[*1]*gattimarad@gmail.com*
[*2]*surekha.r.gondkar@bmsit.in*
[*3]*drchandrasekhar.b@gmail.com*

Abstract

Image compression is a technique to reduce the image file size without affecting the visual quality considerably. In this paper a new technique to compress an image based on the Three-Dimensional Discrete Cosine Transform(3D DCT) is presented. In this method the input image is first partitioned into N sub images and are grouped together to form an N×N×N data cube. Each data cube is transformed using 3D DCT, and quantized. The resulting coefficients are zigzag scanned and entropy encoded to get the compressed image. In decompression the subimages are first reconstructed by applying the inverse operations in the reverse order. The full size image is then obtained by concatenating the reconstructed subimages. The new algorithm is tested on different images for various block sizes. The quality parameters are evaluated in each case. The results for the same are presented and analyzed in this paper.

Keywords— *Compression, 2D-DCT, 3D-DCT, MAD, .MSE, PSNR, CR.*

1. Introduction

In today's world enormous amount of images are being transferred over internet, mobiles, computers, hd tv's, tablets etc,. Generally large number of bits is required to represent the images. It is impractical to store or transfer the images, without reducing their size as it increases the storage requirements, communication bandwidth and hence cost. This has increased the need to develop techniques to store and transmit the data efficiently.

The basic objective of image compression is to reduce the redundancies in image representation with acceptable reconstructed image quality. This not only minimizes the memory requirements, but also reduces the cost of communication. Also reduction in the memory requirements results in storage of more data in less space and hence increases the communication bandwidth [1].

Image compression basically aims at reduction of redundant and irrelevant information in the image. The redundancy reduction is achieved by removing duplication from the input image. The irrelevancy reduction removes those details of the input image for which the Human Visual System (HVS) is insensitive, that is the distortion introduced does not affect the visual perception [2]. As a result, some difference in the regenerated pixel values may be allowed as the HVS will not find any noticeable difference between original and the reconstructed images [3].

The performance of Discrete Cosine Transform (DCT) is very close to that of statistically optimal Karhunen-Loeve transform[4], and hence it has been used as a kernel in many standards like JPEG (e.g., [5], [6]) for compression of still images, MPEG-1 [7], MPEG-2 [8] and H.263 [9] for video coding, CCITT H.261 (also known as Px64), for video compression (video telephony and teleconferencing) [10]. Because of this a number of applications use it for image compression, speech processing, feature extraction etc[11].

The main steps in image compression are transformation, quantization and encoding. Quantization and encoding processes play a significant role in reducing the size of an image.

Even though several compression algorithms are developed based on 2D DCT or a combination of 2D DCT with other transformations (Hybrid techniques), similar attention has not been paid for compressing an image using 3D DCT. The extension of 2D DCT to 3D DCT has some implicit advantages like high compression rates for homogeneous video sequences and symmetric codec structure [12]. In 1976, J. A. Roeseet al. used the three dimensional DCT for the first time, into inter frame transform image coding. The complexity of computation restricted 3D DCT for theoretical analysis only [11]. It can be found from the recent literature that many new algorithms have been developed for the fast calculation of 3D DCT to compress motion picture (video) [15-19]. This has given rise to many 3D sequential applications based on the 3D-DCT.

In this paper a new technique to compress a still image using 3D DCT has been presented. The performance of the new algorithm has been compared to the JPEG compression scheme based on 2D DCT in our previous work [20].In the present work the

experimental results for a sample image to demonstrate the effects of various block sizes on the quality of the reconstructed image are presented and analyzed.

2. New Algorithm To Compress An Image Using 3d Dct

The proposed image compression algorithm uses 3D DCT for compressing a 2D image. The block diagram is shown in Fig.1. An input image of size M×N is first partitioned into N sub images of equal size. Each of these sub images should have the

Fig.1 Compression process based on 3D-DCT

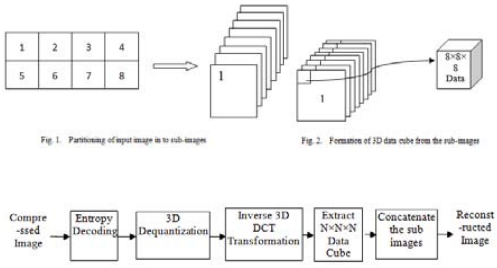

Fig. 1. Partitioning of input image in to sub-images Fig. 2. Formation of 3D data cube from the sub-images

Fig. 3 Decompression process based on 3D-DCT

number of pixels that are multiples of N along the rows and columns. To achieve this condition the image is initially appended with zeros at the ends. Then the 3D data is formed by arranging the N sub images in a sequential order similar to a video sequence as shown in Fig.2. Then N blocks of size N×N are picked from each sub image to form a 3D data cube of size N× N ×N as shown in Fig.3.

These 3D data cubes are transformed using 3D-DCT. The transformed data cube is quantized, scanned in a 2-D zig-zag pattern and entropy coded to get the compressed image. In decompression, all the processes are inverted and applied in reverse order to get the reconstructed image as shown in Fig.4.

A 3D Discrete Cosine Transform

The forward 3D DCT of an N×N×N image block f(x,y,z) is evaluated from (1) given below-

$$C(u,v,w)=\alpha_1(u)\alpha_2(v)\,\alpha_3(w) \sum_{x=0}^{N1-1}\sum_{y=0}^{N2-1}\sum_{z=0}^{N3-1} f(x,y,z)\cos\left[\frac{\pi(2x+1)u}{2N_1}\right] \cos\left[\frac{\pi(2y+1)v}{2N}\right]\cdot\cos\left[\frac{\pi(2z+1)w}{2N}\right],$$

$0\le u\le N-1,\ 0\le v\le N-1,\ 0\le w\le N-1,\ \alpha(0)=\sqrt{\frac{1}{N}}$ and $\alpha(i)=\sqrt{\frac{2}{N}}, i=1,2,..N-1$ (1)

The (u,v,w) entries of the transformed image are calculated from the elements of the input image matrix.

The Inverse Transform 3D-IDCT is calculated from (2) –

$$f(x,y,z)=\sum_{u=0}^{N-1}\sum_{v=0}^{N-1}\sum_{w=0}^{N-1}\alpha(u)\alpha(v)\alpha(w)C(u,v,w)\cdot \cos\left[\frac{\pi(2x+1)u}{2N}\right]\cdot\cos\left[\frac{\pi(2y+1)v}{2N}\right].\cos\left[\frac{\pi(2z+1)w}{2N}\right]$$

$0\le x\le N-1,\ 0\le y\le N-1,\ 0\le z\le N-1$ and $\alpha(0)=\sqrt{\frac{1}{N}}$,

$\alpha(i)=\sqrt{\frac{2}{N}}\ i=1,2,..N-1.$ (2)

The literature on the distribution of coefficients of 3D-DCT and their dynamic range for the compression of sequential images from video based on 3D DCT show that the DC coefficients range from several hundred to several thousands, whereas the magnitude of AC coefficients is much smaller and most of them are close to zero. Only in the case of busy scenes larger AC coefficients result. Thus the energy of AC coefficients is very less for the entire 3D-DCT cube compared to the DC coefficient [12-14].

B Quantization

This is a major process in achieving the compression because it involves the division of the transform coefficients by a constant and this reduces their magnitude. The smaller coefficients require lesser bits for their representation. Since the coefficients with very small magnitudes are rounded off to zeros after quantization, these cannot be restored by any technique; this step introduces some loss of information in the reconstructed image. The selection of quantization matrix plays a major role in deciding the quality and the compression rate to be attained. Thus it is very important to select a proper quantization matrix for any lossy compression scheme using transforms.

For a 2D DCT based image compression, a standard quantization table has been developed in JPEG compression and other related standards, but for 3D DCT based compression schemes, such standard table is not available. The 3D DCT when applied on a data cube gives a volume of coefficients. Thus the standard tables developed for 2D DCT based compression schemes may not be appropriate to use in the compression schemes using 3D DCT. Hence it is necessary to use a general quantization volume for 3D DCT compression. The quantization matrix design has to be based on the parameters like- The distribution of AC and DC coefficients resulting from subjective and qualitative experiments for some standard test data cube and the matrix elements must have small values at low frequencies and large values at high frequencies. Raymond K.W,Chan and M.C.Lee[12] have introduced a general formula to obtain optimum 3D quantization matrix for the 3D DCT given by (3). As in our work a still image is to be compressed using the 3D DCT, the same function for quantization has been selected.

$$Q(u,v,w)=\begin{cases} A_i\left(1-\frac{e^{-\beta_i(uvw)}}{e^{-\beta_i}}\right) & \text{for } f(u,v,w)\le C \\ A_0\left(1-e^{-\beta_0(uvw)}\right) & \text{for } f(u,v,w)>C \end{cases} \quad (3)$$

Each transformed coefficient is divided by the corresponding element of the quantization matrix. The result of this division is rounded off to complete the quantization step as given by (4).

$$D(u,v,w)=\text{round}\left[\frac{C(u,v,w)}{Q(u,v,w)}\right] \quad (4)$$

Here D(u,v,w) denote the quantized coefficients, Q(u,v,w) represent the elements of quantization matrix and C(u,v,w) represent the 3D DCT coefficients obtained after applying 3D DCT.

C Entropy Coding

The DC and AC coefficients are separated and then entropy coded. Entropy coding technique is a lossless method of compressing the data. That is the recovered data is identical to the original. In this technique the symbols with greater probability of occurrence are assigned with shorter code words and the symbols that occur with less probability are assigned longer code words. The example for entropy coding is the Huffman's encoding procedure.The scanning order should be in accordance with the order of quantization value from small to large and then Run Length Encoded. Hence a "zig-zag" scanning order is incorporated. This is also called diagonal scanning.

D Decompression

Image cube is reconstructed by first decoding the Run Length coded sequence and restoring it in a matrix form. This matrix is then dequantized by multiplying each value of D by the corresponding value from the quantization matrix Q as given by (5).

$$R(u, v, w) = Q(u, v, w)\ X\ D(u, v, w)$$

The Inverse Discrete Cosine Transform (3D IDCT) is then applied to matrix R. The 3D IDCT transform convert the data from frequency domain to spatial domain. These steps are repeated on each data cube to complete the image compression and decompression.

3. Experimental Results And Discussions

The new algorithm developed has been applied on different images of varied dimensions and content for different data cube sizes. The results for a sample input image of size 160 x 120 are shown in this section. Fig.5. shows the input image considered. Fig.6 shows the partitioning of the input image into sub images for N=4.

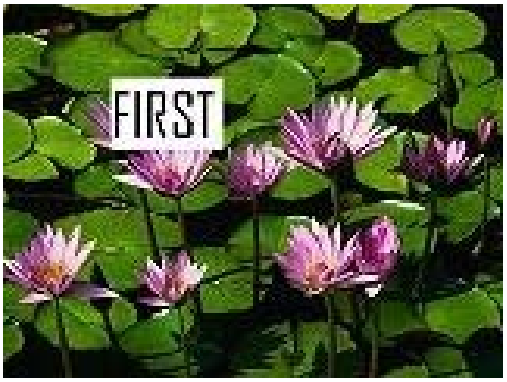

Fig. 5 Input Image

Fig. 6 Partitioning of input image into sub images

Fig.7. shows reconstructed sub sub-images after compression

Fig. 7 Reconstructed Sub images

Fig.8 shows the reconstructed image obtained by concatenating the sub images.

Fig. 8 Reconstructed Image

Various quality measures are calculated such as Mean Absolute Deviation (MAD), Mean Square Error (MSE), PSNR, Compression Ratio(CR) from equations (6) to (9)respectively and execution time.

$$MAD = \frac{1}{MNP}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\sum_{k=0}^{p-1}[f'(i, j, k) - f(i, j, k)] \quad (6)$$

$$MSE = \frac{1}{MNP}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\sum_{k=0}^{P-1}[f'(i,j,k) - f(i,j,k)]^2 \quad (7)$$

In equations "(6)" and "(7)", $f'(i,j,k)$ is the reconstructed image, $f(i,j,k)$ is the original input image; M and N are the number of pixels along rows and columns of the image respectively. P is number of frames (Here P=3 as there are 3 planes R, G and B) respectively.

$$PSNR = 10\log_{10}\left(\frac{255\times255}{MSE}\right) dB \quad (8)$$

$$\text{Compression Ratio (CR)} = \frac{Size\ of\ the\ original\ image}{Size\ of\ the\ compressed\ image} \quad (9)$$

Table.1.lists various quality measures calculated for the different block sizes.

Table.1 Quality measures for different block sizes

Lily	MAD	MSE	PSNR	CR	Execution time in seconds
N=4	10.6012	71.8864	29.5643	1.87128	2.937857
N=8	10.6111	74.0051	29.4382	2.54349	3.147991
N=16	11.6878	77.1145	29.2594	4.49648	13.020991

Fig. 9 Shows the graph of MAD for different block sizes.

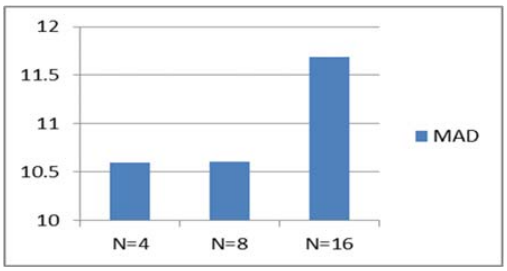

Fig. 9 Graph of MAD versus block size

From the graph it can be observed that Mean Absolute Deviation which is a measure of distortion in the reconstructed image increases with increase in the block size.

Fig. 10 shows the graph of MSE for different block sizes.

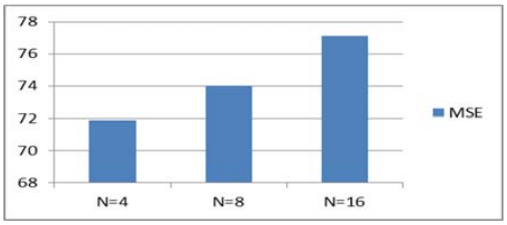

Fig. 10 Graph of MSE versus block size

From the graph, it is observed that if the block size is increased then the MSE also increases. That is quality of the reconstructed image reduces as the block size increases.

Fig.11 shows the graph of PSNR for different block sizes.

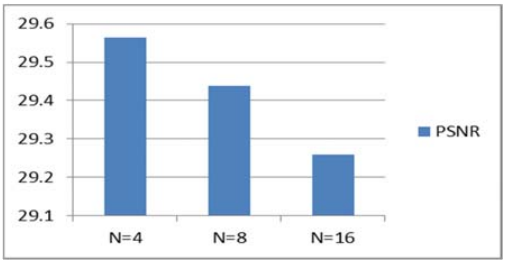

Fig. 11 Graph of PSNR versus block size

From the graph it is clear that the PSNR value reduces with increase in the block size. The result is that the quality of the reconstructed image has reduced but not significantly.

Fig.12 shows the graph of CR for different block sizes.

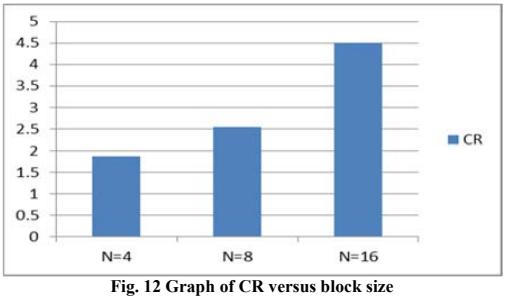

Fig. 12 Graph of CR versus block size

It is clear from the graph that the compression ratio for N=16 is more than double as compared to N=4.

Fig.13 shows the graph of elapsed time versus block size.

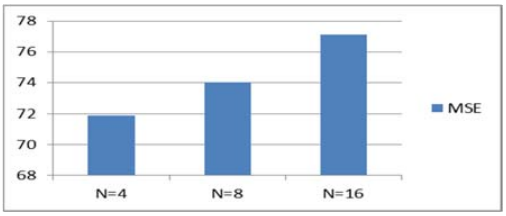

Fig. 13 Graph of Elapsed Time versus block size

The time of execution increases with the increase in block size drastically. This is due to increase in the number of computations for large N values.

4. Conclusions

In general, 2D DCT is used for compressing a still image and 3D DCT to compress a sequence of images. In this research work, an image is compressed using 3D DCT. In this technique, the image is first divided into N sub images. The data cubes of size N×N×N is formed by selecting N× N blocks from the N sub images. Each data cube is then 3D DCT transformed, quantized and encoded. In the decompression process after 3D IDCT, the reconstructed sub images are concatenated to get the full size original input image. This algorithm is tested for different block sizes like N=4,8 and 16 and in each case the quality metrics like MAD, MSE, PSNR,CR and elapsed time are computed. It is found that as the data block

size increases the MAD and MSE values increase which results in reduced PSNR value. Also the elapsed time increases as the block size increases. This is because, as the data block size increases, the number of computations also increases drastically.

References

[1] Abhishek Kaushik, Maneesha Gupta, "Analysis of Image Copression Algorithms", International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 2, pp.773-779, Mar-Apr 2012.

[2] Tsai, M. & Hung, H. "DCT and DWT based image watermarking using sub sampling", in the proceeding of 2005 IEEE Fourth International Conference on Machine Learning and Cybernetics, China (pp. 5308–5313).

[3] Al-Haj, A. "Combined DWT-DCT digital image watermarking", Journal of Computer Science, 3(9), 740–746, 2007.

[4] K. R. Rao and P. Yip, "Discrete Cosine Transform; Algorithms, Advantages and Applications", Academic Press Inc., 1990.

[5] G. K.Wallace, "The JPEG still-picture compression standard," Commun.ACM, vol. 34, pp. 30–44, Apr. 1991.

[6] W. B. Pennebaker and J. L. Mitchell, "JPEG Still Image Data Compression Standard", New York: Van Nostrand Reinhold, 1992.

[7] Puri, A."Video coding using the MPEG-1 compression standard". Society for Information Display Digest of Technical Papers 23: 123-126, 1992.

[8] "MPEG-2 video," ITU-T Recommendation H.262-ISO/IEC 13818-2,Jan. 1995.

[9] "Video coding for low bitrate communication," ITU-T Recommendation H.263, Dec. 1995

[10] Andrew B. Watson," Image Compression Using the Discrete Cosine Transform" Mathematica Journal, 4(1), pp.81-88, 1994,

[11] Zhishun Wang, Zhenya He, Fellow, IEEE, Cairong Zou, and J. D. Z. Chen, Senior Member, IEEE "A Generalized Fast Algorithm for n-D Discrete Cosine Transform and Its Application to Motion Picture Coding" IEEE Trans, Circuits and Systems-II: Analog and Digital Signal Processing, Vol. 46, No. 5, pp. 617-627, MAY 1999.

[12] Raymond K.W. Chan and M.C. Lee, "3D-DCT Quantization as a Compression Technique for Video Sequences", Proceedings. International Conference on Virtual Systems and MultiMedia VSMM 97 (Cat. No.97TB100182), 0-8186-8150-0/97 IEEE, pp 188 – 196, 1997.

[13] Tang Haiyan, Sun Wenbang, Gao Bingzhe, Zhang Fengjing," Research on Quantization and Scanning Order for 3-D DCT Video Coding", International Conference on Computer Science and Electronics Engineering, 978-0-7695-4647-6/12, IEEE, pp 200-204, 2012.

[14] Malavika Bhaskaranand and Jerry D. Gibson," DISTRIBUTIONS OF 3D DCT COEFFICIENTS FOR VIDEO", IEEE International Conference on Acoustics, Speech and Signal Processing- ICASSP 2009, 978-1-4244-2354-5/09, IEEE, pp 793-796, 2009.

[15] Said Boussakta and Hamoud O Alshibami,"Fast Algorithm for the 3-D DCT II", IEEE Transactions on Signal Processing, Vol 52,No 4, pp 992-1001, April 2004.

[16] JieLiangandTrac D. Tran," Fast Multiplierless Approximations of the DCT With the Lifting Scheme", IEEE TRANSACTIONS ON SIGNAL PROCESSING, VOL. 49, NO. 12, DECEMBER 2001,pp 3032-3044.

[17] Tomáš FRÝZA, Stanislav HANUS, "Algorithms for Fast Computing of the 3D-DCT Transform", ,RADIOENGINEERING, VOL. 12, NO. 1, APRIL 2003, pp 23-26.

[18] Qionghai Dai, Xinjian Chen, and Chuang Lin," Fast Algorithms for Multidimensional DCT-to-DCT Computation Between a Block and Its Associated Sub blocks", IEEE TRANSACTIONS ON SIGNAL PROCESSING, VOL. 53, NO. 8, AUGUST 2005,pp 3219-3225.

[19] Geetha K. S. and M. Uttarakumari," Multidimensional Fast Multiplierless DCT Algorithm Using Ramanujan Ordered Numbers", International Journal of Computer and Electrical Engineering, Vol. 4, No. 4, August 2012,pp 511-514.

[20] Gondkar S.R., Attimarad G.V., Chandrasekhar B. (2016) Compression of a 2D Image Using 3D-DCT. In: Shetty N., Prasad N., Nalini N. (eds) Emerging Research in Computing, Information, Communication and Applications. Springer, Singapore.

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DESIGN AND SOFTWARE CHARACTERIZATION OF FINFET BASED FULL ADDERS

Raju Hajare[1] and C. Lakshminarayana[2]
[1]*Department of Telecommunication Engineering, BMS Institute of Technology and Management, India*
[2]*Department of Electrical and Electronics Engineering, BMS College of Engineering, India*

Abstract

Adder is the most important arithmetic block that is used in all processors. Most of the logical circuits till today were designed using Metal Oxide Semiconductor Field Effect Transistors (MOSFET's). In order to reduce chip area, leakage power and to increase switching speed, MOSFET's were continuously scaled down. Further scaling below 45nm, MOSFET's suffers from Short Channel Effects (SCE's) which leads to degraded performance of the device. Here the Performance of 28T and 16T MOSFET based 1-bit full adder cell is characterized and compared with FinFET based 28T and 16T 1-bit full adders at various technology nodes using HSPICE software. Results show that FinFET based full adder design gives better performance in terms of speed, power and reliability compared to MOSFET based full adder designs. Hence FinFET are promising candidates and better replacement for MOSFET.

Keywords:

Adder, MOSFET, FinFET, CMOS, Pass Transistor Logic

1. INTRODUCTION

Today there is a huge demand for portable applications such as laptops, iPhones etc. with limited amount of power availability, requiring minimum area and high switching speed circuitry [1]. Therefore, circuits which provide low power consumption and high switching speed becomes the major candidates for design of microprocessor and other subsystems [2]. Addition is a basic arithmetic operation and is used in most of the VLSI subsystems like application specific DSP architectures and microprocessors [9]. Therefore 1-bit Full Adder cell is the most important and basic block of arithmetic logic unit in digital systems.

In low power VLSI systems, Metal Oxide Semiconductor field effect Transistors (MOSFET's) are the basic transistors used in most of the digital circuits. Continuous scaling of MOSFET's has resulted in better performance of the device parameters such size, delay and power. Further scaling of MOSFETs below 45nm node technology leads to short channel effects (SCE's), which modifies the device characteristics. The major SCE's includes

- Drain Induced Barrier Lowering.
- Velocity saturation.
- Hot electrons effect.
- Channel length modulation.
- Oxide breakdown.

To avoid these effects as well as to improve the switching speed ad to reduce the power requirements, MOSFET's were replaced by FINFET's in design circuitry [5] [6]. FINFET's are multiple gate devices. These multiple gates provide better control over the channel and hence reduce the short channel effects [6]. FINFET based adder in general shows an average of 94% drop in delay, 97% decrease in power dissipation over the conventional MOSFETs [7] [8].

2. FINFET TECHNOLOGY

FINFET known as Fin Field Effect Transistors non-planar or 3D transistor used to design modern processor. The main characteristics of FINFET is that it has a conducting channel wrapped by a thin silicon "fin" and hence the name FINFET. The thickness of the fin determines the effective channel length of the device. This wrap around gate structure provides better electrical control over the channel and this helps in reducing the leakage current and overcoming other short channel effects. This fin allows multiple gates to operate on single transistor. The multiple gates of FINFET extend Moore's Law which allows the semiconductor manufacturers to create microprocessor subsystem and memory modules that provides faster performances, less energy consumption and reduction in space complexity.

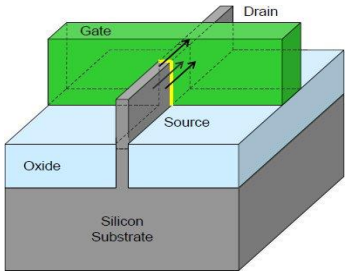


Fig.1. FinFET Structure [7]

The Fig.1 shows a FinFET structure. It has four terminals and it consists of source, drain and channel wrapped by multiple gates. Here we consider two gates FinFET structure namely front gate and back gate. FinFET can substitute in place of MOSFET by merely shorting the front and back gates together during device fabrication and allow FinFET work as single gate device.

3. 1-BIT FULL ADDER CELL

The operation of 1-bit full adder cell includes three inputs *A*, *B*, C_{in} using which outputs sum and carry are calculated.

$$Sum = A \oplus B \oplus C_{in}$$

$$C_{out} = A \cdot B + C_{in} (A \oplus B)$$

In this paper, a 1-bit full adder is implemented using both CMOS and FINFET technology. The full adder circuitry has been designed using different logic styles:

- Conventional CMOS logic style.
- Complementary pass transistor logic and transmission gates logic.

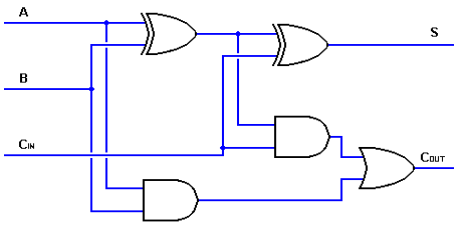


Fig.2. Basic Adder Circuit [9] [10]

Table.1. Full Adder Truth Table [9] [10]

A	*B*	C_{in}	*Sum*	C_{out}
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

4. MOSFET BASED FULL ADDER

The device parameters considered are based on predictive Technology Model (PTM) for developing a spice model and then simulating using HSPICE tool. The parameters are considered with respect to PTM as shown in the Table.2.

Table.2. Design considerations

Parameter	90nm MOSFET	45nm MOSFET
Gate Length (L_g)	90nm	45nm
Supply Voltage	1.5V	1.2V

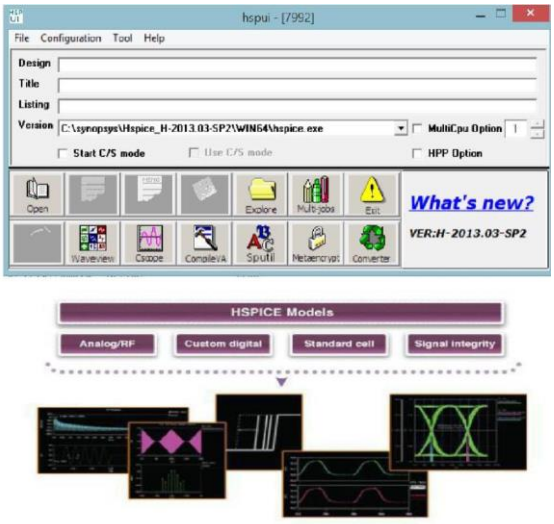


Fig.3. Hspice user interface and integration

The Fig.3 shows HSPICE user interface and integration, the netlist written for a particular circuit model is characterized via the Hspice user interface and the software is powerfully integrated to find the errors and produce the output results in accurate manner.

4.1 28T CONVENTIONAL CMOS FULL ADDER

This CMOS full adder consists of both PMOS and NMOS in the form of pull-up and pull- down network. The Fig.4 shows the schematic diagram of 28T conventional CMOS full adder cell.

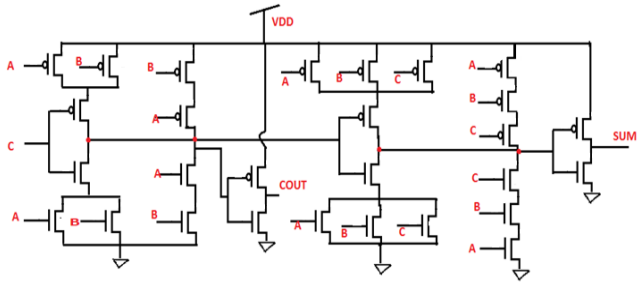


Fig.4. 28T conventional CMOS full adder

Output waveform of 28T full adder cell is as shown in Fig.5.

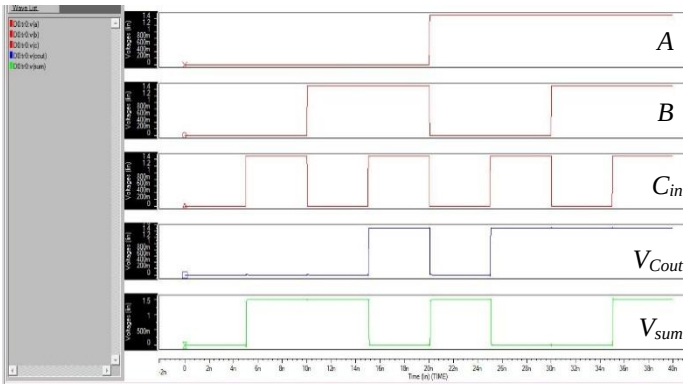


Fig.5. Output waveform at 90nm

In Fig.5, *A*, *B* and C_{in} are inputs to the adder circuit and V_{sum} and C_{out} are the sum and carry outputs respectively. The switching delay in generating sum and carry out along with power are calculated and tabulated in the Table.3. Same procedure is applied to all the node technologies evaluated using MOSFET and FinFET devices.

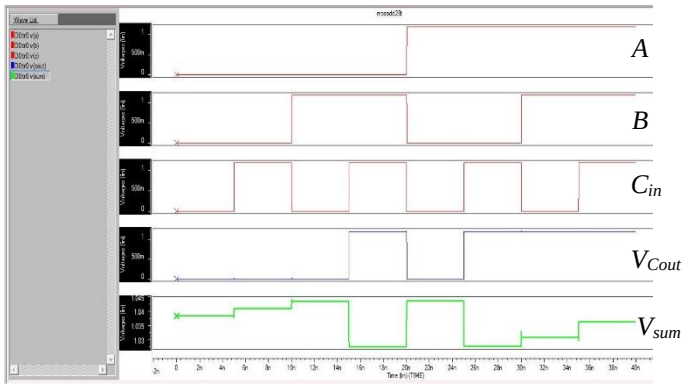


Fig.6. Output waveform at 45nm

Table.3. Results of 28T full adder cell

Node	Average Power (W)	Maximum Power (W)	Sum Delay (s)	Carry Delay (s)
250nm	23.6828µ	1.7951m	211.7751p	136.2695p
180nm	6.5605µ	557.1307µ	176.1207p	112.5616p
90nm	1.1997µ	158.9428µ	66.3052p	45.6138p
45nm	27.3311m	27.4380m	Failed	Failed

From the Table.3, it is clear that performance of MOSFET based full adder in terms of the power and delay values are obtained and it can be concluded that there is an increase in the power and delay values of MOSFET based Full Adder at 45nm node and below due to short channel effect faced by MOSFET devices.

4.2 16T MOSFET FULL ADDER

In order to reduce the number of transistors and to obtain optimum results, 16T full adder is designed and simulated using complementary pass transistors and transmission gates. The simulation is done in HSPICE tool. The Fig.7 shows the design of 16T MOSFET full adder cell.

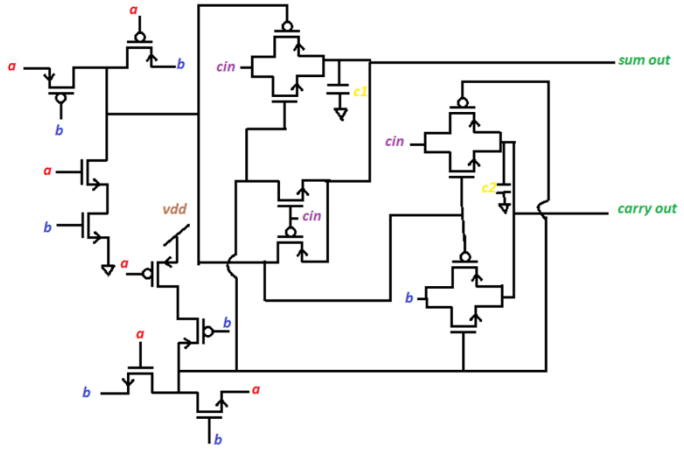


Fig.7. 16T MOSFET full adder cell

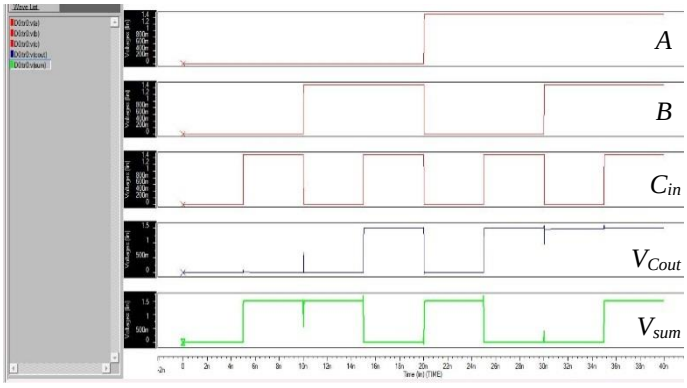


Fig.8. Output waveform at 90nm

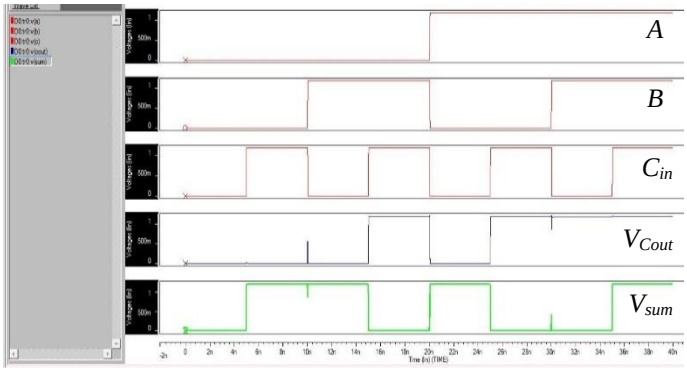


Fig.9. Output waveform at 45nm

Table.4. Results of 16T full adder cell

Node	Average Power (W)	Maximum Power (W)	Sum delay (s)	Carry delay (s)
250nm	17.0502µ	1.9958m	23.6453p	3.6746p
180nm	3.6266µ	548.9434µ	21.5174p	3.2325p
90nm	2.1733µ	195.1429µ	15.0140p	2.6017p
45nm	1.8895µ	90.9523µ	3.5366p	1.2495p

The Table.4 contains the power and delay values for MOSFET based full adder. It is observed that there is an increase in the power and delay values of MOSFET based Full Adder at lower nodes due to short channel effect faced by MOSFET devices.

5. FINFET BASED FULL ADDER

To overcome the scaling issue faced by MOSFET, full adder cell is designed using FINFET. The FinFET allows further scaling up to 14nm.

Table.5. Design considerations

Parameter	22nm FinFET	14nm FinFET
Gate length (L_g)	22nm	14nm
Supply voltage	0.9V	0.8V
Fin height (h_{fin})	23nm	30nm
Fin width (t_{fin})	10nm	10nm

5.1 28T FINFET FULL ADDER

This full adder cell consists of both nFET and pFET to replace the complementary CMOS logic. The Fig.10 gives the schematic diagram of 28T FinFET full adder cell.

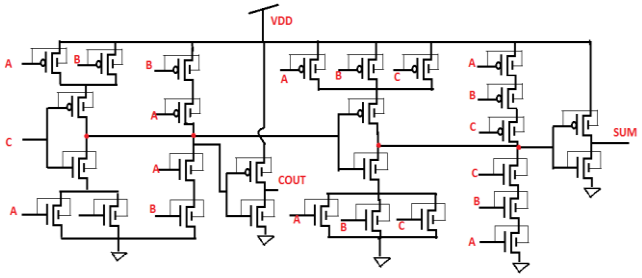


Fig.10. 28T FinFET full adder cell

The output waveforms of 28T full adder cell is as shown in Fig.11 and Fig.12.

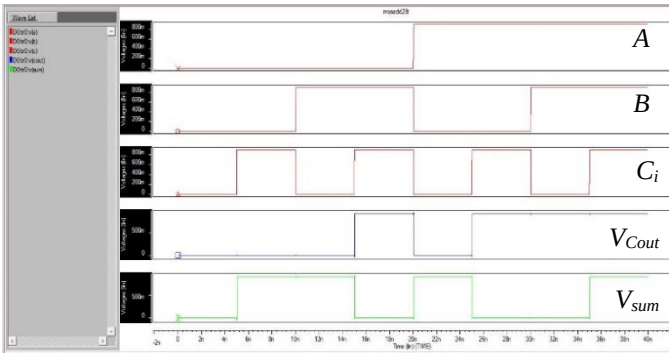


Fig.11. Output waveform at 22nm

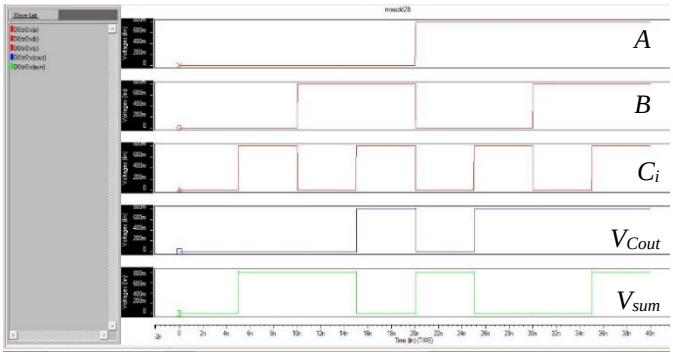


Fig.12. Output waveform at 14nm

Table.6. Results of 28T FinFET full adder cell

Node	Average Power (W)	Maximum power (W)	Sum delay (s)	Carry delay (s)
22nm	62.147n	26.768µ	25.489p	15.966p
14nm	32.242n	25.230µ	13.944p	9.7921p

From the simulated results of Table.5 contains the power and delay values for 28T FinFET based Full Adder it can concluded that FinFET is a better replacement for MOSFET devices.

5.2 16T FINFET FULL ADDER

Similar to Fig.13 with 28T FinFET full adder cell, a schematic diagram of 16T FinFET based full adder cell can be drawn and characterized at 22nm and 14nm technology nodes as observed in following waveforms. The output waveforms of 16T full adder cell are as shown in Fig.13 and Fig.14.

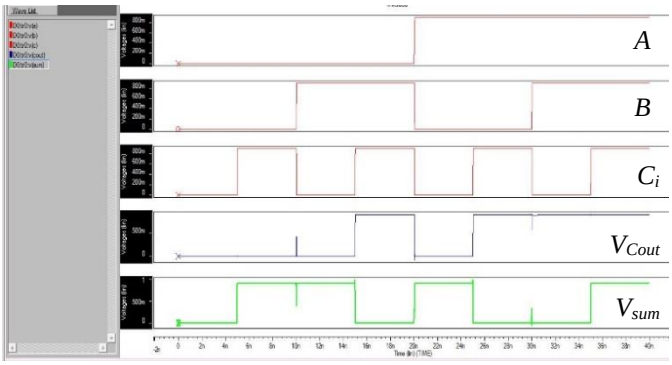


Fig.13. Output waveform at 22nm

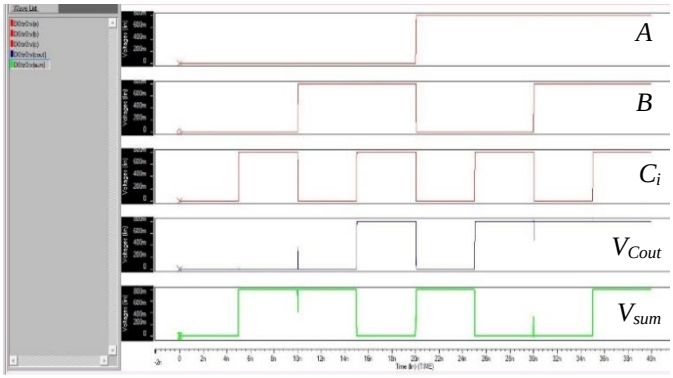


Fig.14. Output waveform at 14nm

Table.7. Results of 16T FinFET full adder cell

Node	Average Power (W)	Maximum Power (W)	Sum delay (s)	Carry delay (s)
22nm	35.012n	20.056µ	10.503p	2.089p
14nm	19.721n	10.426µ	8.942p	2.069p

6. RESULTS AND DISCUSSIONS

The spice models of MOSFET based full adders are created for 28T and 16T at 90nm and 45nm and are simulated using HSPICE. The simulation waveforms are viewed using Avanwaves. The comparison of the results between 28T and 16T MOSFET based full adder cell is as shown in Table.8.

Table.8. Comparison of MOSFET based full adder at 90nm

No. of transistors	Average power (W)	Maximum Power	Sum delay	Carry delay (s)
28T	1.199µ	158.942µ	63.382p	42.161p
16T	1.185µ	93.037µ	13.846p	2.439p

Table.9. Comparison of MOSFET based full adder at 45nm

No. of transistors	Average power	Maximum Power	Sum delay(s)	Carry delay(s)
28T	29.321m	29.939m	Failed	30.127p
16T	1.816µ	108.223µ	3.536p	1.428p

From the comparisons made, it is analysed that (1) as number of transistors decreases, the power dissipation has decreased. (2) Scaling of MOSFET from 90nm to 45nm has led to increase in power dissipation. Hence further scaling down of MOSFET leads to degraded output and increase in leakage power.

The spice models based on PTM files are referred from BSIM-IMG for characterization of device and FinFET based full adders are built for 28T and 16T at 22nm and 14nm and are simulated using HSPICE. The comparison of the results between 28T and 16T FinFET based full adder cell at 22nm and 14nm nodes is as shown in Table.10.

Table.10. Comparison of FinFET based full adder at 22nm

No. of transistors	Average power (W)	Maximum Power (W)	Sum delay (s)	Carry delay (s)
28T	62.147n	26.768µ	25.489p	15.966p
16T	35.012n	20.056µ	10.503p	2.089p

Table.11. Comparison of FinFET based full adder at 14nm

No. of transistors	Average power (W)	Maximum Power (W)	Sum delay (s)	Carry delay (s)
28T	32.242n	25.230µ	13.944p	9.7921p
16T	19.721n	10.426µ	8.942p	2.069p

From the comparisons of FinFET based full adder cell, we can analyse that FinFET has overcome the scaling issues of MOSFET as illustrated above at 22nm and 14nm.

7. CONCLUSIONS

The MOSFET and FinFET based full adder cell for 28T and 16T at different nodes are characterized using software mainly in terms of Power dissipation and delay. The obtained results for the FinFET full adder spice models used here shows a promising solution for MOSFETs scaling issues. The power dissipation in 28T FinFET based adder at 14nm is reduced to 32nW from 62nW at 22nm adder, similarly delay get reduced from 25ps to 13.9ps when node size is reduced from 22nm to 14nm node. Likewise, the results for the power and delays values for sum and carry operation are for 16T FinFET based full adders. And from the result table 6.3 and 6.4 it can be concluded that FinFET based full adder cell is reliable at lower technology nodes and the tolerant capacity is better at the nanometer regime. The power dissipation of the FinFET based device has decreased significantly at lower technology nodes. The speeds of the adder circuits are increased terms of the sum and carry delay operation. Thus FinFET based circuits are promising candidates for the future Digital systems.

REFERENCES

[1] Ruchi Dantre and Sudha Yadav, "Design and Analysis of FinFET based High Performance 1-bit Half Adder-Half Subtractor Cell", *Proceedings of International Conference on Recent Innovations in Electrical, Electronics, Computer and Mechanical Engineering*, pp. 14-18, 2015.

[2] Yingtao Jiang, Abdul Karim Al-Sheraidah, Yuke Wang, Edwin Sha and Jin-Giun Chung, "A Novel Multiplexer based Low Power Full Adder", *IEEE Transactions Circuits and Systems*, Vol. 51, No. 7, pp. 345-348, 2004.

[3] Likhitha Dhulipalla and Lourts Deepak, "A Design and Implementation of 4-bit ALU using FinFETs for Nano Scale Technology", *Proceedings of International Conference on Nanoscience, Engineering and Technology*, pp. 1-4, 2011.

[4] Debajit Bhattacharya and Niraj. K. Jha, "FinFETs: From Devices to Architectures", *Advances in Electronics*, Vol. 2014, pp. 1-21, 2014.

[5] Anindya Ghosh and Debapriyo Ghosh, "Optimization of Static Power, Leakage Power and Delay of Full Adder Circuit using Dual Threshold MOSFET based Design and T-Spice Simulation", *Proceedings of International Conference on Advances in Recent Technologies in Communication and Computing*, pp. 27-31, 2009.

[6] Raju Hajare, C. Lakshminarayana, G.H. Raghunandan and Cyril Prasanna Raj, "Performance Enhancement of FINFET and CNTFET at Different Node Technologies", *Microsystem Technologies*, Vol. 22, No. 5, pp. 1121-1126, 2016.

[7] Raju Hajare, C. Lakshminarayana, Sunil C. Sumanth and A.R. Anish, "Design and Evaluation of FinFET based Digital Circuits for High Speed ICs", *Proceedings of International Conference on Emerging Research in Electronics, Computer Science and Technology*, pp. 162-167, 2015.

[8] Raju Hajare, C. Lakshminarayana, Cyril Prsanna Raj, G.H. Raghunandan, and Yogesh Hegde, "Performance Evaluation of FinFET and Nanowire at Different Technology Nodes", *Proceedings of International Conference on Emerging Research in Electronics, Computer Science and Technology*, pp. 114-119, 2015.

[9] Ahmed M. Shans, Tarek K. Darwish and Magdy A. Bayoumi, "Performance Analysis of Low Power 1-bit CMOS Full Adder Cells", *IEEE Transactions on Very Large Scale Integration Systems*, Vol. 10, No. 1, pp. 20-29, 2002.

[10] Sumeer Goel, "Design of Robust, Energy Efficient Full Adder for Deep-Submicrometer Design using hybrid CMOS Logic Style", *IEEE Transactions on Very Large Scale Integration Systems*, Vol. 14, No. 12, pp. 14-21, 2006.

[11] Hideki Takeuchi et al., "FinFET-A Self Aligned Double Gate MOSFET Scaled at 20nm", *IEEE Transactions on Electron Devices*, Vol. 47, No. 12, pp. 2320-2325, 2000.

[12] Halil Kukuer and Moustafa Khatib, "Degradation Analysis of Datapath Logic Sub Blocks under NBTI Aging in FinFET Technology", *Proceedings of 15th International Symposium on Quality Electronic Design*, pp. 3-6, 2014.

[13] Tsu-Jae King et al., "FinFET for Nanoscale CMOS Digital Integrated Circuits", *Proceedings of IEEE/ACM International Conference on Computer-Aided Design*, pp. 6-10, 2005.

[14] Sherif A Tawfik and Volkan Kursum, "FinFET Technology Development Guidelines for Higher Performance, Lower Power and Stronger Resilience to Parameter Variations", *Proceedings of IEEE 52nd International Midwest Symposium on Circuits and Systems*, pp. 2-5, 2009.

[15] Anish Muttreja, Niket Agarwal and Niraj K Jha, "CMOS Logic Design with Independent Gate FinFETs", *Proceedings of IEEE 25th International Conference on Computer Design*, pp. 7-12, 2007

[16] Prateek Mishra, Anish Muttreja and Niraj K Jha, "*FinFET Circuit Design*", Springer, 2001

[17] M. Jurczak, N. Collaert, A. Veloso, T. Hoffmann and S. Biesemans, "Review of FinFET Technology", *Proceedings of IEEE International SOI Conference*, pp. 1-4, 2009.

SECURITY BASED ONLINE MAILBOX SERVICES

[1]Saritha I.G, [2]Sowmyashree M.S

[1,2]Assistant Professor,
Electronics & Telecommunication Engineering,
BMSIT&M

***Abstract*: This paper focus on the advancements in the Radio Frequency and GSM technologies that made a platform to come up with various innovations reducing human effort. Since online shopping has become a part and parcel of common man's life, this is the right time to make use of existing technologies to simplify the procedure. The basic idea is to introduce technology into our lives for monitoring issues which demand our personal presence. By doing so we aim at providing a reliable and user friendly solution to problems incurred during online shopping. A standalone box is designed which receives and stores the intended parcel so that the customer can retrieve it as and when required.**

***Index Terms*: Smart courier, Security and Radio tags.**

I. Introduction:

Most of us have encountered the problems of postal and courier services like delay in delivery, wrong address or ambiguity in delivering the right package. These problems should be addressed with the help of technology so that the solution is simpler and reliable. A device should be designed which can recognize the designated courier as well as collect and store the same so that no ambiguity is occurred. The basic idea of the system is to employ an RFID (Radio Frequency Identification) tag to the courier and send the tag number and item details to the receivers mobile. The receiver of the courier will have information about the goods and the tag with the help of which he can make sure that the correct item has been ordered. To design the whole system, we require a microcontroller which acts as a medium of communication between the RF reader and the GSM (Global System for mobile communication) modem, also the microcontroller monitors the movement of the lid. The presence of the GSM modem is the major advantage of this system and it enables the device to communicate with the receiver no matter wherever he was present on the globe.

II. Present Scenario

With surge in online market, people find it easier to buy things online but the timely delivery of right package to the right person has become long-standing issue. One of very concerned issue is that unavailability of the customer when the delivery has arrived to customer's address which results in lot of phone calls and complicated delivery procedures. Adding to that insufficient information on the package results in wrong delivery, which is unacceptable. The customers demand less involvement of one's time and money which has put delivery companies into predicament situation.

Our idea is to develop a system which manages these issues and lessen the burden on both customer side and the delivery company side.

III. Literature survey:

Common problems faced by customers while shopping online that glorious invention which allows people to buy things from the comfort of their homes. No additional traveling to multiple stores to seek out the correct product; no additional having to influence over-enthusiastic sales persons; no additional standing in long lines at the checkout. The e-commerce boom has definitely modified the approach we have a tendency to buy the better.

Despite all the efforts of e-commerce corporations to alleviate them, there are a few problems that customers still have to face while shopping online. One of the major problem is delivery and logistics One difficulty that perpetually turns up whereas searching online is when the order are going to be delivered. While all e-commerce sites have order tracking systems for their customers, they are not always accurate. Delivery personnel often turn up at our homes when we're at work or out somewhere as there's no way to fix a particular time slot for the delivery to take place.

This same issue exists while returning products. Another problem is that the vast majority of the Indian population which lives in rural areas and Tier-III cities is unable to shop online because not all e-commerce sites provide delivery services to their locations.

IV. Block Diagram:

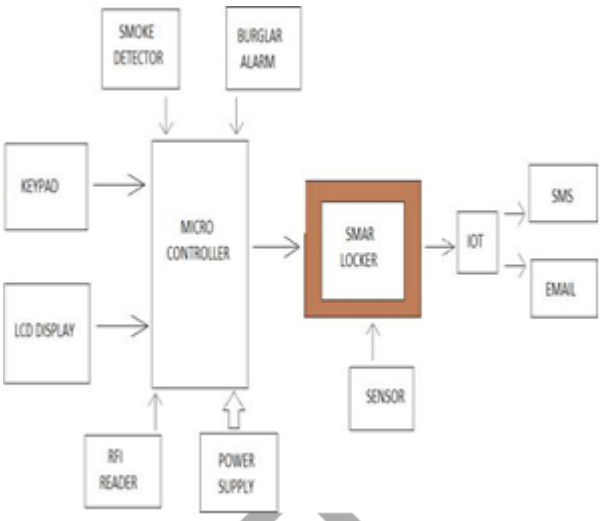


Fig 1. Block diagram of Smart courier system

V. Methodology

As soon as the online order has been launched and therefore the delivery option is chosen, expeditions are taken over by SMART Courier representatives, and in an average of 24 hours they are deposited in the e-BOX chosen by customers.

The system automatically labels sender's package delivery by size (S, M, L) and when the AWB is drawn, a box is reserved in the SMART Courier system according to the size. As dispatches are available in vending machines, the recipients receive a SMS or an email with a secret collection code (PIN) and other information needed to pick up expeditions. All that customers have to do is to enter the keypad screen, SMS / email PIN plus name and signature; the operations they have to perform at terminals are intuitive and easy to go.

When leaving the SMAR Courier warehouse, the system warns the lockers, so from the submission of the shipment, the system already has all the data about the package to be delivered over, the identity of the courier and the password with which it opens and closes the eBox.

At the locker, the courier identifies with ID, password and then logs in and selects the parcel delivery option.

After handing over the parcel, the compartment closes and the system automatically generates a unique collection code that is sent to the recipient via email and SMS.

The messenger cannot submit another referral in a very compartment till the primary deposit is utterly secure. If the client has incorrectly chosen the size of the package, the courier has the option to manually choose another compartment.

Based on the reception of email or SMS, the customer can pick up the shipment from the chosen wardrobe: type the unique authentication code received, sign electronically on the touch screen, and pick up the expedition. The locks are installed in controlled areas and are provided with alarm and anti-burglary systems.

V. Flow Diagram:

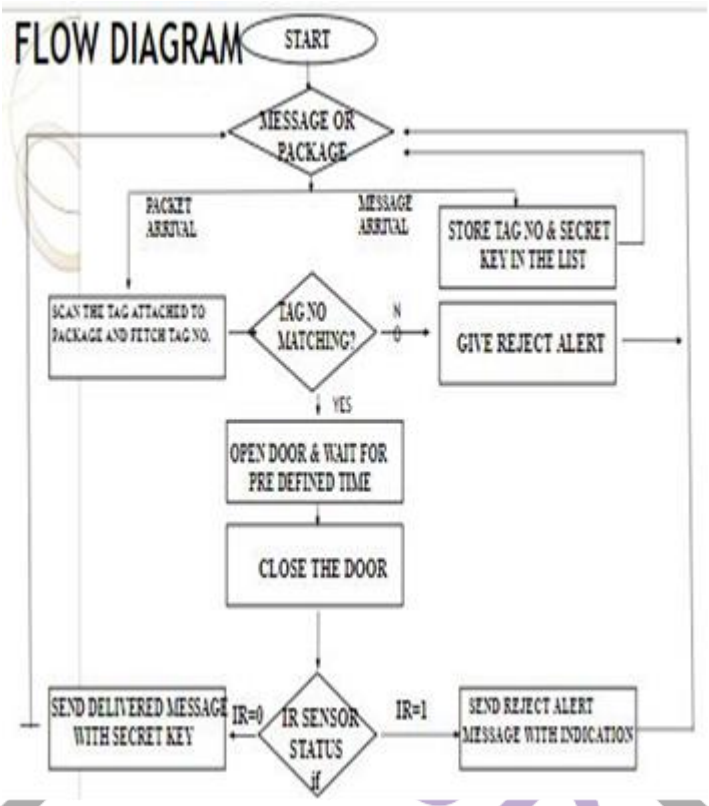


Fig 2. Flow diagram of Smart courier system

VI. Expected Output

- Places the Order.
- Sends Order id, Barcode and weight information.
- Feeds knowledge (Order id, Barcode, weight) into the cloud.
- Passes the data to Smart Box display.
- Places the parcel inside Smart Box.
- Verifies Barcode and Weight with the info retrieved from Cloud.
- Sends a Parcel Received Message via cloud.
- Sends a Delivered Message.
- Sends a Confirmation Message.
- Sends an Acknowledgement Message.

VII. Advantages

- Advantages Installing this smart box in houses and customer premises would result in
- Providing a contactless identification and tracking
- Real-time delivery status
- Less human errors
- The tags contain all the information needed for sorting the mail and efficient delivery of the same
- Real-time up-to-date database

- RFID technology and its reliance on radio waves doesn't need a line-of sight for identification or a straight-line alignment between the tags and readers

- Could use passive and very cheap tags since range is not a concern

- Reusability of the tags
- Enhanced security and safety

- Less money and time spent on tracking and handling of the packages.

VIII. Result

Fig 3. Prototype of Smart courier system

In this project, a new idea for automating parcel delivery collection has been proposed. This makes delivery of the parcel easier and safe even in the absence of the customer. Future work can be focussed on customizing the Smart courier box which improves Security and Scalability.

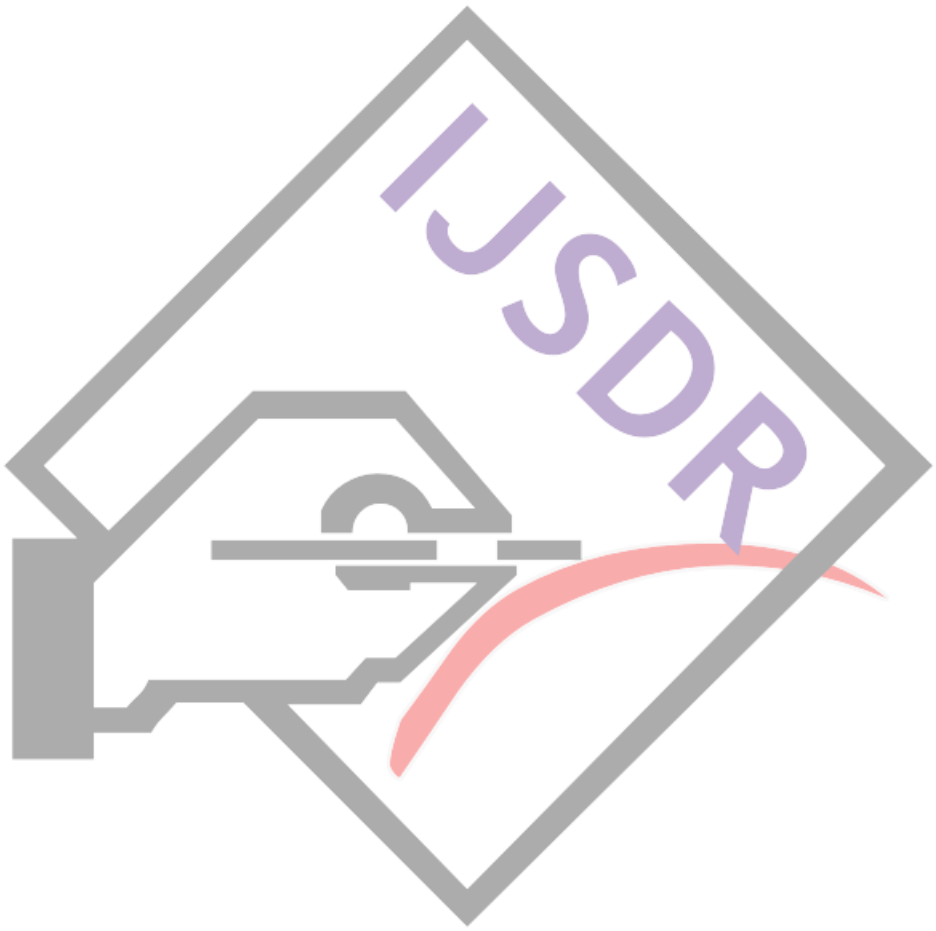
References:

[1] Internet of Things for Smart Cities Andrea Zanella, Senior Member, IEEE, Nicola Bui Angelo Castellani, Lorenzo Vangelista, Senior Member, IEEE, and Michele Zorzi, Fellow, IEEE, IEEE Internet Of Things Journal, VOL. 1, NO. 1, FEBRUARY 2014.
[2] K. Nirosha, B. Durga Sri, Ch. Mamatha and B. Dhanal axmi, Automatic Street Lights On/Off Application using IO T, International Journal of Mechanical Engineering and Technology ,8(8),2017,pp.38-47.

[3] "Smartmart: IoT-based in-store mapping for Mobile devices" ,Dylan Hicks, Colombia university , Kevin mannix , Boston university , Hannah M Bowels ,Texas state university,Byron J gao, Texas state university.

[4] "IoT Applications on secure smart shopping" Ruinian li , Bowling Green State University, Tianyi Song, The George Washington University; Nicholas Capurso Qilu University of Technology; Jiguo Yu ; Xiuzhen Cheng, The George Washington University.

"A location-based smart shopping system with IoT technology" Javad Rezazadeh, Kumbesan, Sandrasegaran ; Xiaoying Kong, Sydney University



IOT Based Healthcare Assistance through ThinkSpeak

Sowmyashree M.S, Saritha I.G, K.Aishwarya, Sahil A, Abhishek B Kalnoor, Rahu S
Telecommunication Engneering, BMSIT&M, Bengaluru, India

Abstract- In this developing era of IOT where in the information provided by objects across network proves to be an asset in various fields, this work is an implementation of the same. Mobility on roads has been subjected to accident occurrences every day which has raised a concern to improvise the availability of healthcare norms. In this system the accident zone detection is done and the location of the vehicle is intimated to the ambulance with help of GSM. The ambulance then rushes to the place with healthcare assistance kit to measure the vital health parameters of the victim. The health measure are sent to the near by hospital using Thing Speak. Apart from that it also provides real time health monitoring through visual graphs representation. Since the condition of the victim can be identified early the patient can be taken directly to the near by hospital with all the required facilities to save the life of victim.

Keywords- Arduino, ArmLPC2148, ESP8266, Think Speak.

I. INTRODUCTION

Internet of things is becoming a life changer for human beings. It provides a simplified and faster approach to various day to day tasks ranging from home automations to military application. For information exchange in open computing and recognition of data transfer, Internet of things appear to be a great choice. After the age of robots ,IOT has become a new technology for helping humans at the time of need. As introduction of latest technologies aims to serve the user better similarly IOT can also can be observed to provide a better solution for hazardous situation. Road accidents which tops the list of hazardous occurrences calls for an improvisation for bringing heath helps on roads. A system for overall monitoring of the victim has to be provided in order to make sure the person reaches the hospital soon.

Sensors fitted on the vehicle can be used to identify the collision impact during accident and measure the tilt of the vehicle to confirm the occurrence of the accident .Once the accident has been detected by the sensors the GSM module can be used to intimate the ambulance with the GPS coordinates of the accident zone. The ambulance can figure out the place where accident occurred and reach that located area for helping the victim. The healthcare assistance kit presented in the ambulance can provide an accurate measure of the health condition parameters of the victim. Real time health parameters of the victim are being monitored by the hospital. The objects utilized in the ambulance for health measure can comprise of a wireless network which is provided by IOT to exchange data. The hospital is able to retrieve the health parameters of the victim using an web application known as ThingSpeak which is an application of the IOT cloud data transfer.

II. LITERATURE REVIEW

In this mechanism it will detect whether the person is wearing helmet or not and check whether the person is over consumed alcohol, the sensors like tilt sensor & impact sensor are used to detect the accident and data are sent to the server through Application Programming interface[1].

Initial process starts with identifying the accident location. The intimation of the accident can be given by Arduino interfaced with GSM to send alert message along with the coordinates provided by GPG[2].

Monitoring the basic health Parameters of patients after the accident within the ambulance with sensors such as heartbeat, MEMS, Blood pressure, temperature etc and sending the same data to the hospital[3].

Proposing a System with help of Internet of Things (IOT) detecting the accidents occurred in the two wheelers using microcontroller and a accelometer and notifying the same to authorized person or to the emergency contact of the rider and creating a plot of accidents occurred in the city for future analysis[4].

Due to the delay of providing Emergency medical services(EMS) there is a high mortality rate in road accidents in our country as there is delay involved in each and every stage of the process starting from reporting an accident to dispatching an ambulance until the victim is handed over to the hospital or to the concerned person. If this delay can be reduced then many lives can be saved to overcome this when an vehicle meets with an accident the module presents in it will automatically send a message to the nearest ambulance to the accident location, with the help of android application the driver takes the shortest path to the hospital without wasting any time[5].

As internet is a platform that leverages the functionality and usefulness of smart object. Smart things or smart objects are the buildings block of IOT. These objects generate great amount of data which can be stored, processed, and formatted into an efficient and seamless useful form. IOT is not only a platform for sensing the data from environment, but also using internet standards to provide services for transfer of information or data. Various technologies are being used in our daily life some of them are Bluetooth, radio frequency identification on which the IOT operates effectively[6].

Using Automatic smart accident detection(ASAD) which is an auto detection system that notifies an emergency contact through a text message when there is an instant change in acceleration, rotation and an impact force on the vehicle is detected by the system, providing the location and time of the accident occurred so that further congestion as well as the passengers can be escorted to the hospital without wasting any time[7].

It identifies the intelligent frame works and report an accidents in city. which included microcontroller based Accident detection unit , it contains GPS & GSM to sense the accident and send the event to the accident detection server. The GPS coordinates and sensor parameters are sent to the Accident detection server through GSM[8].

By knowing the heart rate of the person its sends an alert message along with GPS coordinates to the emergency contact through SMS,E-mail only when the heart rate is reached beyond its range[10].

III. METHODOLGY

This work constitutes of three segments namely

1. Vehicle unit.
2. Ambulance unit.
3. Hospital unit.

TABLE I.

Components	*Specification*
Pressure sensor	FSR 402
Tilt sensor	ADXL335
Gsm module	SIM 800A
Pulse rate	SEN-11574
Temperature sensor	LM35
Blood pressure sensor	BPS-BTA
Wifi module	NODE MCU ESP8266

1. Vehicle unit:-

Implementation of this unit facilities the process of detection the accident through sensors fitted on two/four wheelers sensors attached to user Arduino interface along with GSM and GPS. When the sensor an impact Arduino interface with GPS gets the location of the accident spot and forwards it to GSM. The GSM module then sends a message of those coordinates to the ambulance.

Software used:- Arduino IDE provides a text editor to create codes in accordance to the purpose to be fulfilled. The codes can be developed in embedded c and it allows to interface Arduino hardware components to which the program has to be uploaded. The provision of set of AT commands along with the program are also required to establish a connection between the mobile operator and GSM.

Sensors:-

i. Pressure Sensor :- It can also be called piezoelectric pressure sensor which can be used for measuring the impact of force on it by converting them to electric charge. The sensor consists of a pressure sensitive diaphragm which provides a change in resistance when force is applied, the change in resistance is later converted into electric signal.

Fig.1: Pressure Sensor.

ii. Tilt Sensor:- ADXL335 also know as accelerometer is a electromagnetic device used for measuring the acceleration of the vehicle. It measures acceleration only caused due to gravity in g units in x, y and z direction. The tilt is measured using the output of the x ,y and z direction measures. The output signal from this sensor is analog this sensors is analog voltage that is proportional to the acceleration.

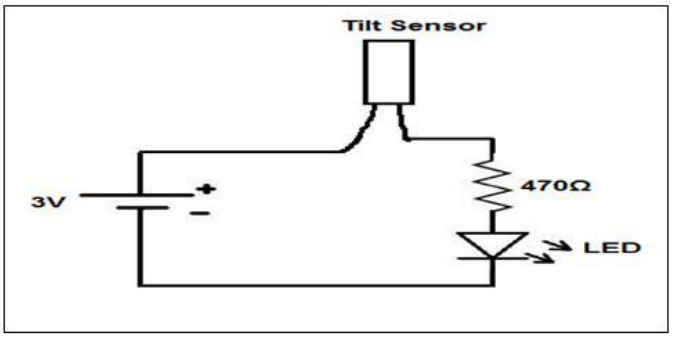


Fig.2:Tilt Sensor.

iii. GSM:- The mobile communication model(GSM) is an open and digital cellular technology used for transferring the data services. It is used to establish a communication link between GPRS and Arduino.

Fig.3: GSM Module.

iv. GPS:- The Global positioning system (GPS) module is a device that is used to calculate the geographical position using the information received from the GPS Satellites. This unit is installed in our vehicle unit mainly to provide the position of the accident and to provide the necessary directions to access the accident location. The GPS system can get the location of the accident at any point of time irrespective to change in the weather, temperature and other conditions.

2. Ambulance Unit:-

This unit works to provide the necessary help to the victim after the accident. After reaching to the accident spot it identifies the health condition of the victim by measuring the health parameters using the health care assistance kit. The kit consists of equipments such as pulse sensors, temperature sensors and blood pressure sensors which measures the respective health fields of the victim. These parameters are the transferred to the IOT cloud so that hospital can avail the data of the patient. Hospital can be aware of the condition of the patient before he reaches the hospital so that all necessary arrangements for treatments is made available.

Software Involved:-

i. ARM LPC2148:- It gives a family of instruction set architecture to the computer processor because of its reduced instruction set architecture(RISC). It required fewer transistors than traditional ones because of the RISC architecture. LPC2148 microcontroller has a 16/32 bit ARM7TDMI-S CPU with embedded trace support and real time simulation combines the microcontroller with embedded flash memory from 33kb to 512kb. The alternative 16-bit thumb mode reduces the code over head significantly in case of critical code size application. Tiny size, power efficiency, inbuilt peripherals makes it suitable and more reliable for end application developing purposes.

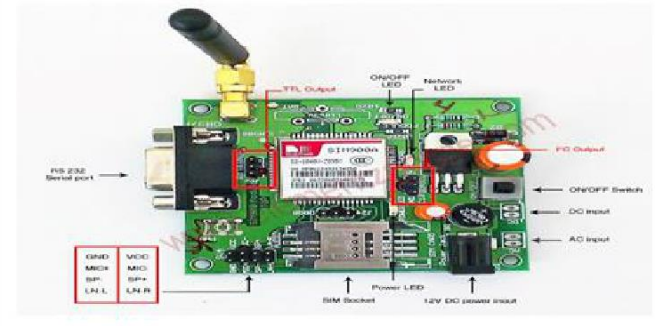


Fig.4: ARM Microcontroller.

ii. Pulse Sensor:- Pulse sensor is a heart rate sensor which is incorporates live heart rate data to the user. This sensors is plug and play unit. This sensor can be clipped to the finger tip or to the earlobe to measures constant heart rate and plugs the data right into the Arm board. It uses an ambient light sensors, which senses the light which bounces back from LED devices fixed to the sensors. It has amplification and noise cancellation circuit making it fast and easy to obtain pulse reading from the victim.

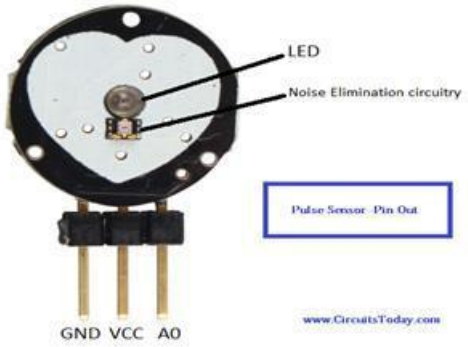


Fig.5: Pulse Sensor

iii. Temperature Sensors:- Temperature sensor is a device used to measure the hotness or coldness of an object. We are using this sensor to obtain the temperature of the victim. We are making use of precision IC temperature i.e. LM35. It calibrates the temperature value which is digital directly in degree Celsius hence does not require and external analog to digital converter. It produces electrical output value which is directly proportional to temperature.

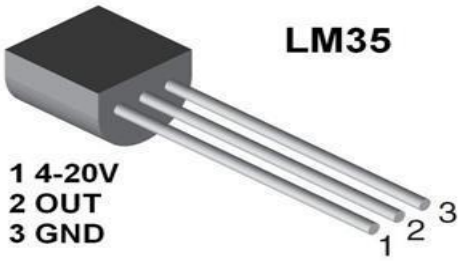


Fig.6: Temperature Sensor.

iv. Blood Pressure Sensor:- BP sensor's main task is to measure the pressure of circulating blood on the walls of blood vessels and produce a digital value corresponding to the BP of the victim. This sensor uses the oscillometric method to calculate the blood pressure. In this technique, the observation of cuff pressure by the sensor are caused by oscillating of blood flow, i.e. the pulse. Blood pressure is recorded as two numbers , the systolic pressure (as the heart beast) over the diastolic pressure(as the heart relaxes between the blast).

Fig.7: BP Sensor.

v. WIFI Module:- The data that is measured using different sensor devices i.e. pulse, blood pressure, and temperature is transferred to the cloud storage, for this purpose a WIFI module is being used. ESP8266 is a system on a chip with integrated TCP/IP protocol stack that can be provided any microcontroller access to WIFI network. This is a system with a powerful enough on-board processing and storage capability that allows it to be integrated with sensors and other applications specific devices through its GPIO with minimal developments up-front and minimal loading during runtime.

Fig.8: ESP 8266(WiFi Module)

3.Hospital Unit:-

i. ThinkSpeak:- ThingSpeak is an open source application of internet of things, it also an application programme interface which helps to store and retrieve data from the objects using basic protocols such as HTTP protocol, etc over the internet or wireless LAN network. This application has integrated support from MATLAB which allows it to analyse and visualize the uploads data and represents them in the graphical way.

IV. WORKING PRINCIPLE

The working of the whole unit can be explained by using the following flowcharts as shown in Fig. 4.

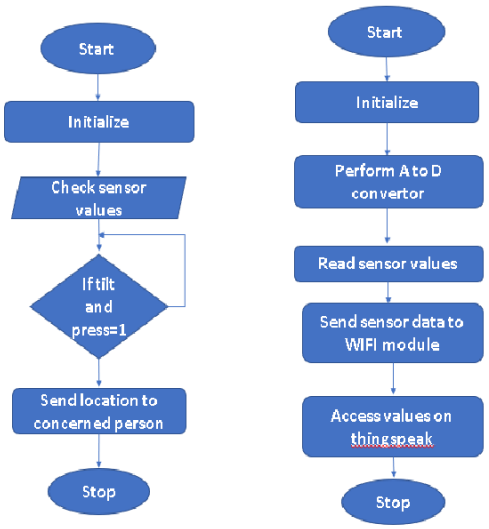


Fig.9: Working of vehicle unit and ambulance unit.

There are two sensors that are fixed to the vehicle, one being the tilt sensor and other being the pressure sensor. The tilt sensor is an analog sensor while the pressure sensor is a digital sensor. The tilt sensor has a threshold range of tilt that is set initially by the programmer,if the tilt crosses the threshold then the sensor is said to send an intimation to the Arduino mentioning about the occurance of the accident.this is the first kind of intimation that can be sent. The pressure sensor can only hold two values i.e. 0 and 1,where 0 represents that there is no force or pressure applied to the sensor and 1 represents that there is a force that is applied on the sensor during the accident. When an accident occurs, the detection can be done in two different intimations that are received from the tilt and pressure sensors.

As soon as the intimation of accident is received by the sensors, the GPS unit which is fixed to the vehicle unit locates the accident by finding the co-ordinates of the accident. These latitude and longitude coordinate values are saved and sent to the ambulance unit or the recipient using the GSM module.The intimation which is sent by the vehicle unit is shown in the Fig. 5. This whole procedure forms the working of the vehicle unit.

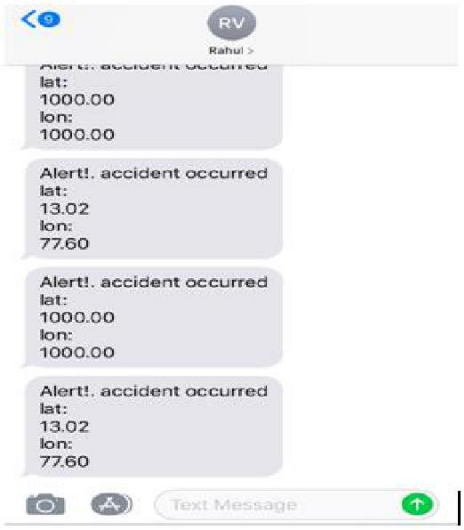


Fig.10: The intimation message from vehicle unit.

The ambulance unit is mainly used to check the vital health parameters of the victim and keep a track of the same before the victim reaches the hospital. The sensors such as BP sensor, Temperature sensor and Pulse rate sensor gives the values of victim's Blood pressure, Body Temperature and heartbeat rate in digital values respectively. These values are uploaded to the cloud using the WiFi module.

The Hospital unit consists of an IOT Application called ThingSpeak. This application is used to retrive the values of the Ambulance unit with respect to time and display all those values in a Graphical format. The advantage of this application is that it can keep the track of victim's information at each interval of time from accident spot till the time the patient reaches the hospital. The variation in the victim's vital health parameters can also be kept track. The different parameters are showcased with respect to time as shown in the Fig. 6, Fig.7 , and Fig. 8.

V. RESULTS

Fig.11: Blood Pressure of victim.

Fig.12: Temperature of victim..

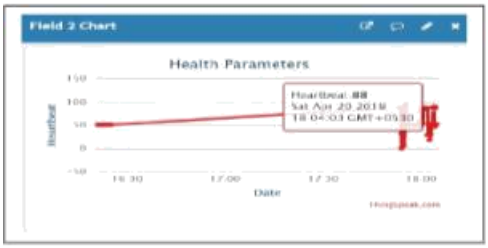


Fig.13: Pulse Rate of victim..

VI. RESULTS

The Pressure sensor and tilt sensor identifies the event of accident. The Arduino interfaced with GSM and GPS responds to the event and the GPS coordinates of the victim is found. The accident alert intimation along with the GPS coordinates of the victim are then sent to the ambulance in the form of a text message using GSM.

Once the accident alert message has been received by the ambulance it reaches the spot of accident. The pulse rate, temperature and blood pressure of the victim is calibrated using sensors. This data is then sent to the hospital using IOT cloud web application Thing Speak.

The above three graphs provides the respective health condition graph in accordance to the time. This way real time monitoring can be achieved as the hospital is able to observed the graph patterns from the time to time and predict the condition of the victim accordingly.

VII. CONCLUSION

In this paper we propose a system for providing immediate healthcare assistance to the victim on the event of accident. Once the accident occurrence is detected and the victim has been located an approach for the ambulance to provide health condition of the victim to hospital has been discussed. This work tells how ambulance can be equipped with IOT based healthcare assistance module to transfer the vital health parameters of the victim. These parameters are available at the hospital using ThingSpeak so that real time monitoring of the patient is achieved right from the time victim is in ambulance and even after reaching the hospital. IOT has been used to transfer data over distance efficiently similarly health condition of the victim are sent to the hospital frequently to

avail according health services immediately as soon as patient arrives at the hospital.

VIII. FUTURE SCOPE

This work provides a prototype which can be used for real system application to provide the road safety and healthcare services management. By implementing a web application which can be hosted by traffic police of each country. The accident zone coordinates can be intimated directly to traffic police server and so the nearest ambulance and hospital can be identified in no time. This way the healthcare services for road hazards can be provide quickly without any delay and hence can bring an overall improvisation services at the time of need.

IX. REFERENCES

[1]. Sayan Tapadar, Shinjini Ray, Arnab Kumar Saha, Robin Karlose, and Dr.Himadri Nath Saha, " Accident and Alcohol Detection in Bluetooth enabled Smart Helmets for Motorbikes", 2018 IEEE.

[2]. A.Ajay, G.Vishnu, V.Kishoreswaminathan, V.Vishwanth, K.Srinivasan, and S.Jeevanantham, "Accident Identification And Navigation System In Helmet", 2017 IEEE.

[3]. Madhuri Baswa, R Karthik, P B Natarajan, K Joythi, and B Annapurna, "Patient health Managment System Using e-Health Monitoring Architecture", 2017 IEEE.

[4]. Shoeb Ahmed Shabbeer and Merin Meleet, "Smart Helemet For Accident and Navigation", 2017 IEEE.

[5]. Hari Sankar S, Jaydev K, Suraj B and Aparna P, "A Comprehensive Soloution To Road Traffic Accident Detection and Ambulance Managment", 2016 IEEE.

[6]. Ahmed I. Abdul-Rahman, and Corey A. Graves, " Internet of Things Application using tethered MSP430 to ThingSpeak clou", 2016 IEEE.

[7]. Asad Ali and Mohamad Eid, "An Automated System For Accident Detection", 2015 IEEE.

[8]. Amit Meena, SriKrishna Iyer, Monika Nimiji, Saket Jogelkar, Sachin Jagtap, Mujeeb Rahman, "Automatic Acident Detection and Reporting FrameWork for Two Wheelers", 2014 IEEE International Conferance on Advanced Communication Control and Computing Technologies(ICACCCT).

[9]. Purav Javale, Shalmali Gadgil, Chinmay Bhargave, Yogesh Kharwandikar, Prof. Vaishali Nandedkar, "Accident Detection and Surveillance System using Wireless Technologies", 2014 International Organization of Scientific Research – Journal of computer Engineering(IOSR-JCE).

[10]. Megha Nirbhavane and Shashi prabha, "Accident Monitoring System using Wireless Application", 2014 International journal of Advanced Research in Computer Engineering & Technology(IJARCET).

An Intelligent System To Detect Urban Flash Flood Using Wireless Sensors

Sumathi M S
Dept of TCE,
BMSIT & M, Bengaluru, India.

Antha G S
Dept. of EEE
RVCE, Bengaluru, India

Laxmisagar H S
Dept. of ECE
BMSIT & M, Bengaluru, India.

shruthi J
Dept. of ECE
BMSIT & M, Bengaluru, India

***Abstract*: Urban flash flood are the most interminable type of unforeseen event worldwide resulting from intense storms leading to large amount of rain within a concise period. These are notably pernicious because of the short timescales on which they occur, and because of the population size of cities. Since most flood casualties are caused by a lack of information on the impending flood ,sensing such catastrophes is critical to generate authentic and detailed warnings .To provide short term forecasts to address this issue we are deploying a wireless sensor detection system to accurately detect the water level and sense the intensity of rainfall to alert the counterminous areas. This is based on the combination of arduino uno with two RF modules along with sensors .Firstly we intend to have a threefold methodology to identify a potential benefits in measuring the water level. Secondly using GSM module notification is sent via SMS and also triggers the buzzer. There are many existing technologies for flash flood measurements, but they have many drawbacks and hence give unreliable results and are not real time based. In this system the delay of the warning is less and will be operating 24 hours so that it can detect flash flood adequately and is very economical**

***Keywords:* Urban flash flood, Arduino Uno, sensors, RF module, GSM module, SMS, Wireless Sensor Network(WSN)**.

I.INTRODUCTION

A flash flood is nothing but a rapid flooding of geomorphic low-lying areas such as rivers, washes, basins and dry lakes. It is due to heavy rain along with a severe thunderstorm, tropical storm, hurricane or melt water from snow or ice flowing over ice sheets.

Flash floods is due to collapse of debris dam or natural ice or a man-made dam. Flash floods can be distinguished from regular by a timescale of which is less than six hours. The water that is provisionally available is frequently used by shrubbery with rapid germination and short growth cycles, and by particularly modified animal life.

Flash floods occurring quickly is due to various things, but it is due to enormously deep rainfall from thunderstorms. It is due to Dam or Levee Breaks and debris flow. Flash flooding may occur due to the various reasons like the location, intensity of the rainfall, distribution of the rainfall, topography, vegetation types, soil type and soil water control. So, as discussed many factors influences where the Flash floods may occur. Occasionally, rainfall over an urban area will cause flooding faster and more-severe.

In the urban areas the solid surfaces do not allow water to penetrate the ground, hence the water runs off to the lower region rapidly.Flash Flooding occurs so fast that people are jammed off-guard. Their circumstances may become hazardous if they come across high, vigorous water while traveling. If people are at their homes or businesses, the water may increase rapidly and shut in them, or cause harm to the assets without them having a possibility to guard the assets.

II.EXISTING SYSTEMS

In past decades various flood detection methods were introduced. Among them one of the system uses images. Images are here captured by satellite in different ways which detect the areas where flood has been occurred. These techniques are useful only in flood localization but they cannot foresee whether flood occurs or not in the next hours. A prototype intelligent system was developed for flood warning and alert in real time. It uses an ARM Microcontroller, Marvel 88F6281 and for Interface and Data Integration Unix FreeBSD was used. The data will be transmitted using radio communication technique to make proper decision.A flood warning system was introduced by E.Tate and K. Cauwenberghs where in cluster of servers collect the data and process data from the hydrological observation station in the real time.the available results can be then displayed on client computer by distant access.

The flood warning system used in the most developed country are costlier and it depends on the proficient hydrologists who supervise real-time data 24 hours a day and run complicated computational models at a centralized place. These kinds of possessions are excessive & unreasonable for poor counties as well as emergent country. Floods ends with the loss of abundant lives and leaves the flooded area with enormous demolition of assets every year, particularly the temper of flash flood in the deprived and emergent countries is most conspicuous, where people are the sufferer of the natural mercy.

III.SYSTEM MODEL

Intense rain dropping can be the main reason for flash flood that too in short span of time.

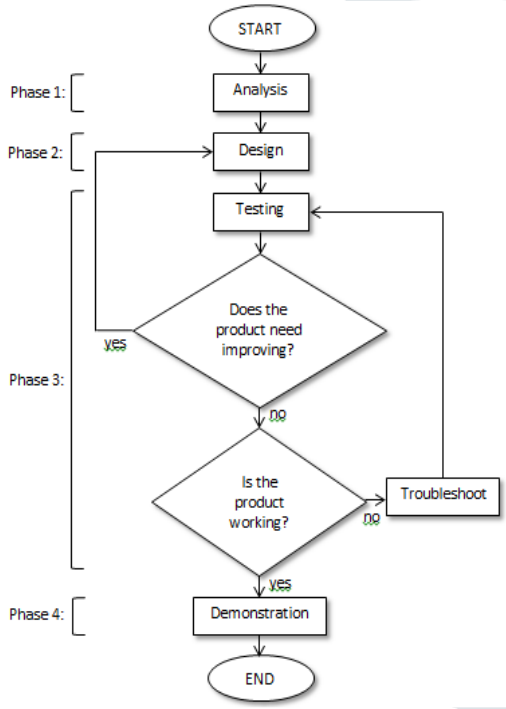
Flashflood occurs with very light warning or nil warning and can reach to the maximum in very short span of time before we take any action. As and when the intensity of the rain increases major portion of the rain water runoff and very light will be absorbed by the land. The extra overflow water

can be very dangerous and can result into fast swelling rivers and streams. Low areas will also be pooled.

Streams that were just dried up or light wet few minutes before can be now a ranging torrent few in few minutes.

In addition, city sewer systems can quickly become overwhelmed and back up, resulting in street and overland flooding. It is the sum of these factors that creates a flash flood. So a system is necessary to spread the news quickly during the flood disaster to the general public.

Rapid application development(RAD) model is used in the proposed algorithm, which shortens the construction cycle to build the project.



Many advantages lies in this model. The development time can be the main advantage of the system which is very less. Next advantage can be increased reusability of the component and

Integration from very beginning solves a lot of integration issues.

The main disadvantage is this model is this requires an individual who is experienced and familiar with the system to be developed.

To identify the requirements of the system depends on the individual performance and the strong team. This model can be built using system that is modular.

This needs highly expert designers. This requires high enslavement on modeling skills.

The team may be tempted to rush the product, skipping important forecast and design consideration.

IV.SYSTEM PROPOSED

In our system , audunio uno microcontroller is used. The controlled at the transmitter is interfaced with the sensor used. Sensor used in our system are water level sensor, raindrop sensor ,temperature and humidity sensor.

The raindrop sensor used determines the intensity of the rainfall.

The temperature sensor and humidity sensor at the transmitter is used to foretell the persistency of rainfall causing flood.

The high risk of flood can be identified using the water level sensors that is placed at a position called bottom line, when it touches the bottom line indicates moderate risk of flood and the higher level indicates high risk of flood.

The levels of risk can be indicated by using LED / Alarm system that is placed one at the transmitter and another at the receiver. Once the sensors are actuated it sends the signal to the micro-controller.

The signal is processed at the transmitter and sent to the receiver using RF module attached to the receiver.

The GSM module is attached to the microcontroller at the receiver side to sense alert messages to the number stored in the database system. As the water level increases this process is repeated.

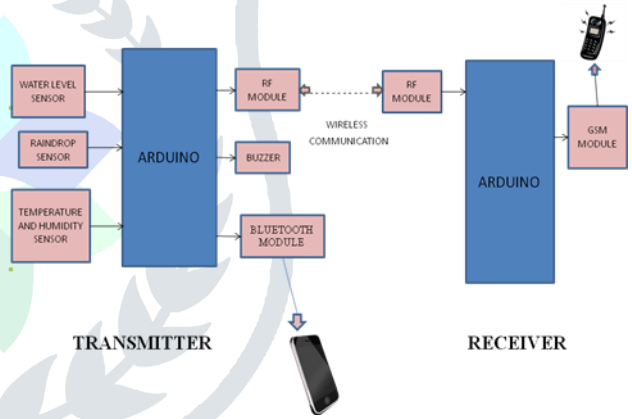


Fig 1 : Wireless communication between Transmitter and Receiver

V.CONCLUSION

The system will find out the present water level by using wireless sensor network, which will also provide warning of SMS using GSM modem. SMS is very much supportive cautious information exchange tool that can give out the information to floods sufferer in a particular region. This system is able to notice a level of water and fling that data to the main flood control centre close or too far away from the sensor that senses the level of water. The need of radio communication module in this project is used as the medium to transmit the information from transmitter module to the receiver module.

Flood is alarmed with the valuable lives and wealth of a country that is why it is required to take crucial actions to avoid and contract with the after consequence .The Flood Observatory System is designed to be an intelligent system

which is capable of sending real time water level information from a remote location to a monitoring station which could be at a distance away, regardless of time. The self monitoring in the Flood Observatory System ensures that the system performs efficiently and reliably for the monitoring station. The flood monitoring and detection system monitors and know the development of floods and then send flood notification SMS to the residents of such zones for necessary action. The main purpose of this project is to send alert to riverside people so they can safely move from flood area it gives advanced alert through SMS. We design a system with low-cost, small-sized, easily configurable and extensible WSN systems to monitor, detect, and track various environmental phenomena and events.

This technology could be further customized or enhanced as per the individual necessitate and interests. We have discussed some basic thoughts of this technology and depending on ground-breaking applications, user can upgrade as per prerequisite.

System can be upgraded to increase the distance between transmitter and receiver by using different frequencies of RF Module for which special permission is required. A Bluetooth module can also be interfaced to get updates about various parameters involved for flood detection in the smart phone. The features/hardware can be added/modified to suit any application. This project is subjected to future work.

VI. REFERENCES

[1]M. Mousa and C. Claudel, "Energy parameter estimation in solar powered wireless sensor networks," in Real-World Wireless Sensor Networks. Cham, Switzerland: Springer, 2015, pp. 217–229.
[2] M. Ceriotti et al., "Monitoring heritage buildings with wireless sensor networks: The Torre Aquila deployment," in Proc. Int. Conf. Inf. Process. Sensor Netw., 2016, pp. 277–288.
[3] A. Burns et al.,"SHIMMER—A wireless sensor platform for noninvasive biomedical research," IEEE Sensors J., vol. 10, no. 9, pp. 1527–1534, Sep. 2016.
[4] A. H. Dehwah, M. Mousa, and C. G. Claudel, "Lessons learned on solar powered wireless sensor network deployments in urban, desert environments," Ad Hoc Netw., vol. 28, pp. 52–67, May 2015.
[5] Mustafa Mousa King Abdullah University of Science and Technology, Thuwal, Saudi Arabia,Xiangliang Zhang Christian Claudel University of Texas at Austin, Austin, TX, US, "Flash Flood Detection in Urban Cities Using Ultrasonic and Infrared Sensors," IEEE,19 July 2016 [6] Petr Rapant; Tomáš Inspektor; Jaromír Kolejka; Kateřina Batelková; Jana Zapletalová; Karel Kirchner; Tomáš Krejčí, "Early warning of flash floods based on the weather radar", IEEE, 02 July 2015.
[7]Hamra Afzaal; Nazir Ahmad Zafar, "Cloud computing based flood detection and management system using WSANs", IEEE, 16 January 2017.
[8] Hamra Afzaal; Nazir Ahmad Zafar, "Formalism of network restructuring in Flood Control System", IEEE, 04 May 2017.
[9] A. D'Addabbo,A. Refice,G. Pasquariello,F. Lovergine, "SAR/optical data fusion for flood detection", IEEE, 03 November 2016.
[10] N. K. Suryadevara and S. C. Mukhopadhyay, "Wireless sensor network based home monitoring system for wellness determination of elderly," IEEE Sensors J., vol. 12, no. 6, pp. 1965–1972, Jun. 2014.

Multifunctional Robot

Mrs. Thejaswini .S
Assistant Professor, TCE
BMS Institute Of Technology and Mgmt.
Bangalore, India
thejaswini.s@bmsit.in

Mr. Sadam Hussain Kazimi
Student, TCE
BMS Institute Of Technology and Mgmt.
Bangalore, India
azizkazimi2012@yahoo.com

Ms. Soundarya .V
Student, TCE
BMS Institute Of Technology and Mgmt.
Bangalore, India
soundarya_vijay@yahoo.co.in

Ms. Lavanya .M
Student, TCE
BMS Institute Of Technology and Mgmt.
Bangalore, India
mlavanya304@gmail.com

Ms. Chandana B. V
Student, TCE
BMS Institute Of Technology and Mgmt.
Bangalore, India
chandana.balekoppa@gmail.com

Abstract -- **This paper proposes a working prototype of a multi functional robot that mainly deals with an idea of integrating multiple features like real time face recognition, object recognition, reading the text, sensing natural agents, picking & placing the objects and voice based interaction. Image processing is used to implement real time face recognition, object recognition and text reading through MATLAB. Real time face recognition is implemented using PCA algorithm. IP Webcam is used to capture the real time images. Object recognition is implemented taking into consideration the different colors and the area of the object. Text reading is done in two stages namely training stage and testing stage which consists of pre-processing, feature extraction, model estimation and classification. The movement of the robot and the robotic arm is controlled by dc motors which are driven by L293D IC. This prototype model is capable of performing the above mentioned features which can be used in military surveillance, in industries to detect hazardous condition, medical fields as lifting supporters and household applications.**

Keywords— Face recognition, object recognition, robotic arm, PCA.

I. INTRODUCTION

In today's advancing technologies, Robotics is one of the best technology that is growing rapidly. Robotics deals with the design, construction, operation, and application of Robots, computer systems for their control, sensory feedback and information processing. A robot is a programmable machine that takes the actions or appearance of an intelligent creature which is usually a human. The robot will be combination of multiple technologies integrated in one unit and performs multiple tasks at the same time [1].

In this work, we have designed a prototype of a robot that performs various functions like face and object recognition, reading the text, sensing natural agents, picking and placing the objects and voice based interaction. Various sensors like temperature, fire, water and gas sensors are used to detect abnormal temperature, fire, water and gas detection respectively. Real time face recognition uses PCA algorithm for implementation and this feature can be used in military applications and security purposes. Text reading can be used to provide information for blind people as the output will be audible. The pick and place feature can be useful for performing repetitive tasks and can reduce the consumption of time. On a whole this prototype can be used in military applications, medical fields, industries and also household applications.

In [1], face recognition and detection was implemented using PCA algorithm in MATLAB. In [2], object is sorted based on color and dimension with process control of induction motor.

In [3], Raspberry PI was used to detect text and faces for visually impaired. In [4], a system for disaster detection was developed. Our proposed work includes the integrated implementation of the above features along with movement and pick and place mechanism.

II. PROPOSED WORK

The designed prototype consists of a transmitter and receiver where PC is used as transmitter and the robot as receiver. In the transmitter section as shown in figure 1, MATLAB is used for features such as real time face recognition, object recognition and text reading through the cell phone using an application called IP Webcam where real time images are captured through it and are processed using MATLAB and the result of recognition is sent serially through ZigBee to the receiver.

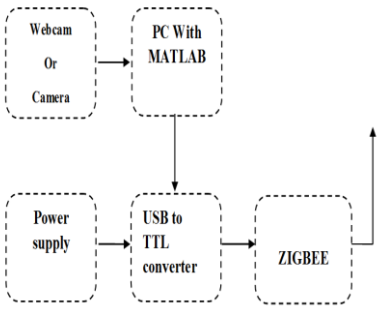


Figure 1: Block Diagram of Transmitter section

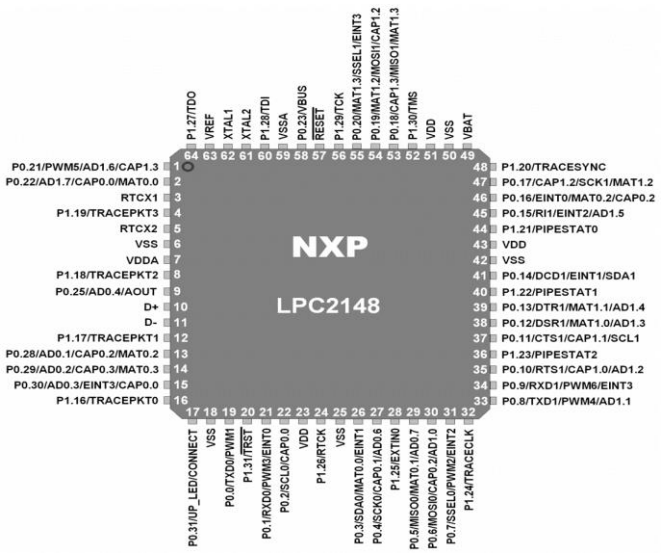


Figure 2: Pin Diagram of LPC2148

The robot receives the data from transmitter serially and displays the result on LCD. Picking and placing the objects and movement of the robot is achieved by receiving characters from the PC. The robot can sense the natural agents such as fire, temperature, gas leakage and rain and displays the detection message on LCD, and further preventive actions can be taken upon receiving outputs of the sensors in future. Motor drivers are used as a microcontroller cannot drive a motor directly. The motor drivers take the low level signal from the ARM7 LPC2148 controller and provides sufficient voltage and current to the motors. Motors are used to drive the robotic vehicles and robotic arm for picking and placing the objects. DC motors are often used due to lesser rpm and have sufficient torque that can drive all kinds of mechanical load. A 12V battery is preferred to drive the motors.

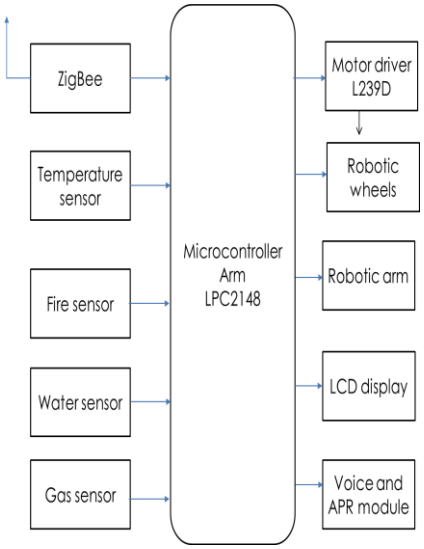


Figure 3: Block Diagram of Receiver section.

III. IMPLEMENTATION

The working prototype of the multifunctional robot is built using ARM 7 controller to implement features like face and object recognition, reading the text, sensing natural agents, picking and placing the objects and voice based interaction. Face recognition, object recognition and text reading are done using MATLAB. Face recognition is implemented using Principal Component Analysis (PCA). A set of facial patterns for each individual is stored in a database. The characteristic features called ‘eigenfaces’ are extracted from the stored images using which the system is trained for subsequent recognition of new images. Object recognition is implemented based on different colours and the area of the object. Text reading is done in two stages namely training stage and testing stage which consists of pre-processing, feature extraction, model estimation and classification . In a typical OCR(object character recognition) systems, input characters are digitized by an optical scanner. Character recognition techniques associate a symbolic identity with the image of character. The image is first being converted to a gray scale image which is further converted into binary image by threshold technique. A connectivity test is performed on a binary image in order to check for the maximum connected component which is in the form of a box. After locating the box, the individual characters are then cropped into different sub images that are the raw data for the feature extraction. Binarization is presented with a grayscale image to select a threshold value. The isolated specks and holes in characters are removed using morphological operators. Segmentation is an important aspect of that allows the recognizer to extract features from each individual character.

Various sensors like temperature, fire, water and gas sensors are used to detect abnormal temperature, fire, water and gas leakage respectively. The movement of the robot is controlled using dc motors. The robotic arm is used for picking and placing the objects. The upward movement, downward movement, opening and closing of the arm is also controlled using dc motors. Voice Recognition module is used for interaction purpose and APR module is used for voice storage and playback. The Voice Recognition Module is a compact and easy-control speaking recognition board. It is a speaker-dependent voice recognition module which supports up to 80 voice commands in all. Any sound could be trained as command. The module is trained first before letting it recognize any voice command. The different messages are recorded and can be played by sliding a switch towards the recorder and playback option on the module respectively. Embedded C is used for programming the sensors, movement of the robot, movement of robotic arm and voice interaction. Kiel microvision 4 software is used to run, compile and debug the embedded code. Flash magic is used for downloading the code into the microcontroller.

IV. RESULTS AND CONCLUSION

The prototype model designed is capable of detecting fire, temperature, water and gas leakage using various sensors. In addition, it performs face, object recognition using PCA and OCR algorithms respectively. Text reading, movement of the robot, pick & place features are achieved. Also, interaction with the robot through voice is implemented.

Figure 4: Water sensor output

Figure 5: Fire sensor output

Figure 6: Temperature sensor output

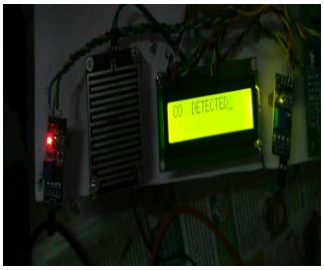


Figure 7: Gas sensor output

Face recognition using PCA algorithm is carried out by capturing real time images through IP Webcam application, processed in MATLAB and the result is displayed on lcd.

Figure 8: Capturing real time images

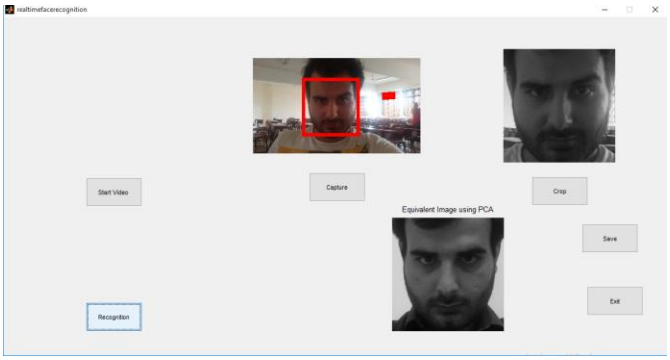


Figure 9: Face Recognition output through MATLAB

Object recognition is implemented using OCR algorithm and the result is displayed on lcd.

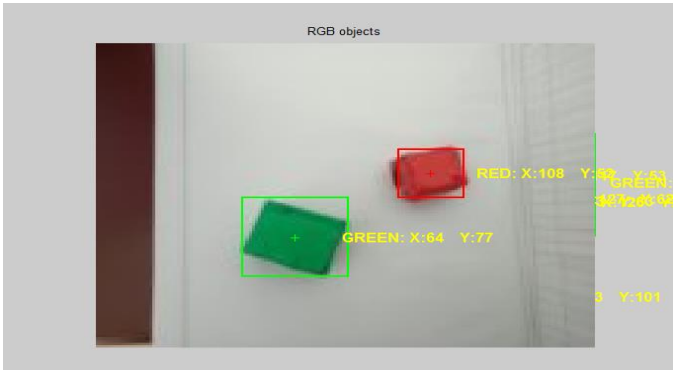


Figure 10: Object recognition

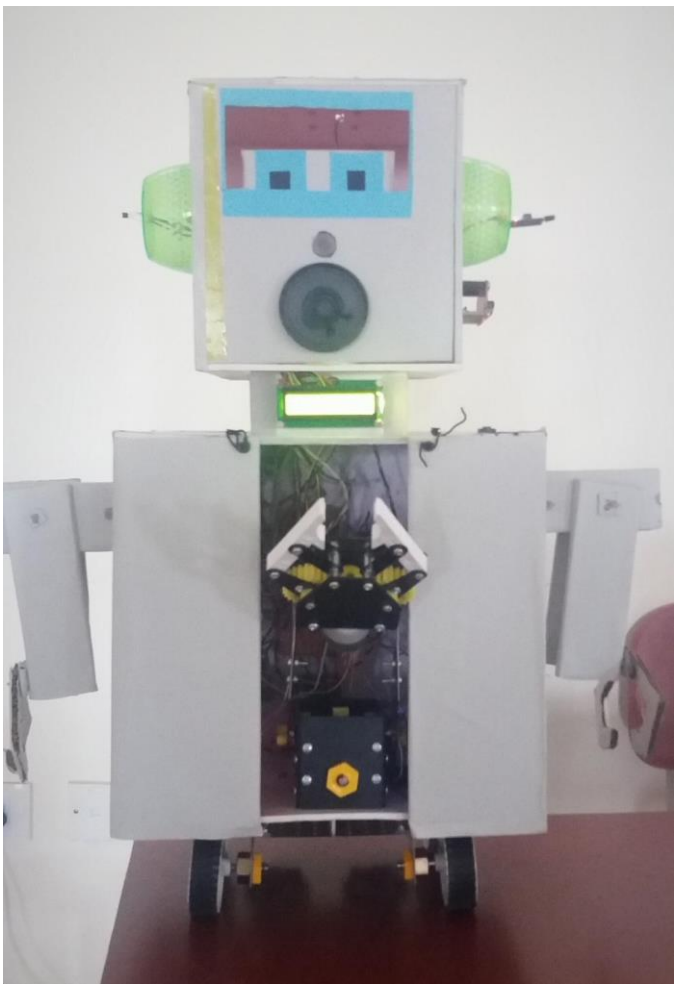


Figure 11: Prototype model

V. FUTURE SCOPE

Features can be improvised to make the robot more effective where real time face recognition can be further used with wireless modules to give access to some restricted places, or it can also be integrated with a robotic arm for triggering weapons in military applications. Picking and placing the objects can be integrated with real time object recognition where the robot can pick the objects based on the output of recognition and place it. On receiving the sensor outputs further these outputs can be processed and used to take preventive actions like in case of fire it can automatically release fire extinguisher or in case of gas leakage it can automatically send a message about the hazardous situation. In future, the robot can be made independent of PC using DSP kits.

REFERENCES

[1] Dr. K. Nagabhushan Raju; K. Sai Prasad Reddy, *Design and Implementation of an Algorithm for Face Recognition by using Principal Component Analysis (PCA) in MATLAB,* International Journal of Advanced Research in Computer Science and Software Engineering 2016.

[2] Amit Kumar Singh; Mohd Shadman Rashid Ali, *Automatic sorting of object by their color and dimension with speed or process control of induction motor,* International Conference on Circuit, Power and Computing Technologies (ICCPCT)2017.

[3] M. Rajesh; Bindhu K. Rajan; Ajay Roy; K. Almaria Thomas; Ancy Thomas; T. Bincy Tharakan; C. Dinesh, *Text recognition and face detection aid for visually impaired person using Raspberry PI,* International Conference on Circuit ,Power and Computing Technologies (ICCPCT)2017.

[4] Sankalp Mehra, Tanmay, *Disaster detection system using Arduino*, International Conference on Information Communication and Embedded Systems (ICICES)2017.

[5] Tasneem M. Yousif; Aysha K. Alharam; Wael Elmedany; Abeer A. Alkhalaf; Zainab Fardan, *GPRS-Based Robotic Tracking System with Real Time Video Streaming*, Future Internet of Things and Cloud Workshops (FiCloudW) 2016.

[6] Midhat Noor Kiyani; Muhammad Uzair Masood Khan,*A prototype of search and rescue robot*,2nd International Conference on Robotics and Artificial Intelligence (ICRAI)2016.

[7] P. Shanmuga Prabha; N. Shivaanivarsha, *A design of firefighting and supervising self-sufficient robots*, Science Technology Engineering & Management (ICONSTEM), 2017.

[8] Supantha Mandal; Suraj Kumar Saw; Shilpi Maji; Vivek Das; Sravanth Kumar Ramakuri; Sanjay Kumar, *Low cost arduino wifi bluetooth integrated path following robotic vehicle with wireless GUI remote control,* International conference on Information Communication and Embedded Systems (ICICES)2016.

[9] *The 8051 Microcontroller and Embedded Systems Using Assembly and C* By Muhammad Ali Mazidi, Janice Gillispie Mazidi & Ro linD. McKinley.

A Survey On Bandwidth Allocation Schemes In Wsns Using Priority Based Mac Protocol

Sowmyashree M S
Department of TE, BMSIT&M, Bangalore, India.
Sowmyashree.m.s@bmsit.in

C S Mala
Department of TE, BMSIT&M, Bangalore, India
csmala@bmsit.in

***Abstract*— Wireless sensor networks(WSN) play an essential role in the communication of wireless systems due to its enormous advantages and applications. The sensor nodes in WSN has many constraints such as limited battery power, idle listening, overhearing, limited bandwidth and communication speed. To overcome these issues an efficient MAC layer protocol has to be designed. Designing a MAC layer is a challenging task, specially due to the difficulty in allocating resources effectively. There are many approaches available to fulfill the resource allocation(bandwidth) requirements for a WSN such as TDMA, FDMA and CSMA. Due to congestion the resources may not be allocated efficiently. The resources can be allocated to a network in numerous ways according to the applications. Priority based allocation is one such approach. This paper proposes a variety of congestion control techniques used in deciding the priority and assigning the resources to the network.**

Key words: MAC Layer, Wireless Sensor Network, Priority based, Bandwidth allocation.

I. INTRODUCTION

Wireless Sensor Network (WSN) is defined as a large number of tiny nodes in groups, autonomous to each other, with low cost and lower power consumption. These nodes are multifunctional sensors and are deployed in various environmental conditions. The Wireless network is considered for the development of environment which consists of few to hundreds and thousands of sensors, which are capable of sensing, computing, and also communicating within the defined area. As seen below, each dot represents a sensor node. The sensors may be of great number which may be homogeneous or heterogeneous; these are distributed randomly in any application environment. This data from the sensor data is transmitted to the sink data either by using single hop or multi hop communication [19]. The sensor node collects the required data. This data is then transmitted to the base station through Gateway as shown in the figure 1.

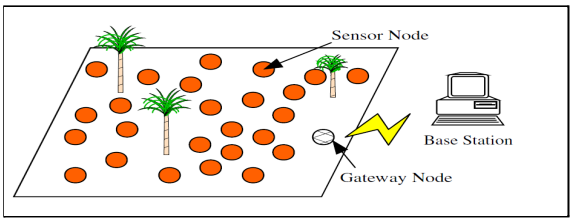


Figure 1: WSN Nodes

The data generated in the network may be continuous data, event driven data or query based depending on the type of application. The data should be carefully transmitted because if congestion occurs then the data may be lost [16]. The gateway has to transmit the data at high speed during the downlink process so that the bandwidth may be allotted fairly in the channel using less energy consumption [17].

WSNs can be categorized as underground, terrestrial, multimedia and aquatic.

The sensors deployed measures these changes in different environmental conditions such as humidity, pressure, sound and temperature depending on the type of application. The sensor node measures all the required parameters and sends it to the base station through the network with the help of the WSN architecture. The architecture of the WSN is presented in figure 2.

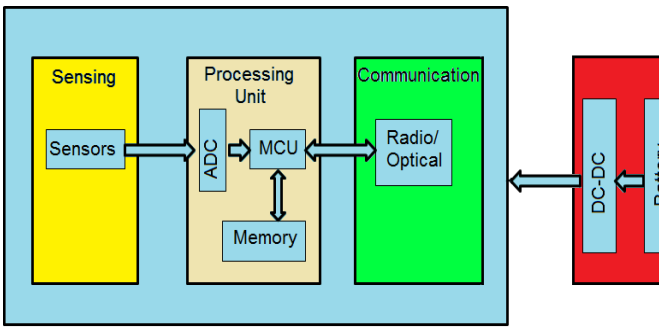


Figure 2: Architecture of WSN

The sensor nodes are all resource constraints equipped with batteries, tiny controllers or processors and transceivers which are used for sensing and information gathering about the environment[1].

The sensed data reaches the destination by travelling in different paths. The bandwidth allocated to a particular channel is then portioned for the data transmission. For real time applications the bandwidth is sensitive and requires a large portion of bandwidth for data having high priority to meet the required dead line. This can be done with the aid of the MAC layer where the availability of multiple non- interfacing and portioned paths is made available for routing. This paper presents a survey carried out on MAC layer modifications for real time requirements. The study details the different data priorities and also the ways to overcome congestion.

II. Classifications of WSN MAC protocols

The wireless sensor MAC protocols are broadly classified into two different categories which are Contention based and schedule based.

a. Contention based protocols:
In contention based, all the nodes share a common medium for transmission of data. This may lead to collision during transmission and in turn to congestion. To overcome this problem, some probabilistic coordination is required. The sender node before transmitting listens to the shared medium, and waits for a random period to check whether the medium is busy and tries again. For this reason, contention based MAC is better for the networks having less contention and where burst traffic is expected. The most common examples for contention based MAC protocols are Additive Link On-line Hawaii System (ALOHA) and Carrier Sense Multiple Access(CSMA).

b. Schedule based protocols:

In schedule based, the nodes access to the shared medium is either time or frequency multiplexed. Hence, different nodes are allowed to access the shared medium without interfering with each other and thus avoid collision effectively. But in some conditions the load becomes heavy and the data traffic increases randomly which leads to congestion [6].

There are two reasons for congestion in WSN, the first congestion occurs is node level when the packet arrival rate is more than the packet rate of service rate. This type of congestion occurs mainly in the sensor nodes which are close to the sink node where combined upstream traffic is available. The second case is called the link level congestion which occurs because of contention, interference and bit error rate.

A lot of work is being carried out on congestion control of wireless sensor networks. Some of them are as follows:

a. Congestion detection and avoidance (CODA)
b. Congestion control and Fairness (CCF)
c. Priority based congestion control protocol (PCCP)
d. Congestion control protocol with priority support (QCCP-PS)

CODA: is based on measuring the congestion level[7] using buffer occupancy and load of the channel,
CCF: is based on probabilistic selection for fair allocation[8],
PCCP : detects the congestion at both node and link level in a node[24]
QCCP-PS: uses the queue length as an indication of congestion degree[21].

III. Bandwidth Allocation based on priority

There are different approaches to solve the problem of bandwidth allocation and congestion in a sensor network. For our study we consider prioritization approach to overcome the issue [20]. The different methods in prioritization are discussed below:

3.1 Queuing Model using Little's formula:

The nodes in a sensor share the available resources such as buffer storage, transmission bandwidth and the processing capability. The performance loss and delay can be quantified as explained in this subsection. When a connection or packet request arrives at a node, the node may be in a state of blocking due to the unavailability of the resources. The data packets arrive at the node in a random manner; the time spent in the node is also random. Due to non-availability of resources, the packets may be lost or blocked. The arrival rate on an average can be specified by the inverse of the inter average time of arrival. To estimate this time, the Little's formula can be applied to a network on the basis of queuing model [2]. A queuing model is said to be considered at the nodes where requests can be considered at the nodes which belong to one of N priority classes. When the packet containing the data arrives, the packet joins the queue depending on the class of priority. Every time when the Packet is fetched from the queue, the packet which has to be serviced next is selected from the head of the line having highest priority non empty queue. The Poisson distribution is used for the arrival of data at each priority class with the rate i_n and the average service time of a class N customers is E [sn]. Therefore the load that is offered by the class N is given by $\rho n = i_n E [sn]$, in which ρ is the factor of utilization. The node with the highest priority class (class 0) has an average waiting time given by

$$E [w0] = (in\ e\ [s\hat{}2]) / (1 - \rho 0) \qquad (1)$$

Where E [W0] saturates as the value of ρ approaches to 1. The saturation point of class 0 is obtained by its own load. The time of waiting for class 1 is given by

$$E [W1] = (in\ E\ [s\ \hat{}2]) / (1 - \rho 0)\ (1 - \rho 0 - \rho 1) \quad (2)$$

The queue saturates in class 1 only when ρ0 + ρ1 approaches to 1. Thus the queue saturate point of class 1 is affected by class 0 load , Similarly, the queue saturation point of class N can be determined by the
Summing the loads of the classes of priority up to N.

3.2 Queuing model based on Exponential Weighted moving average formula (EWMA):

In this model a class traffic identifier/ classifier is inserted into the queue to identify the class traffic. The sensor node also maintains a separate traffic queue. The classifier is used to classify the packets depending on the traffic class and sends to an appropriate queue. Then Priority is assigned to each queue. Depending on the priority the scheduler schedules the packets. High and low priority is assigned depending on the source traffic and transit traffic [3]. The congestion detection is measured using packet service ratio r(i).

Congestion Detection:

The measure the level of congestion the service packet ratio r (i) is used at each node i. Then the service Packet ratio is calculated by using

$$r\ (i) = R^i_{serv} / R^i_{sch} \qquad (2)$$

Where, $R^i serv\ is$ the packet service rate of the node and
R^i_{sch} is the scheduling rate of the packet with respect to node i.

The packet service ratio reflects the level of congestion at each sensor node. If the obtained ratio is equal to 1, then the scheduling rate and service rate are said to be equal. Else if the ratio is greater than 1, then the rate of scheduling is less than the rate of packet service. In both these cases, detection of congestion does not happen. In the meanwhile if the ratio of packet service is less than 1 and if the rate of scheduling is more than the rate of service it causes the packets to be queued which indicates the congestion. This congestion can be overcome by using the rate adjustment hop by hop. When the node receives the notification information about congestion, the nodes adjust the rate accordingly. The algorithm is as follows:
Step 1: The average time of service t^i_s is calculated by using EWMA formula

$$t^i_s = (1\text{-}Ws)\ t^i_s + Ws\ t^i_s \qquad (3)$$

Where Ws is constant between 0< *Ws* <1

The average service packet rate is calculated as the inverse of the average time of service

$$R^i_{serv} = 1 / t^i_s \qquad (4)$$

Step 2: Let SP^i_j denotes the priority of source traffic for an application j with respect to sensor node i. The total source priority for each node i is then calculated as the summation of all the source traffic priority of all the applications running in it.

$$SP(i) = \sum SP^i_j \qquad (5)$$

Step 3: The rate of source traffic priority for different applications running in it is calculated as follows

$$R^i_J = R^i_{sch} * SP^j / SP^j_i \qquad (6)$$

Using these formulas the different source priorities is calculated and class is assigned to each node.

3.3 *Queuing model based on probability*:

For obtaining fair allocation the intermediate nodes are divided as near sink nodes and near source nodes. Then the route is established which depends on low and high priority of the sensed data. If there is congestion detection, auxiliary routing is established to make a node to non congestion. For allocation using fair rate near source and sink source control congestion module is designed based on the probability[4].

The intermediate node estimates the ratio P_R as:

$$P_R = \frac{\#\text{ of packets(label>0)}}{\#\text{ of total delivering packets}} \qquad (7)$$

If the value of P_R is larger then the node is closer to the source node. If the value of P_R is less then threshold the node is closer to the sink node. For the route allocation the probability PSR_i is calculated using the equation

$$PSR_i = \frac{L R_i / HN_i}{\sum_k (LR_k / HN_k)} \qquad (8)$$

Where LR_i is the length of the route between sink node and node I,
HN_i is the number of hop count for the i^{th} record route.
Through this, low and high priority is recorded at the node and routing is done based on this decision.

3.4 Queuing model using window technique:

The window technique used is fair allocation control window (FACW). In this technique, every sensor maintains a control window of size N which stores the traffic classes of latest packets sent by neighbors or by it. The traffic class 'c' in the window is represented by 'h_c', if this value is higher then it corresponds to higher priority, otherwise it corresponds to lower priority. When the sensor collects data with type c, it behaves as follows: if the number of 'c' classes in its window is less then ' hc' it transmits the packet, else it waits a random time (or may drop the packet) and retry later .The packet sent through the window is updated by inserting an object of class 'c' according to First In First Out (FIFO) policy[5]. This technique is explained well through Continuous Time Makrov Chain (CTMC) with finite state machine.

The main idea of FACW is that the data traffic in a sensor network is classified into a finite set of M classes K= { $c_1, c_2, \ldots c_M$}. Each node maintains a control window of N size where the latest N transmissions are stored. In the window h_c entries of class c is stored. The entries in the window has the values of h_c for which c ε K.

The CTMC model assumptions of FACW is that, the packets generated are according to the independent Poisson Process whose rate depends on the state of the window and the tree structure. The CTMC equation for finite state space is given by

$$Q(x, x') = \begin{cases} \lambda_c(|x|_c) & \text{if } x' = (c, x_1 \text{ to } x_{n-1}) \\ & \text{and } |x|_c < h_c \\ 0 & \text{otherwise} \end{cases} \qquad (9)$$

Where

$(|x|_c)$ = represents the state of the window.
λ_c = Independent poison rate
c = class
h_c = Traffic priority

This method maintains a window at each node with the information about traffic perceived and drops the packets that has reached maximum population in the window by fairly allocating the bandwidth.

IV. CONCLUSION

The survey comparison presents the thorough understanding of bandwidth allocation techniques based on prioritization using the MAC protocols. We have studied the major classifications of queuing model based on various applications which solves the problem of collision, idle listening and so on. Among the various techniques studied, the queuing model with little's formula proves to be better for fair allocation of bandwidth as it also considers the delay factor for assigning the priority for data transmission. In this study static base station and nodes are considered, further studies may be extended for the scenario where mobility of the sink or sensor nodes or both can be considered.

References

[1] Ratna B Patil, S K Padaganur, J D Mallapur, Namratha Bannur, " A survey on Bandwidth allocation schemes in WSNs using TDMA based MAC protocol," International Journal of research in engineering and technology, volume 5, issue 2, Feb 2016, pg 251-254.

[2] Mary Cherian, T R Gopalkrishnan Nair, "Priority based bandwidth allocation in wireless sensor networks,"International journal of computer networks and communications, Volume 6, Issue 6, november 2014, pg 119-128.

[3] S Sridevi, M Usha, G Pauline Amertha Lithurin, "Priority Based Congestion control for heterogeneous traffic in multipath wireless sensor networks," International conference on computer communication and informatics,IEEE, january 2012, pg 1-5.

[4] Jilani Sayyad, Dr Nitin Choudhari,"Priority Based Congestion Control and Fair Rate Allocation in Wireless Sensor Networks," International Journal of Engineering Sciences and Researh Technology, December 2014,Pg 393-404.

[5] Andrea Marin, Sabina Rossi," Priority Based bandwidth allocation in wireless sensor networks," January 2016, pg 8-16.

[6] Pilus Kumar Pal, Punyasha Chatterjee, " A survey on TDMA based MAC protocol for wireless Sensor Network," International Journal of Emerging Technology and Advanced Engineering, volume 4, Issue 6, june 2014, pg 219-230.

[7] C Y Wan, S B Eisenman, and A T Campbell, "CODA: Congestion detection and avoidance in sensor networks," proceeding of ACM SenSys, November 2003,pg 266-279.

[8]C T Ee, and R Bajcsy, "Congestion Control and Fairness for many to one network routing in sensors," ACM SenSys, November 2004, pg 148-161.

[9]Thaskani S, Vinod Kunar K, Rama Murthy G,"Mobility Tolerant TDMA based MAC Protocol for WSN," IEEE symposium on computer and informatics, july 2011, pg 515-519.

[10] S Zhuo, Z Wang, Y-Q Song, Z Wang and L Almeida,"A traffic adaptive duty cycled MAC protocol with dynamic Slot allocation," SECON, 10th IEEE Communiction Society Conference , june 2013, pg 95-103.

[11] D Mathavan, R Karunakaran, J Kapelan, "Bandwidth Allocation in Application oriented networks based on Prioritization," SSRG-ILMCA, Volume 4, Issue 1, January 2017, pg 25-30.

[12] Mohamed Amine Kafi, Djamel Djenouri, Jalel Ben –Othman and Nadjib Babache, "Congestion Control Protocols in Wireless Sensor Networks: A survey," IEEE Communications Surveys & Tutorals, volume 16, issue 3, December 2014, pg 1369-1390.

[13] Xiaoyan Yin, Xingshe Zhou, Rongsheng Huang, Yuguang Fang and Shining Li," A Fairness Aware Congestion Control Scheme in WSN," IEEE Transactions on ehivular Technology, Volume 58, Issue 9, November 2009.

[14] Akbar Majidi and Hamid Mirvaziri,"A New Mechanism for congestion control in wireless Multimedia Sensor Networks for Quality of Service and Network Life Time," Amreican Journal of Computing Research Repository , volume 2, Issue 1, 2014, pg 22-27.

[15] Charalambos Sergiou and Vasos Vassiliou, " Source Based Routing Trees for Efficient Congestion Control in Wireless Sensor Networks," IEEE 8th International Conference on Distributed Computing in Sensor Systems , 2012, pg 378-383.

[16] Mian Ahmad Jan, Syed Rooh Ullah Jan, Muhammad Alam, Adnan Akhunzada, Izaz Ur Rahman," A Comprehensive Analysis of Congestion Control Protocols in Wireless Sensor Networks" Springer- Mobile Networks and Applications, June 2018, Volume 23, Issue 3, pp 456–468.

[17] Yitian Zhang , Kun Yang , Xiaofeng Lu, "Energy Efficient Prioritized Bandwidth Allocation Algorithm supporting RF Energy Charging " IEEE 2018 14th International Wireless Communication and

Mobile Computing conference (IWCMC), Pg no 1213-1218.

[18] D. Setiawan, A. A. Aziz, D. I. Kim, K. W. Choi, "Experiment modeling and analysis of wireless-powered sensor network for energy neutral power management", IEEE Systems Journal, vol. PP, no. 99, pp. 1-12, 2017.

[19] Lokesh B. Bhajantri , Shiddalingesh S. Hiremath, "Bandwidth Allocation and Scheduling in Distributed Sensor Networks", Internet of Things and Cloud Computing- Science Direct, Vol. 5, No. 5-1, 2017, pp. 30-37.

[20] Subha Kanta Swain and Pradipta Kumar Nanda," Priority Based Fairness Rate Control in Wireless Sensor Networks", IEEE WiSPNET 2017 conference,Pg no 2206-2213.

[21] Shayesteh Tabatabaei, Mohammed Rahim Omrani." proposing a method for controlling congestion in wireless sensor networks using comparative fuzzy logic", Springer Wireless Personal Communications, June 2018, Volume 100, Issue 4, pp 1459–1476 .

[22] O. Chughtai, N. Badruddin, A. Awang, M. Rehan, "Congestion-aware and traffic load balancing scheme for routing in wireless sensor networks", ", Telecommunication Systems, vol. 63, no. 4, pp. 481-504, 2016.

[23] Rehan Shams, Fozia Hanif Khan, Shaheen Abbass,Rukaiya Javaid," Bandwidth allocation for wireless cellular nerwork by using Genetic lgorithm" July 2017, Volume 95, Issue 2, pp 245–260

[24] S. Iniya Shree , M. Karthiga , C. Mariyammal, "Improving congestion control in wsn by multipath routing with priority based scheduling", IEEE-International Conference on Inventive Systems and Control (ICISC), 2017, pg no 1-6.

[25] Yongbo Cheng, Shiliang Xiao, Jianpo Liu, Feng Guo, Ronghua Qin, Baoqing Li, Xiaobing Yuan," An approximate bandwidth allocation algorithm for tradeoff between fairness and throughput in WSN", Springer - Wireless Networks, August 2018, Volume 24, Issue 6, pp 2165–2177

[26] C. Sergiou, V. Vassiliou, A. Paphitis, "Congestion control in wireless sensor networks through dynamic alternative path selection", computer Networks, Dec. 2014, vol. 75, pp. 226-238,

[27] P. Mohanty, M. R. Kabat, "Energy efficient reliable multi-path data transmission in WSN for healthcare application", International Journal Wireless. Network, 2016, vol. 23, no. 2, pp. 162-172.

Decision support system for Precision Agriculture using Wireless Sensor Network

Raghunandan G H, Sushmitha K R, Vaishnavi P S, Manasa M, Samhitha C S, Spoorthi H Shetty
Department of Telecommunication Engineering,
BMS Institute of Technology and Management,
Bengaluru, India.
Email: raghunandangh@bmsit.in
Email: sushmitharamarao@gmail.com

***Abstract*—Due to the development of agriculture, most of the food needed to feed the population has been produced through industrialized agriculture. Agriculture is demographically the broadest economic sector and plays a significant role in overall socio-economic fabric in India. India ranks second worldwide in farm output. Digital agriculture or precision agriculture is an abstraction where the farmer will be able to access the parameters related to his farm and control them manually or automatically. The wireless sensor networks play a major role in achieving the need. They include computation, wireless communication capabilities and small nodes of sensing. This proposed technology will improve the crop yield and maintain quality. In this paper, we have used various sensors in garden area. This implementation of wireless sensor network technologies is also helpful for faraway surveil in the various applications of the agriculture field.**

Index Terms—Precision Agriculture, Wireless Sensor Networks, GSM, Sensors.

I.INTRODUCTION

In the past, agriculture has played and will continue to play a dominant role in the growth of Indian economy in the foreseeable future. It represents the largest sector producing around 28 percent of the GDP and is the largest employer. New technologies are needed to push out yield frontiers, utilize inputs more efficiently and diversify to more sustainable and higher value cropping patterns. Indian agriculture is faced with a great diversity of needs, opportunities and prospects. Future growth needs to be more rapid, more widely distributed and better targeted. These challenges have profound implications for the way. We prefer a sensor network which uses low cost components and required software.

The wireless sensor network is used in soil moisture management, humidity control, temperature sensing, CO_2 sensing etc. These sensing electronics compute the conditions of environment and convert them into electrical signals which when processed gives the information about the situation near the sensor. This information is communicated with the farmer by means of GSM technology, Zigbee technology etc. The data which is obtained from WSN is saved in the form of numerical data in central base station so that an individual can access the data from a web browser also. Due to the technological advancements, low power and powerful sensor nodes can be produced. Sensor nodes are basic elements which comprise of sensing, computing and wireless communication unit. WSN interfaces with the local or wide area network. In sensor networks, distributed control is used because in centralized control, if the central architecture fails the entire network will disintegrate. In this paper, Section II discusses about existing works, section III explains about proposed system, section IV describes about implementation, section V is about future works and, section VI concludes the paper.

II.RELATED WORK

Research works related to precision agriculture is quite large in number. Some of the works of precision agriculture are listed as follows-

Precision farming solution [1]; Precision agriculture using wireless moisture sensor network [2]; this research work provides the scope for analysing the applications of the soil sensor in precision agriculture. The moto of this research work is to estimate the fluidity or moist content of the soil. Since moisture of the soil required for variety of crops is different and it can be determined with the soil sensors. Realization of precision agriculture monitoring system based on wireless sensors [3]; in this documentation variety of sensors are used and working of each sensor is processed by wireless network. The data collected by each sensor is preserved by the sensor module which notes the working of the sensors the sensor module looks after the further exchange of preserved information intermediate to receiver and transmitter. Precision agriculture for green house using a wireless sensor network [4]; the outcome of this work is to make out the operation of WSN to monitor the agriculture parameters. A low-cost wireless sensor network for precision agriculture [5]; the insight of this project is to appeal WSN for precision agriculture. IoT in precision agriculture applications using wireless moisture sensor network [6]; in

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this paper we can go through the applications of WSN and WMSN in monitoring the moisture sensors.

III.PROPOSED SYSTEM

The system network comprises of a number of sensor nodes as shown in Fig.1. Each sensor node consists of a sensor unit, and a transmitter unit. Then, there is a receiver unit that receives information (the location of the node, status of the particular part of the field i.e. soil moisture content, temperature and humidity etc. from the sensor unit in the node) from the sensor node, processes it, makes decision to whether to irrigate or not to irrigate the field and notifies the farmer to take required action.

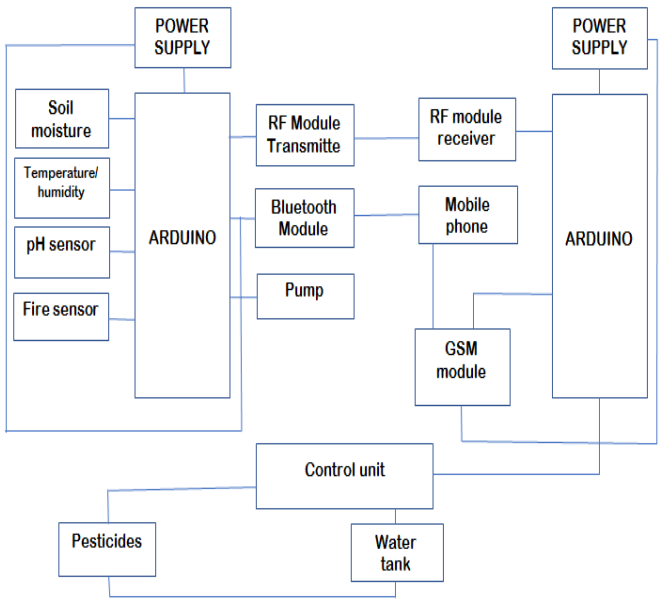

Fig.1 Block Diagram of the proposed system

In the sensing unit, there are four sensors (the soil moisture sensor, temperature/humidity sensor, rain drop sensor and fire sensor) which sense the respective factors and the sensor values obtained are given to the transmitting unit. The transmitting unit takes the information from the sensing unit and through the RF module, sends it to the receiving unit. The receiving unit collects the information sent by the transmitting unit of the sensor node. The data received, is then processed and sent to the farmer (mobile phone) which happens through GSM. The farmer will thereby be notified about the respective node area and given options to turn ON/OFF the motor. The farmer now has to give the necessary command to the system. But if he fails to do so, the system gives a small amount of delay and does the task by itself. This makes the system more efficient as the farmer will be aware of each and everything happening in his farm even when there is nobody in the field. If the soil moisture level is low, the motor is turned ON and as soon as the soil moisture is retained, the motor is turned OFF. If the pre-set time period is say, 30 minutes, then every 30 minutes, the farmer will be notified about status of his field.

IV. IMPLEMENTATION

The proposed system was implemented in the garden of BMSIT&M campus, Bengaluru. The soil was first examined before implementation of the system. The results obtained are listed in Table.1

Table.1: Soil Test Results

Organic Matter	2.8%
pH	7.6
Olsen Phosphorus	45 ppm
Bray 1 Phosphorus	40 ppm
Potassium	89 ppm
Sulfur	6 ppm

The ideal pH for grass and cereal soils vary, the optimum pH for grass is 6.3, while for cereals it is 6.5. If the pH value is lower or higher than these values, the supply of macro-nutrients (N, P, K and S) to the plant will be reduced, which will have a negative impact on the yield. As the pH of the soil was observed to be higher than the optimum value, it was neutralised by the usage of required amount of buffer index. Similarly, the concentration of Nitrogen, Phosphorous, and other essential nutrients were also optimised and the soil was made ready for implementation of the designed system. Two controlling units were used, one of which was placed near the field to which all the sensors were connected and the other controller, a little away from the field. The transmitter unit (Fig.2) is connected with an RF transmitter which helps in transmitting the data from one controlling unit to the other. The other controller at the receiver end (Fig.3) which is placed away from the field is connected to an RF receiver which receives the data transmitted from RF transmitter. Soil moisture sensor, used to give the measure of the moisture content in the soil, is one of the most important sensors which is useful for the irrigation purposes. Based on the soil water content one can know how much to irrigate the field. A rain drop sensor is used to measure the amount of rainfall. A temperature and humidity sensor are used to measure the temperature of the soil and atmospheric humidity which helps the farmer to understand better about the necessities of the crop and decide the quantity of water required for it, type and amount of pesticides to be treated with, and other requirements, for the health of the crop. The temperature and the relative humidity of the surrounding

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environment majorly contribute to the health of the crop. Relative humidity is the ratio of the actual vapour pressure to the saturation vapour pressure expressed as a percentage.

$$RH = 100 \cdot \frac{e}{e_w} \quad (1)$$

A brief study was conducted with the help of the Professors of University of Agricultural Sciences (GKVK), Bengaluru, regarding the dependency of the occurrence of a disease on the temperature and relative humidity. Based on the inferences made, whenever the temperature & RH combination nears to the favourable condition for a disease, a small dosage of chemical or pesticide is mixed with the sprinkler system using valve control, as precautionary measure. If the favourable conditions sustain for long as shown in the Table.2, higher dose of pesticide is added. Different crops have different set points (temperature, RH factor) for different diseases.

Table.2: Set points for different diseases

Disease	Temperature (°C)	Rh (%)	Duration
Late blight	10-16 °C	>90	>100hrs
Early blight	26-29 °C	>80	4-5days
Leaf mold in green house tomato	24°C and 26°C	>85	10days
Powdery mildew	20°C to 30 °C	>95	5-7days

All these determinations made are monitored in the controller at the transmitter end and are transmitted to the receiver through RF transmitter. The RF receiver connected to second controller, receives the data from the transmitter and sends it to the farmer (mobile) through GSM. Any message sent by the user is also received at the second controller any message from the farmer is also received by the receiver. The LM393 (soil moisture sensor) sensor used to advice the customer to water their plants, determines dielectric permittivity of the neighbouring medium. It works at 5V voltage. In soil, dielectric permittivity is a function of the water content. A voltage corresponding to dielectric permittivity is created by the sensor and accordingly the water content of the soil. The sensor averages the water content over the entire length of the sensor.

Fig.2 Transmitter section of the proposed system

Fig.3 Receiver section of the proposed system

The DHT11 (temperature and atmospheric humidity sensor), is a temperature and humidity sensor complex with a calibrated digital signal output. A capacitive humidity sensor and a thermistor is used to determine the neighbouring air and gives out a digital signal on data pin. A resistive type humidity measurement component and an NTC temperature measurement component is also accommodated in the sensor. It connects to high performance 8-bit microcontroller. Offering finest quality and cost effectiveness. It is fairly easy to use but requires careful timing to grab data. Rain observation is done using rain drop sensor. It determines rainfall intensity. A rain board and a control board are included that are separated for more convenience. It has a power indicator LED and a modifiable sensitivity through a potentiometer. The module is based on the LM393 op-amp. Rain drops are collected on a printed circuit board. As rain drops are collected on the circuit board, they create paths of parallel resistance that are determined by the op-amp. Lesser the resistance, the lesser the voltage output. Conversely, lesser water, the greater the output voltage on the analogue pin. The RF module, as the name suggests, operates at radio frequency. It is suitable for long range applications as it can transmit data through larger distances. RF module comprises of an RF transmitter and an RF receiver.

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An RF transmitter module is a small size PCB capable of transferring a radio wave and modulating radio wave to carry data. Transmitter is usually subject to modulating requirement which commands the maximum acceptable transmitter power output. An RF receiver module takes the modulated RF signal to demodulated modules, namely, the super-regenerative receivers and super-heterodyne receivers. Super-regenerative modules are low power designs and low cost using a series of amplifiers to remove modulated data from a carrier wave. The SIM900 is a complete Quad-band GSM solution in a SMT module which can be installed in the user applications. A GSM modem is a device which can be either a mobile phone or a computer or any other processor communicated over a network using GSM modem. When the SIM card mounted GSM modem receives digit command by SMS from any cell phone it sends that data to the MC through serial communication. The GSM modem accepts command 'STOP' to evolve an output at the MC when the program is executed. A wireless communication technology that is used to replace the cables connecting electronic devices is Bluetooth technology. RF technology known as 'star topology' is used to control these devices. Bluetooth networks can be built as piconets or scatter nets depending on the number of nodes in the network.

V.FUTURE WORK

In future the module can be equipped with numerous sensors which are advanced in technology. The system can be annexed with a camera by usage of which, the farmer can also get the visual status of the present situation of the field and its surroundings. Adding different sensors like pH sensor, leaf moisture sensor etc. can yield better results. Also, we can use technologies like Zigbee for wireless data transfer. Irregular or insufficient rainfall can be a serious issue in agriculture. To overcome this issue, we can use sensors which detect the soil moisture, temperature, fire. This can help farmer in decision making about suitable amount of irrigation water. In future, it can also be foreseen that the farmers are given the basic knowledge of system being implemented, which also adds to efficiency of the yield and ease of practicing precision agriculture techniques for the farmer.

VI.CONCLUSION

Precision plays a very important role in agriculture. Primitive methods of irrigation and other agricultural practices that are still in existence in some parts of the world need to be improved. Proper implementation of advancement in science and modern technology with maximum efficiency both in terms of management and control and also economy, can prove to be of great help in achieving progress in agriculture. The aim of this paper is to review the technical and scientific state of art of Wireless Sensor Technologies. In recent times, WSNs are widely applied in various agricultural applications. Sensors are very useful in agriculture. We have successfully implemented the wireless sensor network in the field and the information was communicated to the user.

REFERENCES

[1] George Eldho John, "A low cost wireless sensor network for precision agriculture", *2016 Sixth International Symposium on Embedded Computing and System Design (ISED),* 15-17 Dec. 2016.

[2] Ibrahim Mat, Mohamed Rawidean Mohd Kassim, Ahmad Nizar Harun, "Precision agriculture applications using wireless moisture sensor network", *2015 IEEE 12th Malaysia International Conference on Communications (MICC),* 23-25 Nov. 2015.

[3] Ibrahim Mat, Mohamed Rawidean Mohd Kassim, Ahmad Nizar Harun, Ismail Mat Yusoff, "IoT in Precision Agriculture Applications Using Wireless Moisture Sensor Network", *2016 IEEE Conference on Open Systems (ICOS),*10-12 Oct. 2016

[4] Raghunandan. G .H, Akshata.A.K,Hemika.C.S,"Performance Analysis of Different WSN Based Systems in Precision Farming", *Int. J. Advanced Networking and Applications Volume: 07 Issue: 05 Pages: 2893-2898 (2016),* May 05,2016.

[5] Raghunandan.G.H. Archana R, RachanaPai, RakshaHegde T.N., "Qualitative Analysis of Routing Protocols in WSN", *Int. J. Advanced Networking and Applications, Volume: 08 Issue: 02 Pages: 3021-3025 (2016),* Oct 20,2016.

[6] G. H. Raghunandan, S. Y. Namratha, S. Y. Nanditha, G. Swathi, "Comparative Analysis of different Precision Agriculture Techniques using Wireless Sensor Networks", *2017 4th International Conference on Electronics and Communication Systems (ICECS),* 24-25 Feb. 2017.

[7] Yousef E. M. Hamouda, Basel H. Y. Elhabil, "Precision agriculture for greenhouses using a wireless sensor network", *Information and Communication Technology (PICICT), 2017 Palestinian International Conference,* May 2017.

[8] John Valasek , Han-Hsun Lu, Yeyin Shi, "Development and testing of a customised low cost unmanned aircraft system based on multispectral and thermal sensing for precision agriculture applications", *Unmanned Aircraft Systems (ICUAS), 2017 International Conference,* June 2017.

[9] M. Udin Harun Al Rasyid, Entin Martiana Kusumaningtyas, FajarSetiawan, "Application to Determine Water Volume for Agriculture Based on Temperature & Humidity Using Wireless Sensor Network", *2016 International Conference on Knowledge Creation and Intelligent Computing (KCIC),* 15-17 Nov. 2016.

[10] Wang Yitong, Shi Yunbo, Yu Xiaoyu, "Design of Multi-parameter Wireless Sensor Network Monitoring System in Precision Agriculture", *2014 Fourth International Conference on Instrumentation and Measurement, Computer, Communication and Control,* 18-20 Sept. 2014.

[11] Lei Xiao, Lejiang Guo, "The realization of precision agriculture monitoring system based on wireless sensor network", *2010 International Conference on Computer and Communication Technologies in Agriculture Engineering,* Vol. 3, 12-13 June 2010.

[12] Tagarakis A., Liakos V, Perlepes L, Fountas S, Gemtos T, "Wireless sensor network for precision agriculture", *2011 15th Panhellenic Conference on Informatics,* Sept. 30 2011-Oct. 2 2011.

[13] Ibrahim Mat, Mohamed Rawidean Mohd Kassim, Ahmad Nizar Harun, Ismail Mat Yusoff, "IoT in precision agriculture

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applications using wireless moisture sensor network", *2016 IEEE Conference on Open Systems (ICOS)*, 10-12 Oct. 2016.

[14] G. H. Raghunandan; A. Shobha Rani; S. Y. Nanditha; G. Swathi, "Hierarchical agglomerative clustering-based routing algorithm for overall efficiency of wireless sensor network", *2017 International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT)*, 6-7 July 2017.

[15] G. H. Raghunandan, S. Y. Namratha, S. Y. Nanditha, G. Swathi, "Comparative analysis of different precision agriculture techniques using wireless sensor networks", *2017 4th International Conference on Electronics and Communication Systems (ICECS)*, 24-25 Feb. 2017.

[16] Divya Upadhyay, Ashwani Kumar Dubey, P. Santhi Thilagam, "Application of Non-Linear Gaussian Regression-Based Adaptive Clock Synchronization Technique for Wireless Sensor Network in Agriculture", *IEEE Sensors Journal Year: 2018, Volume: 18, Issue: 10*, March 2018.

[17] Camilo Lozoya, Alberto Aguilar, Carlos Mendoza, "Service Oriented Design Approach for a Precision Agriculture Datalogger", *IEEE Latin America Transactions*, Volume: 14, Issue: 4, April 2016.

[18] Prashant A. Patil, Bhushan G. Jagyasi, Jabal Raval, Nilima Warke, P. P. Vaidya, "Design and development of wearable sensor textile for precision agriculture", *2015 7th International Conference on Communication Systems and Networks (COMSNETS)*, 6-10 Jan. 2015.

[19] Sophocleous Marios, Julius Georgiou, "Precision agriculture: Challenges in sensors and electronics for real-time soil and plant monitoring", *2017 IEEE Biomedical Circuits and Systems Conference (BioCAS)*, 19-21 Oct. 2017.

978-1-5386-5232-9/18/$31.00 ©2018 IEEE