# LECTURE NOTES

## ON

# INTERNET OF THINGS

## 18MCA542

## V Semester

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# UNIT-I

## M2M to IoT —The Vision

### Introduction

Our world is on the verge of an amazing transformation; one that will affect every person, town, company, and thing that forms the basis of our society and economy. In the same way that the Internet redefined how we communicate, work, and play, a new revolution is unfurling that will again challenge us to meet new business demands and embrace the opportunities of technical evolution. Old and new industries, cities, communities, and individuals alike will need to adapt, evolve, and help create the new pat- terns of engagement that our world desperately needs. In response to these issues, we are moving towards a new era of intelligence one driven by rapidly growing technical capabilities.

M2M and the IoT are two of the technologies that form the basis of the new world that we will come to inhabit. Anything in the physical realm that is of interest to observe and control by people, businesses, or organi- zations will be connected and will offer services via the Internet. The physical entities can be of any nature, such as buildings, farmland, and natural resources like air, and even such personal real-world concepts as my favorite hiking route through the forest or my route to work. This book covers our world's transformation towards the IoT, and it is the authors' hope that we will inspire solutions and provide a technical frame- work to some of the world's most pressing needs from environmental change to industrial re-configuration.

Both M2M and IoT are results of the technological progress over the last decades, including not just the decreasing costs of semiconductor compo- nents, but also the spectacular uptake of the Internet Protocol (IP) and the broad adoption of the Internet. The application opportunities for such solu- tions are limited only by our imaginations; however, the role that M2M and IoT will have in industry and broader society is just starting to emerge for a series of interacting and interlinked reasons.

The Internet has undoubtedly had a profound impact across society and industries over the past two decades. Starting off as ARPANET connecting remote computers together, the introduction of the TCP/IP protocol suite, and later the introduction of services like email and the World Wide Web (WWW), created a tremendous growth of usage and traffic. In conjunction with innovations that dramatically reduced the cost of semiconductor tech- nologies and the subsequent extension of the Internet at a reasonable cost via mobile networks, billions of people and businesses are now connected

to the Internet. Quite simply, no industry and no part of society have remained untouched by this technical revolution.

At the same time that the Internet has been evolving, another technol- ogy revolution has been unfolding the use of sensors, electronic tags, and actuators to digitally identify, observe and control objects in the physi- cal world. Rapidly decreasing costs of sensors and actuators have meant that where such components previously cost several Euros each, they are now a few cents. In addition, these devices, through increases in the computational capacity of the associated chipsets, are now able to commu- nicate via fixed and mobile networks. As a result, they are able to communicate information about the physical world in near real-time across networks with high bandwidth at low relative cost.

So, while we have seen M2M solutions for quite some time, we are now entering a period of time where the uptake of both M2M and IoT solutions will increase dramatically. The reasons for this are three-fold:

1. An increased need for understanding the physical environment in its various forms, from industrial installations through to public spaces and consumer demands. These requirements are often driven by efficiency improvements, sustainability objectives, or improved health and safety (Singh 2012).
2. The improvement of technology and improved networking capabilities.
3. Reduced costs of components and the ability to more cheaply collect and analyze the data they produce.

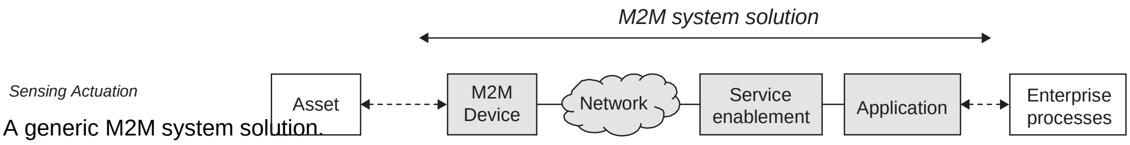
*A typical M2M solution overview*

A typical M2M system solution consists of M2M devices, communication networks that provide remote connectivity for the devices, service enable- ment and application logic, and integration of the M2M application into the business processes provided by an Information Technology (IT) system of the enterprise, as illustrated below in Figure

The M2M system solution is used to remotely monitor and control enterprise assets of various kinds, and to integrate those assets into the business processes of the enterprise in question. The asset can be of a wide range of types (e.g. vehicle, freight container, building, or smart elec- tricity meter), all depending on the enterprise.

The system components of an M2M solution are as follows:

- *M2M Device*. This is the M2M device attached to the asset of interest, and provides sensing and actuation capabilities. The M2M device is here generalized, as there are a number of different realizations of these devices, ranging from low-end sensor nodes to high-end complex devices with multimodal sensing capabilities.
- *Network*. The purpose of the network is to provide remote connectivity between the M2M device and the application-side servers. Many different network types can be used, and include both Wide Area Networks (WANs) and Local Area Networks (LANs), sometimes also referred to as Capillary Networks or M2M Area Networks. Examples of WANs are public cellular mobile networks, fixed private networks, or even satellite links.
- *M2M Service Enablement*. Within the generalized system solution outlined above, the concept of a separate service enablement component is also introduced. This component provides generic




A generic M2M system solution.

functionality that is common across a number of different applications. Its primary purpose is to reduce cost for implementation and ease of application development. As we will see later and in Chapter 6, the emergence of service enablement as a separate system component is a clear trend.

- *M2M Application*. The application component of the solution is a realization of the highly specific monitor and control process. The application is further integrated into the overall business process system of the enterprise. The process of remotely monitoring and controlling assets can be of many different types, for instance, remote car diagnostics or electricity meter data management.

***IoT***

The IoT is a widely used term for a set of technologies, systems, and design principles associated with the emerging wave of Internet-connected things that are based on the physical environment. In many respects, it can initially look the same as M2M communication connecting sensors and other devices to Information and Communication Technology (ICT) sys- tems via wired or wireless networks.

In contrast to M2M, however, IoT also refers to the connection of such systems and sensors to the broader Internet, as well as the use of general Internet technologies. In the longer term, it is envisaged that an IoT eco-system will emerge not dissimilar to today's Internet, allowing things and real world objects to connect, communicate, and interact with one another in the same way humans do via the web today. Increased understanding of the complexity of the systems in question, economies of scale, and methods for ensuring interoperability, in conjunction with key business drivers and governance structures across value chains, will create wide-scale adoption and deployment of IoT solutions. We cover this in more detail in Chapter 3.

No longer will the Internet be only about people, media, and content, but it will also include all real-world assets as intelligent creatures exchanging information, interacting with people, supporting business pro- cesses of enterprises, and creating knowledge (Figure 2.3). The IoT is not a new Internet, it is an extension to the existing Internet.

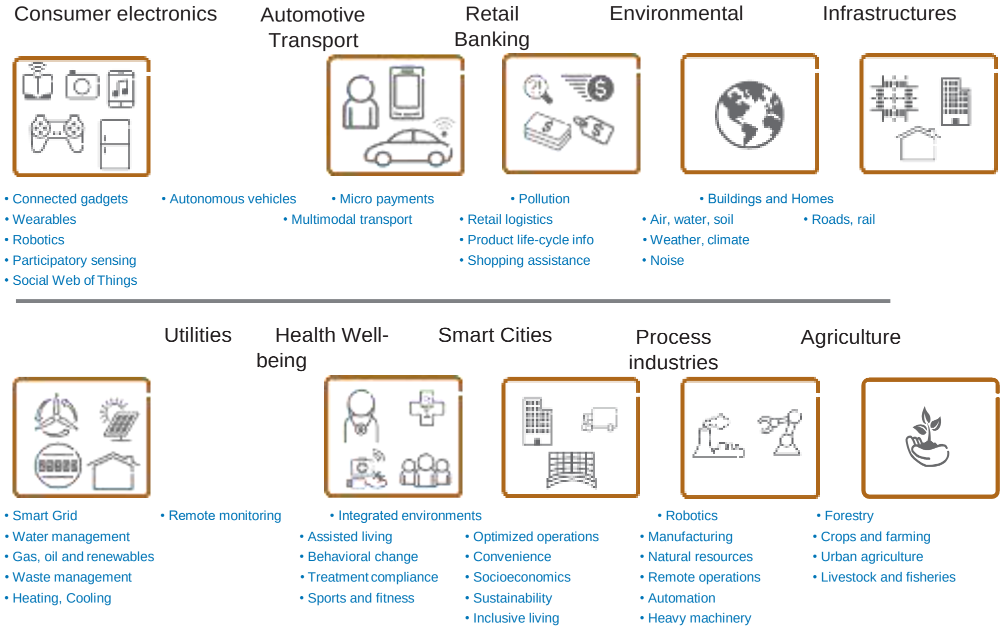
IoT is about the technology, the remote monitoring, and control, and also about where these technologies are applied. IoT can have a focus on the open innovative promises of the technologies at play, and also on advanced and complex processing inside very confined and close environments such as


When employing IoT technologies in more closed environments, an alternative interpretation of IoT could then be "Intranet of Things."

Visions put forward (e.g. SENSEI 2013) have included notions like a global open fabric of sensor and actuator services that integrate numerous Wireless Sensor Network (WSN) deployments and provide different levels of aggregated sensor and actuator services in an open manner for applica- tion innovation and for use in not only pure monitor and control type of applications, but also to augment or enrich other types of services with contextual information. IoT applications will not only rely on data and ser- vices from sensor and actuators alone. Equally important is the blend-in of other information sources that have relevance from the viewpoint of the physical world. These can be data from Geographic Information Systems (GIS) like road databases and weather forecasting systems, and can be of both a static nature and real-time nature. Even information extracted from social media like Twitter feeds or Facebook status updates that relate to real world observations can be fed into the same IoT system. An example is in the EU FP7 project (CityPulse 2013), and this is also further described in Chapter 15, which is on Participatory Sensing (PS).

Looking towards the applications and services in the IoT, we see that the application opportunities are open-ended, and only imagination will set the limit of what is achievable. Starting from typical M2M applications, one can see application domains emerging that are driven from very diverse needs from across industry, society, and people, and can be of both local interest and global interest. Applications can focus on safety, convenience, or cost reduction, optimizing business processes, or fulfilling various requirements on sustainability and assisted living. Listing all possi- ble application segments is futile, as is providing a ranking of the most important ones. We can point to examples of emerging application domains that are driven by different trends and interests (Figure 2.4). As can be seen, they are very diverse and can include applications like urban agriculture, robots and food safety tracing, and we will give brief explana- tions of what these three examples might look like.

Urban Agriculture. Already today, more than 50% of the world's pop- ulation lives in urban areas and cities. The increased attention on sustain- able living includes reducing transportation, and in the case of food production, reducing the needs for pesticides. The prospect of producing food at the place where it is consumed (i.e. in urban areas) is a promising



**M2M towards IoT — the global context**

M2M solutions have been around for decades and are quite common in many different scenarios. While the need to remotely monitor and control assets personal, enterprise or other is not new, a number of concurrent things are now converging to create drivers for change not just within the technology industry, but within the wider global economy and society. Our planet is facing massive challenges environmental, social, and economic. The changes that humanity needs to deal with in the coming dec- ades are unprecedented, not because similar things have not happened before during our common history on this planet, but because many of them are happening at the same time. From constraints on natural resources to a reconfiguration of the world's economy, many people are looking to technology to assist with these issues.

Essentially, therefore, a set of *megatrends* are combining to create *needs and capabilities*, which in turn produce a set of *IoT Technology and Business Drivers*. This is illustrated in Figure 2.5.

A megatrend is a pattern or trend that will have a fundamental and global impact on society at a macro level over several generations. It is something that will have a significant impact on the world in the foreseeable future. We here imply both game changers as challenges, as well as technology and science to meet these challenges. A full description of megatrends is beyond the scope of this book, and interested readers are directed to the many excellent books and reports available on this topic, including publications from the National Intelligence Council (NIC 2012), European Internet Foundation (EIF 2009), Frost & Sullivan (Singh 2012), and McKinsey (McKinsey 2013). In the following section, we focus on the megatrends that have implications for IoT.

***Game changers***

The game changers come from a set of social, economic, and environmen- tal shifts that create pressure for solutions to address issues and problems, but also opportunities to reformulate the manner in which our world faces them. There is an extremely strong emerging demand for monitoring, con- trolling, and understanding the physical world, and the game changers are working in conjunction with technological and scientific advances. The transition from M2M towards IoT is one of the key facets of the technol- ogy evolution required to face these challenges. We outline some of these more globally significant game changers below, and their relationship to IoT:

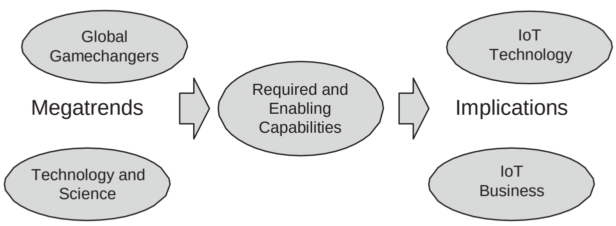


Table 2.1 A Summary of Megatrends, Capabilities, and IoT Implications

## Megatrends

### Global gamechangers

- Natural resource constraints
- Economic shifts
- Changing demographics
- Socioeconomic expectations
- Climate change
- Environmental impacts
- Safety and security
- Urbanization

### Technology and Science

- Information and Communication Technologies
- Material science
- Complex and advanced machinery
- Energy production and storage

## Capabilities

### Required capabilities

- Integrated infrastructures
- Asset-to-expert system integration
- Large scale monitor and control
- Autonomous operations
- Complex remote control
- Workforce offloading
- Domain expertise inside systems
- Visualization
- Data and service exposure
- Advanced analytics
- Increasing levels of security
- Cross value chain integration

### Enabling technologies

- Sensing and actuation
- Embedded computing
- Ubiquitous connectivity
- Data processing and storage
- Intelligent software
- Virtualization and cloud
- Application development

## Implications

### Technology

- Vertical to horizontal systems
- Application independent devices
- Technology consolidation
- IP and Web enabled
- Open software development
- Exposure APIs
- Software enabling architectures
- Cloud deployments
- Intelligence and automation

### Busi nes s

- Open and innovation driven
- Cloud and as-a-Service delivered
- B2B2C
- Service oriented
- Developer community reach
- Long tail empowerment
- Marketplaces of data and services
- New market roles/value systems
- Cross domain integration

• Natural Resource Constraints. The world needs to increasingly do more with less, from raw materials to energy, water or food, the growing global population and associated economic growth demands put increasing constraints on the use of resources. The use of IoT to increase yields, improve productivity, and decrease loss across global supply chains is therefore escalating.
• Economic Shifts. The overall economy is in a state of flux as it moves from the post-industrial era to a digital economy. One example of this is found in the move from product-oriented to service-oriented economies. This implies a lifetime responsibility of the product used in the service offering, and will in many cases require the products to be connected and contain embedded technologies for gathering data and information. At the same time, there are fluctuations in global economic leadership. Economies across the globe must handle the evolving nature of these forces. As technology becomes increasingly embedded and more tasks automated, countries need to manage this shift and ensure that M2M and IoT also create new jobs and industries.
• Changing Demographics. With increased prosperity, there will be a shift in the demographic structures around the world. Many countries will need to deal with an aging population without increasing economic expenditure. As a result, IoT will need to be used, for example, to help provide assisted living and reduce costs in healthcare and emerging "wellcare" systems.
• Socioeconomic Expectations. The global emerging middle class results in increasing expectations on well-being and Corporate Social Responsibility. Lifestyle and convenience will be increasingly enabled by technology as the same disruption and efficiency practices evident in industries will be applied within people's lives and homes as well.
• Climate Change and Environmental Impacts. The impact of human activities on the environment and climate has been long debated, but is now in essence scientifically proven. Technology, including IoT, will need to be applied to aggressively reduce the impact of human activity on the earth's systems.
• Safety and Security. Public safety and national security becomes more urgent as society becomes more advanced, but also more vulnerable. This has to do both with reducing fatalities and health as well as crime prevention, and different technologies can address a number of the issues at hand.

• Urbanization. We see the dramatic increase in urban populations and discussions about megacities. Urbanization creates an entirely new level of demands on city infrastructures in order to support increasing urban populations. IoT technologies will play a central role in the optimization for citizens and enterprises within the urban realm, as well as providing increased support for decision-makers in cities.

***Barriers and concerns***

With the explained transformations in moving from M2M towards IoT, which involves many opportunities, we should not forget that some new concerns and barriers will also be raised.

With the IoT, the first concern that likely comes to mind is the com- promise of privacy and the protection of personal integrity. The use of RFID tags for tracing people is a raised concern. With a massive deploy- ment of sensors in various environments, including in smartphones, explicit data and information about people can be collected, and using analytics tools, users could potentially be profiled and identified even from anonymized data.

The reliability and accuracy of data and information when relying on a large number of data sources that can come from different providers that are beyond one's own control is another concern. Concepts like Provenance of Data and Quality of Information (QoI) become important, especially considering aggregation of data and analytics. As there is a risk of relying on inaccurate or even faulty information in a decision process, the issue of accountability, and even liability, becomes an interest. This will require new technology tools; an example effort includes the work on QoI related to both sensor data and actuation services in the EU FP7 project SENSEI (SENSEI 2013).

As has already been mentioned, the topic of security has one added dimension or level of concern. Not only are today's economical or social damages possible on the Internet, but with real assets connected and control- lable over the Internet, damage of property as well as people's safety and even lives become an issue, and one can talk about cyber-physical security.

Not a concern, but a perceived barrier for large-scale adoption of IoT is in costs for massive deployment of IoT devices and embedded technolo- gies. This is not only a matter of Capital Expenditure (CAPEX), but likely more importantly a matter of Operational Expenditure (OPEX). From a technical perspective, what is desired is a high degree of automated provi- sioning towards zero-configuration. Not only does this involve configura- tion of system parameters and data, but also contextual information such as location (e.g. based on Geographic Information System (GIS) coordi- nates or room/building information).

These different concerns and barriers have consequences not only on finding technical solutions, but are more importantly having consequences also on business and socioeconomic aspects as well as on legislation and regulation.

**A use case example**

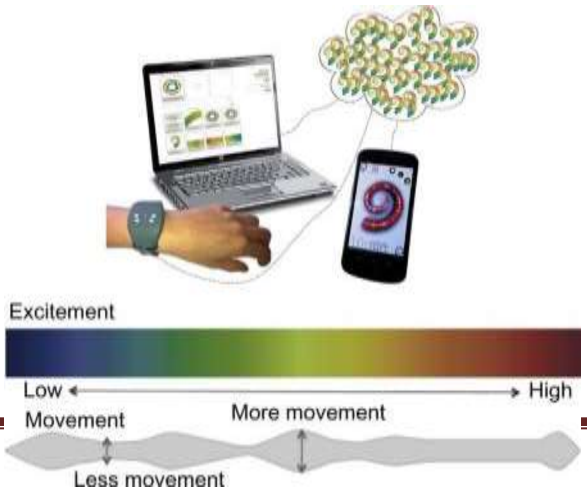
In order to understand how a specific problem can be addressed with M2M and IoT, respectively, we provide a fictitious illustrative example. Our example takes two different approaches towards the solution, namely an M2M approach and an IoT approach. By that, we want to highlight the potential and benefits of an IoT-oriented approach over M2M, but also indicate some key capabilities that will be required going beyond what can be achieved with M2M. Our example is taken from personal well-being and health care.

Studies from the U.S. Department of Health and Human Services have shown that close to 50% of the health risks of the enterprise workforce are stress related, and that stress was the single highest risk contributor in a group of factors that also included such risks as high cholesterol, over- weight issues, and high alcohol consumption. As stress can be a root cause for many direct negative health conditions, there are big potential savings in human quality of life, as well as national costs and productivity losses, if the factors contributing to stress can be identified and the right preven- tive measures taken. By performing the steps of stressor diagnosis, stress reliever recommendations, logging and measuring the impacts of stress relievers for making a stress assessment, all in an iterative approach, there is an opportunity to significantly reduce the negative effects of stress.

Measuring human stress can be done using sensors. Two common stress measurements are heart rate and galvanic skin response (GSR), and there are products on the market in the form of bracelets that can do such measurements. These sensors can only provide the intensity of the heart rate and GSR, and do not provide an answer to the cause of the intensity. A higher intensity can be the cause of stress, but can also be due to exer- cise. In order to analyze whether the stress is positive or negative, more information is needed.

The typical M2M solution would be based on getting sensor input from the person by equipping him or her with the appropriate device, in our case the aforementioned bracelet, and using a smartphone as a mobile gateway to send measurements to an application server hosted by a health service provider. In addition to the heart rate and GSR measurements, an accelerometer in the smartphone measures the movement of the person, thus providing the ability to correlate any physical activity to the excite- ment measurements. The application server hosts the necessary functional- ity to analyze the collected data, and based on experience and domain knowledge, provides an indication of the stress level. The stress informa- tion can then be made available to the person or a caregiver via smart- phone application or a web interface on a computer. The M2M system solution and measured data is depicted in Figure.

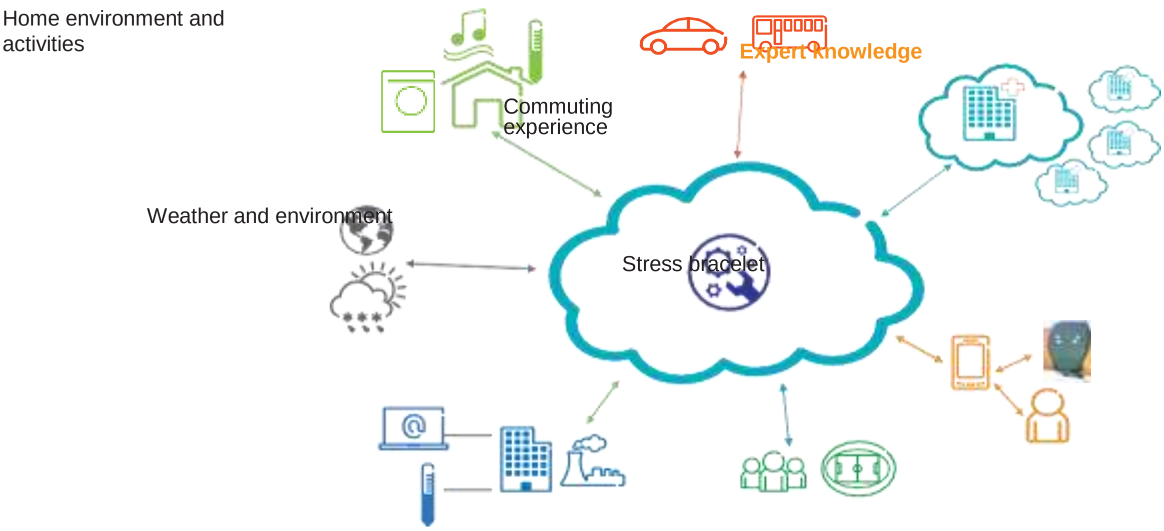
As already pointed out, this type of solution that is limited to a few measurement modalities can only provide very limited (if any) information about what actually causes the stress or excitement. Causes of stress in



Stress measurement M2M solution.

daily life, such as family situation, work situation, and other activities can- not be identified. A combination of the stress measurement log over time, and a caregiver interviewing the person about any specific events at high levels of measured stress, could provide more insights, but this is a costly, labor-intensive, and subjective method. If additional contextual informa- tion could be added to the analysis process, a much more accurate stress situation analysis could potentially be performed.

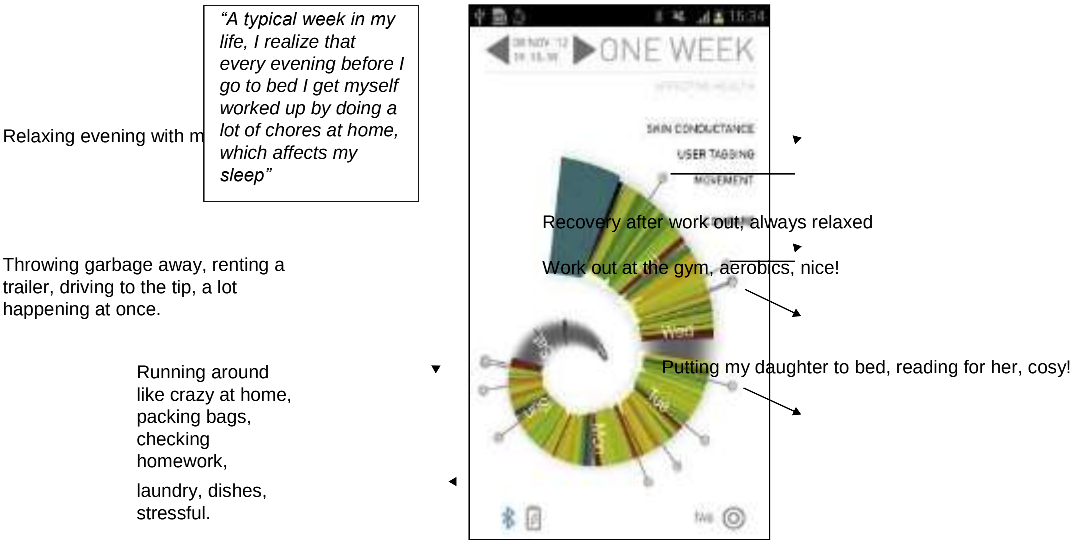
Approaching the same problem situation from an IoT perspective would be to add data that provide much deeper and richer information of the person's contextual situation. The prospect is that the more data is available, the more data can be analyzed and correlated in order to find patterns and dependencies. What is then required is to capture as much data about the daily activities and environment of the person as possible. The data sources of relevance are of many different types, and can be openly available information as well as highly personal information. The resulting IoT solution is shown in Figure, where we see examples of a wide variety of data sources that have an impact on the personal situation. Depicted is also the importance of having expert domain knowledge that can mine the available information, and that can also provide proposed actions to avoid stressful situations or environments.



The environmental aspects include the physical properties of the spe- cific environment, and can be air quality and noise levels of the work environment, or the nighttime temperature of the bedroom, all having impacts on the person's well-being. Work activities can include the amount of e-mails in the inbox or calendar appointments, all potentially having a negative impact on stress. Leisure activities, on the other hand, can have a very positive impact on the level of excitement and stress, and can have a more healing effect than a negative effect. Such different nega- tive and positive factors need to be separated and filtered out; see Figure for an example smartphone application that provides stress analysis feedback.

The stress bracelet is in this scenario is just one component out of many. It should also be noted that the actual information sources are very independent of the actual application in mind (i.e. measurement and pre- vention of negative stress).

By having the appropriate expert knowledge system in place, analytics can be proactive and preventive. By understanding what factors cause neg- ative stress, the system can propose actions to be taken, or even initiate actions automatically. They could be very elementary, such as suggesting to lower the nighttime bedroom temperature a few degrees, but also be more complex, such as having to deal with an entire workplace environment.




Stress analysis visualization.

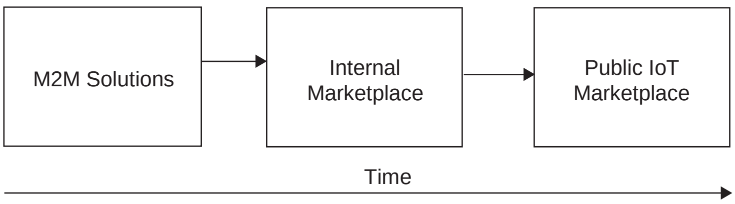
# UNIT-2
# M2M to IoT: A Market Perspective

***Information marketplaces***

A key aspect to note between M2M and IoT is that the technology used for these solutions may be very similar they may even use the same base components but the manner in which the data is managed will be different. In an M2M solution, data remains within strict boundaries it is used solely for the purpose that it was originally developed for. With IoT, however, data may be used and reused for many different purposes, perhaps beyond the original intended design, thanks to web-based technol- ogies. As discussed in Chapter 2, M2M solutions will evolve to be able to share greater data with each other and across value chains or informa- tion marketplaces. Data can be shared between companies and value chains in internal information marketplaces. Alternatively, data could be publicly exchanged on a public information marketplace. These market- places are based on the exchange of data in order to create information products. This is discussed in more detail in Section 3.1.

While public information marketplaces are generally the vision around IoT, in particular for Smart Cities as discussed in Chapter 14, it is unlikely such marketplaces will become commonplace before trust, risk, security, and insurance for data exchanges are able to be fully managed appropriately.

In the following sections, we therefore focus on the business drivers for delivering M2M solutions and marketplaces that span multiple value chains, rather than publicly traded IoT marketplaces.




From M2M to IoT — A Marketplace Perspective.

***Global value chains***

A value chain describes the full range of activities that firms and workers perform to bring a product from its conception to end use and beyond, including design, production, marketing, distribution, and support to the final consumer (Gereffi 2011). A simplified value chain is illustrated in Figure 3.2; it is comprised of five separate activities that work together to create a finalized product.

These activities may be contained within a single firm or divided among different firms (Global Value Chains 2011). Analyzing an industry from a global value chain (GVC) perspective permits understanding of the context of globalization on the activities contained within them by "focus- ing on the sequences of tangible and intangible value-adding activities, from conception and production to end use. GVC analysis therefore pro- vides a holistic view of global industries both from the top down and from the bottom up" (Gereffi 2011).

Within the context of the technology industries, GVC analysis is partic- ularly useful as such an analysis can help identify the boundaries between existing industrial structures such as M2M solutions and emerging indus- trial structures, as seen within the IoT market.

***Ecosystems vs. value chains***

Business Ecosystems, defined by James Moore (Moore 1996), refer to "an economic community supported by a foundation of interacting organiza- tions and individuals .. . The economic community produces goods and services of value to customers, who are themselves members of the ecosystem.


A simplified global value chain.

The member organisms also include suppliers, lead producers, competitors, and other stakeholders. Over time, they co-evolve their capa- bilities and roles, and tend to align themselves with the directions set by one or more central companies. Those companies holding leadership roles may change over time, but the community values the function of ecosys- tem leader because it enables members to move toward shared visions to align their investments, and to find mutually supportive roles."

Many people discuss the IoT market as an "ecosystem," with multiple companies establishing loose relationships with one another that then may "piggy back" on larger companies in the ecosystem to deliver products and services to end-users and customers.

While this is a useful description to begin with, a value chain is associ- ated with the creation of value it is the instantiation of exchange by a certain set of companies *within* an ecosystem. This is an important distinc- tion when we are talking about market creation. A value chain is a useful model to explain how markets create value and how they evolve over time. While a market space composed of only competing value chains will eventually see the overall market value decrease (as they will compete only on price), in an ecosystem, the value chains will complement one another.

***Industrial structure***

Industrial structure refers to the procedures and associations within a given industrial sector. It is the structure that is purposed towards the achievement of the goals of a particular industry. This is one of the key differences between the M2M and IoT markets how the industrial structures will be formed around these solutions, despite very similar technology implementations. This is covered in more detail in the following sections.

**M2M value chains**

As discussed in Chapter 2, the significant majority of M2M applications have and will be in the near future developed for some form of busi- ness process optimization. As a result, the majority of organizations will first take an inward-looking approach to business drivers and the reasoning behind why they will implement such solutions. Reasons for using M2M vary from project to project and company to company, but can include things such as cost reductions through streamlined business processes, product quality improvements, and increased health and safety protection for employees. These solutions are generally all internal to a company's business processes and do not included extensive interactions with other parties. Referring back to Figure, let's take a look at the inputs and outputs of an M2M value chain.

Inputs: Inputs are the base raw ingredients that are turned into a prod- uct. Examples could be cocoa beans for the manufacture of chocolate or data from an M2M device that will be turned into a piece of information.

Production/Manufacture: Production/Manufacture refers to the pro- cess that the raw inputs are put through to become part of a value chain. For example, cocoa beans may be dried and separated before being trans- ported to overseas markets. Data from an M2M solution, meanwhile, needs to be verified and tagged for provenance.

Processing: Processing refers to the process whereby a product is prepared for sale. For example, cocoa beans may now be made into cocoa powder, ready for use in chocolate bars. For an M2M solution, this refers to the aggregation of multiple data sources to create an information component something that is ready to be combined with other data sets to make it useful for corporate decision-making.

Packaging: Packaging refers to the process whereby a product can be branded as would be recognizable to end-user consumers. For example, a chocolate bar would now be ready to eat and have a red wrapper with the words "KitKatt" on it. For M2M solutions, the data will have to be combined with other information from internal corporate databases, for example, to see whether the data received requires any action. This data would be recognizable to the end-users that need to use the information, either in the form of visualizations or an Excel spreadsheet.

Distribution/Marketing: This process refers to the channels to market for products. For example, a chocolate bar may be sold at a supermarket, a kiosk, or even online. An M2M solution, however, will have produced an Information Product that can be used to create new knowledge within a corporate environment examples include more detailed scheduling of maintenance based on real-world information or improved product design due to feedback from the M2M solution.

**IoT value chains**

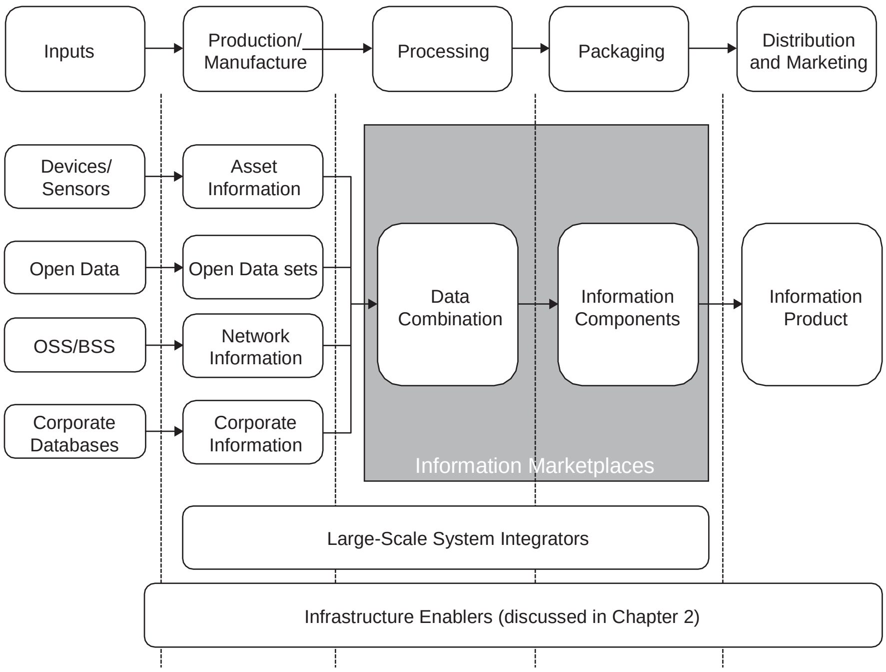
Meanwhile, the move towards IoT from a value creation perspective comes with the desire to make some of the data from sensors publicly available as part of an "information marketplace" or other data exchange that allows the data to be used by a broader range of actors rather than just the company that the system was originally designed for. It should be noted that such a marketplace could still be internal to a company or strictly protected between the value chains of several companies. Another alternative is a public marketplace, where data may be treated as a deriva- tive, but such public trading of data is probably a long way from real-world market realization in 2013.

IoT value chains based on data are to some extent enabled by Open APIs and the other open web-based technologies discussed in Chapter 2. Open APIs allow for the knowledge contained within different technical systems to become *unembedded*, creating the possibility for many different economic entities to combine and share their data as long as they have a well-defined interface and description of how the data is formatted. Open APIs in conjunction with the Internet technologies described in Chapter 2 mean that *knowledge is no longer tied to one digital system*. The cognitive and conceptual human skills that were first embedded in semiconductors during the 1950s and 1960s are now decoupled from the specific techno- logical system that was developed to house them. It is this decoupling of technology systems that allows for the creation of information market- places. This can initially make the value chain of an IoT solution look sig- nificantly more complex than one for a traditional product such as chocolate, but the principles remain the same.

Let's take a closer look at a possible IoT value chain, including an Information Marketplace, illustrated in Figure.

Inputs: The first thing that is apparent for an IoT value chain is that there are significantly more inputs than for an M2M solution. In Figure, four are illustrated:

- Devices/Sensors: these are very similar to the M2M solution devices and sensors, and may in fact be built on the same technology. As we will see later, however, the manner in which the data from these devices and sensors is used provides a different and much broader marketplace than M2M does.
- Open Data: Open data is an increasingly important input to Information Value Chains. A broad definition of open data defines it as: "A piece of data is open if anyone is free to use, reuse, and redistribute it — subject




An Information-Driven Value Chain for IoT.

only, at most, to the requirement to attribute and/or share-alike" (Open Definition 2013). Within the context of this book, we refer to open data as those provided by government and city organizations. Examples include city maps, provided by organizations such as Ordinance Survey in the United Kingdom. Open data requires a license stating that it is open data.

- OSS/BSS: The Operational Support Systems and Business Support Systems of mobile operator networks are also important inputs to information value chains, and are being used increasingly in tightly closed information marketplaces that allow operators to deliver services to enterprises for example, where phone usage data is already owned by the company in question.
- Corporate Databases: Companies of a certain size generally have multiple corporate databases covering various functions, including supply chain management, payroll, accounting, etc. . . . Over the last decades, many of these databases within corporations have been increasingly interconnected using Internet Protocol (IP) technologies.

As the use of devices and sensors increases, these databases will be connected to this data to create new information sources and new knowledge.

Production/Manufacture: In the production and manufacturing pro- cesses for data in an IoT solution, the raw inputs described above will undergo initial development into information components and products. Irrespective of input type described above, this process will need to include tagging and linking of relevant data items in order to provide prov- enance and traceability across the information value chain. Some exam- ples, as illustrated in Figure 3.3, are as follows:

- Asset Information: Asset information may include data such as temperature over time of container during transit or air quality during a particular month. Essentially, this relates to whatever the sensor/device has been developed to monitor.
- Open Data Sets: Open data sets may include maps, rail timetables, or demographics about a certain area in a country or city.
- Network Information: Network information relates to information such as GPS data, services accessed via the mobile network, etc. .. .
- Corporate Information: Corporate information may be, for example, the current state of demand for a particular product in the supply chain at a particular moment in time.

Processing: During the processing stage, data from various sources is mixed together. At this point, the data from the various inputs from the production and manufacture stage are combined together to create infor- mation. This process involves the extensive use of data analytics for M2M and IoT solutions and is described in more detail in Chapter 5.

Packaging: After the data from various inputs has been combined together, the packaging section of the information value chain creates information components. These components could be produced as charts or other traditional methods of communicating information to end-users. In addition, however, they could be fed into knowledge management fra- meworks (discussed in Chapter 5) in order to create not just visualizations of existing information, but to create new knowledge for the enterprise in question.

Both the processing and packaging sections of the Information-Driven Global Value Chain (I-GVC) are where Information Marketplaces will be developed. At this point, data sets with appropriate data tagging and trace- ability could be exchanged with other economic actors for feeding into their own information product development processes. Alternatively, a company may instead select to exchange information components, which represent a higher level of data abstraction of their corporate information.

Distribution/Marketing: The final stage of the Information Value Chain is the creation of an Information Product. A broad variety of such products may exist, but they fall into two main categories:

- Information products for improving internal decision-making: These information products are the result of either detailed information analysis that allows better decisions to be made during various internal corporate processes, or they enable the creation of previously unavailable knowledge about a company's products, strategy, or internal processes.
- Information products for resale to other economic actors: These information products have high value for other economic actors and can be sold to them. For example, through an IoT solution, a company may have market information about a certain area of town that another entity might pay for (e.g. a real-estate company).

In the following section, we investigate what roles different economic actors will take in the industrial structure for IoT.

**An emerging industrial structure for IoT**

Where the technologies of the industrial revolution integrated physical components together much more rapidly, M2M and IoT are about rapidly integrating data and workflows that form the basis of the global economy at increasing speed and precision.

In contrast to fixed broadband technologies, which are limited to imple- mentation in households mainly in the developed world, mobile places consumer electronic goods into the hands of over 4 billion end-users across the globe, and connects billions of new devices into the mobile broadband platform. Concepts such as cloud computing, meanwhile, have the ability to provide low cost access to computational capacity for these billions of end-users via these mobile devices. Combined, these two tech- nologies create a platform that will rapidly redefine the global economy. A new form of value chain is actually emerging as a result one driven by the creation of information, rather than physical products.

The adoption of the mobile broadband platform is therefore different from previous incarnations of Information and Communication Technology (ICT) industrial platforms as it reshapes not just how economic actors within a value chain interact with one another, but also with employees and the wider economic environment in a similar manner to the technology of the industrial revolution. More importantly perhaps, it changes fundamentally the manner in which *individuals* interact with economic actors in a digital world.

As mentioned in Unit-1, the need for System Integrators in the communications industries has increased over the decades. With each generation of platform, a new type of system integrator has emerged. For IoT, however, new sets of system integrator capacity are required for two main reasons:

- Technical: The factors driving the technical revolution of these industries means that the complexity of the devices in question require massive amounts of R&D; as do semiconductors with large amounts of functionality built into the silicon. Services will require multiple devices, sensors, and actuators from suppliers to be integrated and exposed to developers. Only those companies with sufficient scale to understand the huge number of technologies well enough to integrate them fully on behalf of a customer can handle this technical complexity. While niche integrators will continue to exist, full solutions will be integrated and managed by large companies, or partnerships between vendors.
- Financial: Only those companies that are able to capture the added value created in the emerging industrial structure will recoup enough money to re-invest in the R&D required to participate in the systems integration market. It is highly likely that the participants that do not capture part of the integration market will be relegated to "lower" ends of the value chain, producing components as input for other system integrators.

There is in fact a new type of value chain emerging one where the data gathered from sensors and radio frequency identification (RFID) is combined with information from smartphones that directly identifies a specific individual, their activities, their purchases, and preferred method of communication. This information can be combined in any number of ways to create tailored services of direct relevance to the individual or cor- poration in question. Search queries can be localized based on where a person is, and advertising can be targeted directly to the end-user in ques- tion based on personalized information about their age, level of education, employment, and tastes. While it is perhaps questionable whether the world really needs new methods to advertise goods and services, beneath this development lies a fundamental change in some aspects of the global economy.

Firstly, information about individuals is now captured, stored, processed, and *reused* across many different systems that sit on top of the mobile broadband platform. This data has always existed, but with the increasingly low cost of computing capacity in the form of cloud computing platforms, it is now cheap enough to store this data for an extremely long length of time. It is now possible, therefore, for information about individuals and digital systems to be packaged, bundled, and *exchanged* between economic entities with an ease that has previously been impossible. Value is no longer solely measured through "value-in-use" or "value-in-exchange," but there is now also a "value-in-reuse," specifically because the commodity, data, is not consumed within the processes of pro- duction as with previous generations of commodity creation.

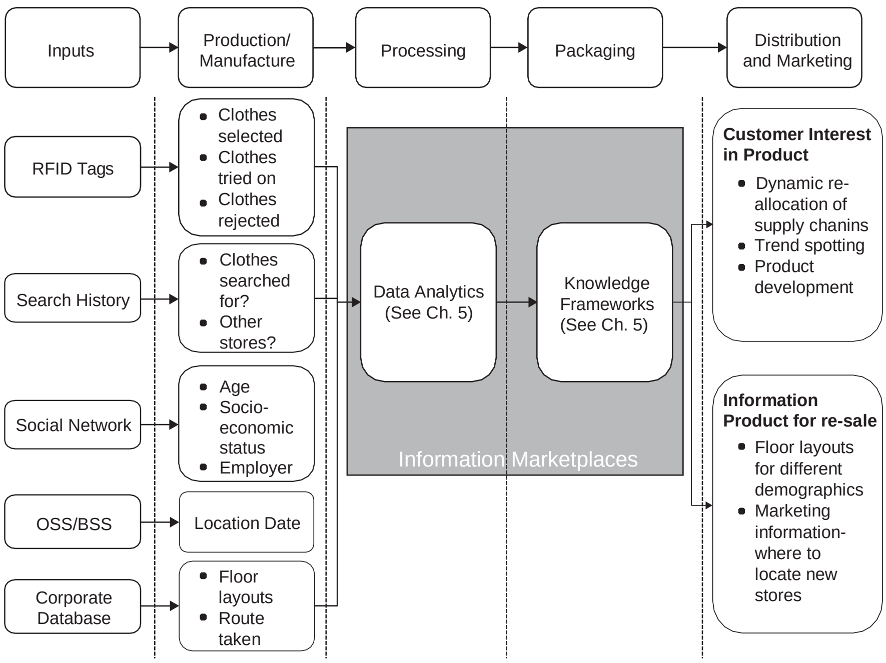
Actors that perform this data collection, storage, and processing are forming the basis of what may be viewed as an *Information-Driven Global Value Chain (I-GVC)*, a value chain where the product is information itself.

As an example, a difference in value can be identified in knowing my location when I step off a train in a new city and am looking for a decent cup of coffee. I may choose to activate my smartphone and perform a localized search using my phone's GPS and browser features. Alternatively, I may be happy enough to just walk around until I find a place that I think looks OK. In this case, the value that I as an individual place on my phone knowing my location and assisting me to find a local coffee store is relatively low personally, I might not value this very highly.

In comparison, however, there is a great deal of value for a coffee com- pany to know that a few hundred women have stepped off a train in search of an espresso. A coffee shop chain would know that it is potentially quite profitable to open a new store there. In addition, understanding the age group of those women, their level of education, and their general tastes would allow the chain to tailor the coffee store to their target market with much greater precision.

Similarly, if I was in a clothing store searching for a new outfit for work, through a combination of information about myself and the RFID tags on the different clothes, I could be guided to the correct clothing selection for my age group, my education level, and also my current employer. Information about what path I take through the store during my search for the clothes could be fed back into an information system that would allow the store to reorganize their floor layouts more effectively, track the clothes that I was interested in, and those which I actually select to try on and purchase. This information can be used to streamline the sup- ply chains of corporations even further than is possible today, and repre- sents the next phase of the impact of communication technologies on the boundaries of the firm within the global economy: companies that share this type of information would be more deeply embedded in one another's workflows, leading to highly concatenated supply chains and a further blurring of the boundaries of the firm within the digital economy. This is illustrated in Figure.

This streamlining could also be extended into the processes of produc- tion, changing orders based on consumer interest in products, and not just their purchasing patterns. This would result in less wasted stock and a much closer understanding of seasonal trends and an increased level of control for those companies working as system integrators. The integration of these data streams allows for concatenation of supply chains not just internally to one company, therefore, but *across industrial boundaries* (Mulligan 2011).




An Information-Driven Value Chain for Retail.

The level of analysis described above requires *aggregation* of data from many different people and its collation into an *information product*, one that may be used as input into corporate and end-user decision-making processes.

While there is obviously a strong link between the I-GVC and physical goods, it is therefore clear that there is an information product in and of itself, one that relates to the development of aggregation databases that collect data from both sensors and people. Moreover, while the informa- tion product is useful to the companies in question, it is not part of their core business to create it. As a result, they look to other actors to develop and create these products for them, which is further driving the creation of a new industrial structure around ICT systems that include IoT and cloud technologies.

The second change in the nature of the economy is the fundamental embedding of human beings into the very foundation of these technology platforms. The most obvious example of this is Google's search engine, which is improved with every search query that is performed using it. Every search that every individual makes is tracked, and every click some- one makes through Google's products is recorded and used to refine the algorithms that form the basis of the platform. Without the humans input- ting their searches into the Google platform, it quite simply would not exist in the form that it does today.

The broad-scale consumerization of technology, combined with the cheap means of "information production" due to cloud computing, has led to information management systems that are now being developed for end-user consumers, not just enterprises. Social networks such as Facebook and LinkedIn, and content sharing sites such as YouTube or Blogger, allow end-users to store information about their lives in a manner previously not possible. Consumers now store their photos, their contact lists, videos, documents, and financial data online. Ostensibly, this is pro- vided for "free;" end-users receive access to the websites merely through creating an account, logging in, and uploading their data.

Within the capitalist economy, however, no service is ever really free. Companies must pay for the costs of computing resources, even those that are housed in the cloud. While the cost to end-users appears to be zero, they are in fact being charged on a daily basis through the use of their pro- file data for targeted advertising. In the early days of social networks, for example, this targeted advertising was no worse than the "traditional" direct advertising methods: based on the data provided by the end-user, they would receive an age-appropriate advertisement for their demographic.

With the mobile broadband platform, however, the level of data that can be gathered about end-users is orders of magnitude larger than previously imaginable. My location, level of education, employment status, health records, tax data, credit rating, purchasing patterns, search history, social networks (both private and professional), relationship status, even how often I call my mother are recorded, stored, and *interconnected* in a vast array of disparate systems that are now linked together through the platform of a converged communications industry.

With the addition of new levels of data that it is possible to retrieve about individuals through mobile devices and sensor networks, the emerg- ing ICT platforms are forcing a redefinition of our established understand- ings of the notion of value both within the communications industries and even beyond these industrial boundaries to all companies and individuals that use these platforms on a daily basis (Mulligan 2011).

***The information-driven global value chain***

There are five fundamental roles within the I-GVC that companies and other actors are forming around, illustrated in Figure 3.5:

- Inputs:
- Sensors, RFID, and other devices.
- End-Users.
- Data Factories.
- Service Providers/Data Wholesalers.
- Intermediaries.
- Resellers.

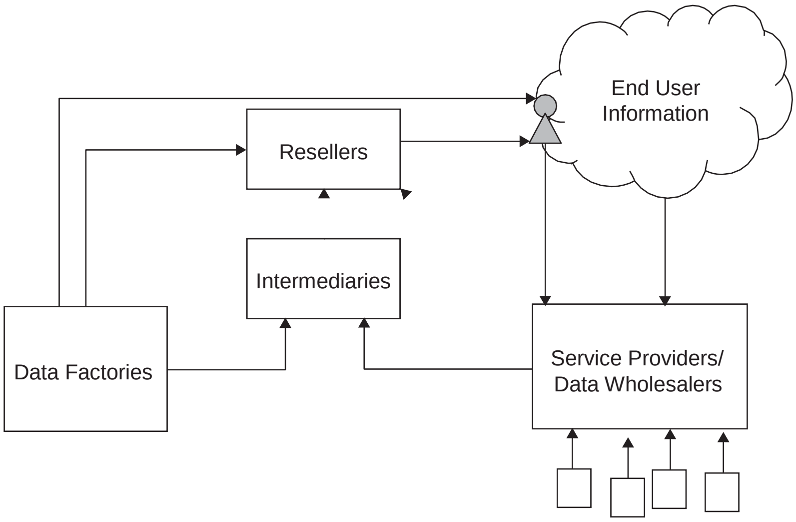
*Inputs to the information-driven global commodity chain*

There are two main inputs into the I-GVC:

1. Sensors and other devices (e.g. RFID and NFC).
2. End-users.

Both of these information sources input tiny amounts of data into the I-GVC chain, which are then aggregated, analyzed, repackaged, and exchanged between the different economic actors that form the value chain.

As a result, sensor devices and networks, RFIDs, mobile and consumer devices, Wi-Fi hotspots, and end-users all form part of a network of



“subcontractors” in the value chain, all contributing to the increased value of the information products.

### Sensors and radio frequency identification

Sensors and RFID are already found in a multitude of different applica- tions worldwide (as discussed in Chapter 2), helping to smooth supply and demand in various supply chains worldwide and gathering climate and other localized data that is then transmitted back to a centralized informa- tion processing system. These devices are working as inputs to the I-GVC through the capture and transmission of data necessary for the develop- ment of information products.

Smartphones have also been developed that allow mobile devices to interact with sensors and RFID. This allows for a two-way interaction between a mobile terminal and the sensor technology. The data exchanged between the actuator and a mobile terminal may not be readily understood or even useful for the device in question. The data, however, is used as one part of the input to the commodity chain, which uses it to create the infor- mation products that are eventually exchanged. In this sense, the sensor net- works, and NFC and RFID technologies may be viewed as subcontractors to the I-GVC, workers that constantly gather data for further processing and sale.

### End-users

The second main inputs to the I-GVC are the end-users. Due to the con- vergence of the computing and mobile broadband platforms, end-users are no longer passive participants in the digital economy, with a role only to purchase those physical products that companies develop and market to them. End-users that choose to use and participate within the digital world are now deeply embedded into the very process of production. Every human that enters a search query into a search engine, every human that agrees to allow the mobile broadband platform to inform a service of their location, every human that uses NFC to allow a bank to establish and con- firm their identity are also functioning as subcontractors to the global information systems that form the basis of the I-GVC. In fact, the creation of the I-GVC would not be possible without the contribution of many mil- lions of individuals *worldwide*. This is perhaps the most unique aspect of the I-GVC there is no national boundary for the contribution of humans to the I-GVC, the data about individuals can be collected from any person in any language, in almost any data format. Each individual’s data can be treated as unique within this value chain; in fact, it is the ability to capture the uniqueness of every person that is a key aspect of the I-GVC in com- parison to the other commodity chains that are at work within the global economy. Every person worldwide that has to use digital technologies to do their banking, their taxes, their information searches, and to communi- cate with friends and colleagues, are constantly working on behalf of the I-GVC, contributing their individual profile data and knowledge to the value chain. In the same manner as the actuators constantly gather local- ized data, humans are now contributing to the development of information products within the I-GVC nearly 24 hours a day.

## *Production processes of the information-driven global value chain*

### Data factories

Data factories are those entities that produce data in digital forms for use in other parts of the I-GVC. Many of these companies existed in the pre- digital era; for example, Ordnance Survey (OS) in the UK has always col- lected map information from the field, and collated and produced maps for purchase. Previously, such data factories would create paper-based pro- ducts and sell them to end-users via retailers. With the move to the digital era, however, these companies now also provide this data via digital means; for example, OS now makes maps and associated data available in digital format. Essentially, its business model has not changed significantly

it still produces maps but its means of delivery of products has changed. Moreover, its products can now be combined, reused, and bundled together with other products by actors in the commodity chain as the foundation of other services. For example, maps from OS can be combined with other data from travel services such as TFL to provide detailed travel applications on mobile devices.

A more complex example is Sveriges Meterologiska och Hydrologiska Institut (SMHI), which provides weather and climate data throughout Sweden. SMHI has a large number of weather stations across Sweden through which it collects weather and environmental information. In addi- tion, it purchases its data from Yr.no, its Norwegian equivalent. SMHI therefore produces raw data, but it also processes the data, and bundles it in different ways based on customer requests and requirements. SMHI functions not only as a data factory, therefore, but also a *reseller*, which is described separately below.

### Service providers/data wholesalers

Service Providers and Data wholesalers are those entities that collect data from various sources worldwide, and through the creation of mas- sive databases, use it to either improve their own information products or sell information products in various forms. Many examples exist; several well-known ones are Twitter, Facebook, Google, etc… . Google "sells" its data assets through the development of extremely accurate, targeted, search-based advertising mechanisms that it is able to sell to companies wishing to reach a particular market. Twitter, meanwhile, through collating streams of "Tweets" from people worldwide, is able to collate customer sentiment about different products and world events, from service at a restaurant to election processes across the globe; through what Twitter refers to as a "data hose," companies and developers can access 50% of end-user Tweets for $360,000 USD per annum.

A new set of data wholesalers is starting to emerge, however: those companies that handle the massive amount of data that is produced by sen- sor networks and mobile devices worldwide. These companies are collat- ing those transactions that are made by the millions of devices worldwide that utilize communications networks to transmit data. The sheer quantity of data that is being transmitted via actuators and mobile devices will be orders of magnitude higher than previously imagined within the supply chains of multinational companies alone.

### Intermediaries

In the emerging industrial structure of the I-GVC, there is a need for intermediaries that handle several aspects of the production of information products. As mentioned above, there are many privacy and regional issues associated with the collection of personal information. In Europe, the man- ner in which Facebook collects and uses the data of the individuals that participate in its service may actually be in contravention of European pri- vacy law. The development of databases such as the ones created by Google, Facebook, and Twitter may therefore require the creation of enti- ties that are able to "anonymise" data sufficiently to protect individuals' privacy rights in relevant regional settings. These corporations will provide protection for the consumer that their data is being used in an appropriate manner, i.e. the manner in which the consumer has approved its usage. For example, I may happily share my personalized information about my tastes with a clothing company or music store in order to receive better service, while I may not be happy for my credit rating or tax data to be shared freely with different companies. I would therefore allow an inter- mediary to act on my behalf, tagging the relevant information in some form to ensure that it was not used in a manner that I had not previously agreed to.

Another reason for an intermediary of this nature is to reduce transac- tion costs associated with the establishment of a market for many different companies to participate in. As an example, Jasper Wireless acts as an intermediary for the M2M market described in Chapter 3. Through provid- ing a connection point for several different parties in the M2M industry, it acts to expand the uptake of M2M technology.

As discussed in the previous section on service providers/data wholesa- lers, the amount of data that is being produced is also problematic even with cloud computing, it is difficult to process the amounts of data pro- duced in the I-GVC. The different types of information products that are to be produced are only of interest to certain types of companies for exam- ple the marketing division of a company may be interested to understand customer sentiment about a particular product within a certain age group. Another company may want to understand what searches are being per- formed in their local area, while a local authority may wish to use sensor data to obtain real-time data about pollution from local factories. The type of data and style of analysis for each of these information products is fundamentally different, and each requires unique skills it is highly improbable that one company will be able to handle all of these types of data in one place. It is therefore more likely that different companies, intermediaries, will develop that target their information products to different niche markets. These companies will be able to focus on certain datasets and become specialists within that particular information product field.

The quantity and nature of data being developed into information pro- ducts also requires a completely new type of intermediary, one that is able to handle the scalability issues and the associated security and privacy ques- tions raised by the use of this data to build products. This is perhaps the most obvious role for operators and network vendors with global services operations to take, as they have many decades of experiences in developing, operating, and maintaining secure systems that scale to millions of users. The average operator network is designed to scale to approximately 100 million end-users. With the advent of data networks for devices (not just human subscribers), operators are now investigating systems that can scale to at least ten-fold that size. Systems that can handle this number of devices and end-users require a huge level of cooperation across industrial structure, and the development of this scale of intermediary will therefore require closer cooperation between equipment manufacturers and service providers at all levels. The I-GVC may therefore also be seen to further blur the boundaries of the firm between the high technology companies that form its basis.

Resellers

Resellers are those entities that combine inputs from several different intermediaries, combine it together, analyze, and sell it to either end-users or to corporate entities. These resellers are currently rather limited in terms of the data that they are able to easily access via the converged communi- cations platform, but they are indicative of the types of corporate entities that are forming within this space.

One example is BlueKai, which tracks the online shopping behavior of Internet users and mines the data gathered for "purchasing intent" in order to allow advertisers to target buyers more accurately. BlueKai combines data from several sources, including Amazon, Ebay, and Alibaba. Through this data, it is able to identify regional trends, helping companies to iden- tify not just which consumer group to target their goods to, but also which part of the country. As an example, BlueKai is able to identify all those end-users in West Virginia currently searching for a washing machine in a certain price bracket.

**The international-driven global value chain and global information monopolies**

Currently within the industrial structure of the converged communications industry, there is a large regional disparity between those companies that produce the infrastructure for the I-GVC and those that make a significant profit from it. Through positioning themselves within the correct part of the GVC, these companies are able to take the lion's share of the profit. Through the breakdown of regional boundaries for collection of data by the development and implementation of a global converged communica- tions infrastructure, these companies are able to enlist every person using a mobile device worldwide as a contributor to the development of their information products in effect, *every person worldwide is working for these corporations so that they are able to sell aggregated data* for a huge profit. Despite this data being collected from people in every corner of the globe, from the UK, Thailand, Australia, China, and Africa, to even the remotest parts of Kashmir, the surplus value of the mobile broadband plat- form is currently being captured, developed, and molded into information products, overwhelmingly by U.S. companies. Through being able to col- lect and analyze data without being restricted by the same level of privacy regulation as in Europe, for example, they are able to create a much better information product. Companies in Europe, Asia, and other parts of the globe are therefore dependent on these companies in order to gain the most appropriate knowledge for their companies' needs. In the same way that the use of IT became a critical success factor for enterprises in the late 1980s and 1990s, the use of information products developed within the I-GVC are becoming critical to securing a competitive advantage in a global market. Companies are therefore compelled to use the most effec- tive information product for their needs.

In effect, the I-GVC, rather than breaking down the digital divide as many have predicted, is in fact leading to a new form of digital discrimi- nation and a new sort of dependency relationship between large multina- tionals and those participants, or “workers,” within the I-GVC. While there may appear to be huge differences between the industrial revolution and the birth of the digital planet in the nature of how workers are treated, in particular with so much being advertised as “free” for end-users, there are in fact many similar parallels in the aggregation of human endeavor in the processes of the accumulation of capital. A multitude of workers contribute to the information products developed, but only a few large corporations capture the surplus value.

This has in fact led to a few interesting discussions within industry about who actually owns this data Is it the company that provides the service, the service provider that delivers the connectivity, or the end- users themselves? An end-user might potentially be able to receive money from the use of his or her data, a nominal contribution for each time that data is used for creation of an information product. Profit sharing arrange- ments might even be possible between companies that develop the plat- form and those that collate the data into product form. The fact remains, however, that it is only those companies with the R&D budgets, the scale, and the global reach necessary to exploit the aggregation of this data that will be able to make significant profits from it.