MODULE - II

M2M to IoT-_A Market Perspective

M2M to IoT- A Market Perspective– Introduction, Some Definitions, M2M Value Chains, IoT Value Chains, An emerging industrial structure for IoT, The international driven global value chain and global information monopolies.

M2M to IoT-An Architectural Overview– Building an architecture, Main design principles and needed capabilities, An IoT architecture outline, standards considerations.

2.1 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 technologies.
- Data can be shared between companies and value chains in internal information marketplaces. Alternatively, data could be publicly exchanged on a public information marketplace is as shown in figure 2.1

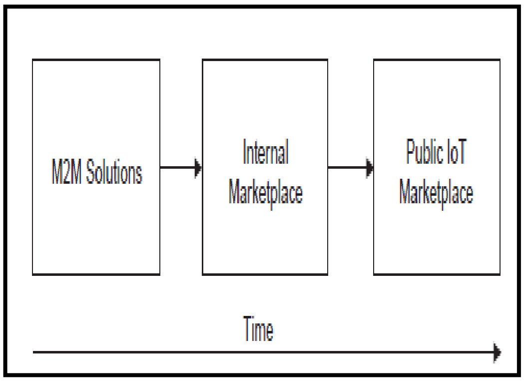

Figure 2.1: A Marketplace perspective

2.2 Some definitions

2.2.1 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.

A simplified value chain is illustrated in Figure 2.2; 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.

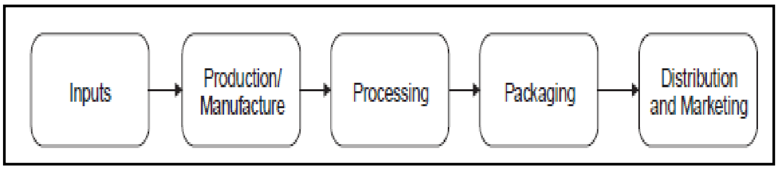

Figure 2.2: A simplified Global value chain

2.2.2 Ecosystems Vs Value chains

- Business Ecosystems, defined by James Moore (Moore 1996), refer to "an economic community supported by a foundation of interacting organizations and individuals.
- The economic community produces goods and services of value to customers, who are themselves members of the ecosystem. The member organisms also include suppliers, lead producers, competitors, and other stakeholders.
- IoT market as an **"ecosystem"** with multiple companies establishing relationships with one another on larger companies in the ecosystem to deliver products and services to end-users and customers.
- A value chain is associated with the creation of value it is the instantiation of exchange by a certain set of companies within an ecosystem.
- A value chain is a useful model to explain how markets create value and how they evolve over time.

2.3 M2M value chains

M2M value chains are internal to one company and cover one solution.

Let us consider **Figure 2.2,** 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 product. 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 process 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 transported to overseas markets.

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.

2.4 IoT Value chains

- IoT Value Chains, meanwhile, are about the use and reuse of data across value chains and across solutions.
- IoT value chains based on data are to some extent enabled by Open APIs.
- 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.

Let's take a closer look at a possible IoT value chain, including an Information Marketplace, illustrated in Figure 1.3.

1. **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 1.3, 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 only, at most, to the requirement to attribute and/or share-alike 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.

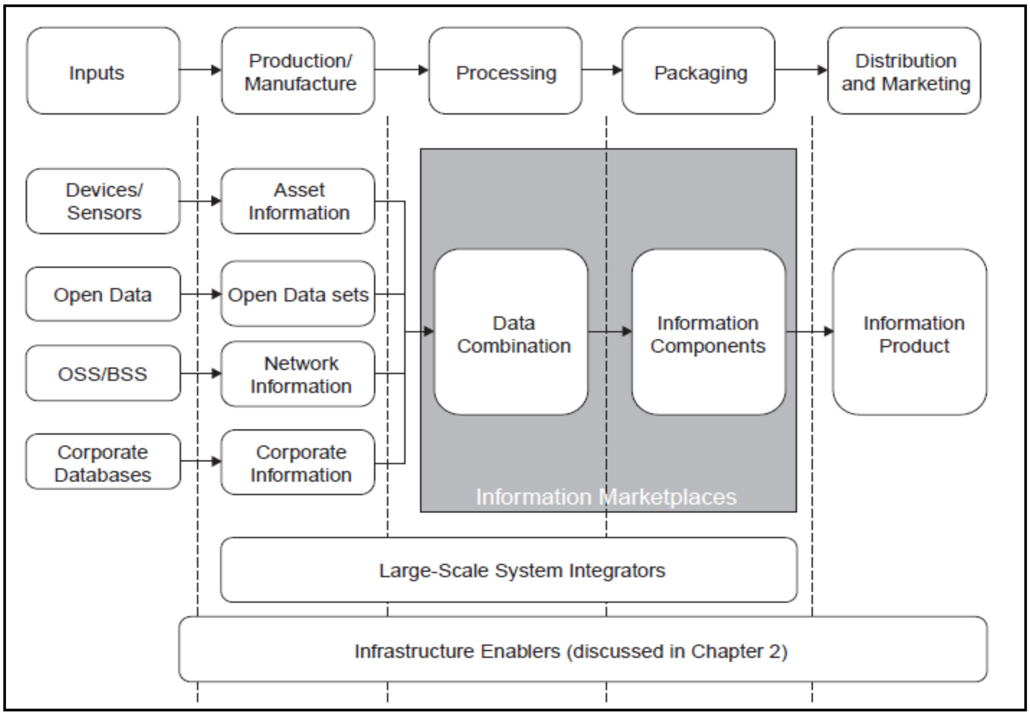

Figure 1.3: Information Driven Value Chain for IoT

2. **Production/Manufacture:** In the production and manufacturing processes 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 provenance and traceability across the information value chain.

Some examples, as illustrated in Figure 1.3, 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 9*/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.

3. **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 information.
4. **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.
5. **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).

2.5 An Emerging industrial structure for IoT

M2M and IoT are about rapidly integrating data and workflows that form the basis of the global economy at increasing speed and precision.

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.

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.

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.

Consider an example of clothing store as in figure 2.4

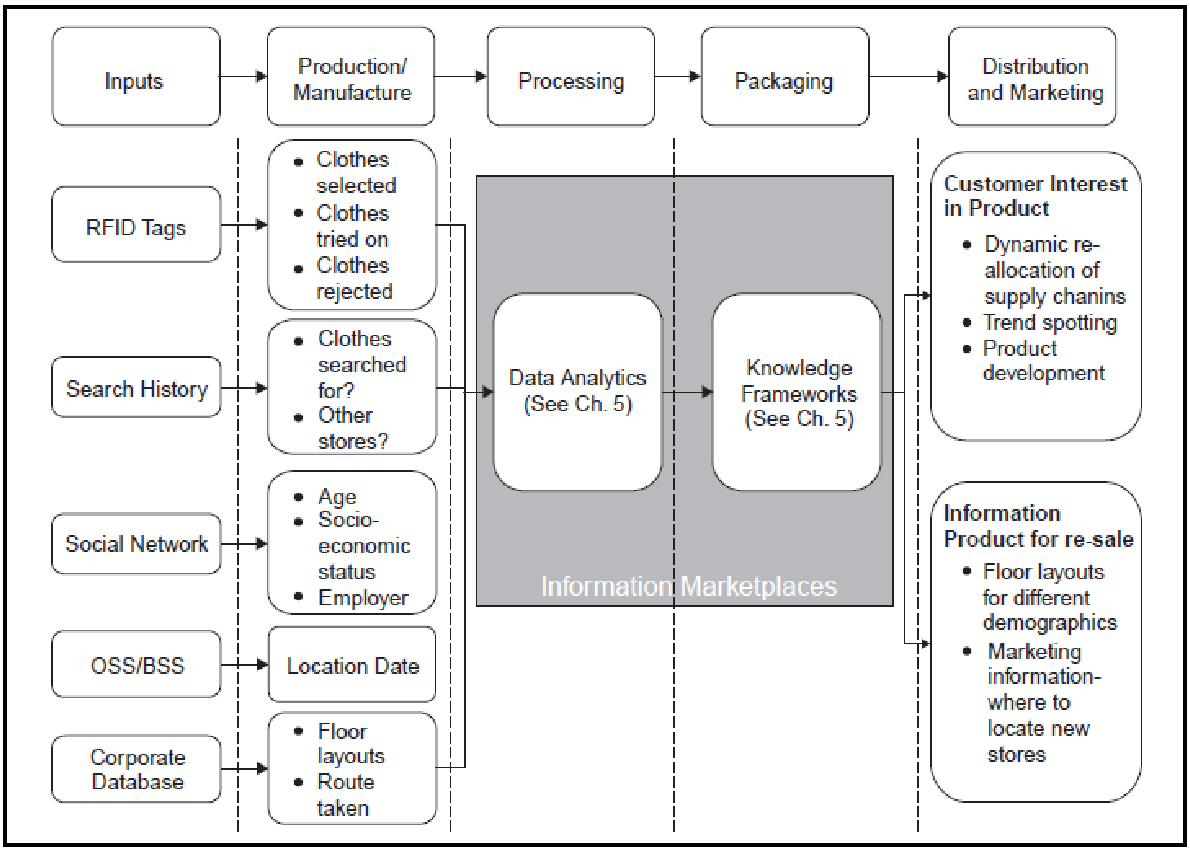

Figure 2.4: An Information Drive Value chain for Retail

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 supply chains of corporations even further than is possible today, and represents 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 2.4.

This streamlining could also be extended into the processes of production, 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.

2.5.1 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 2.5

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

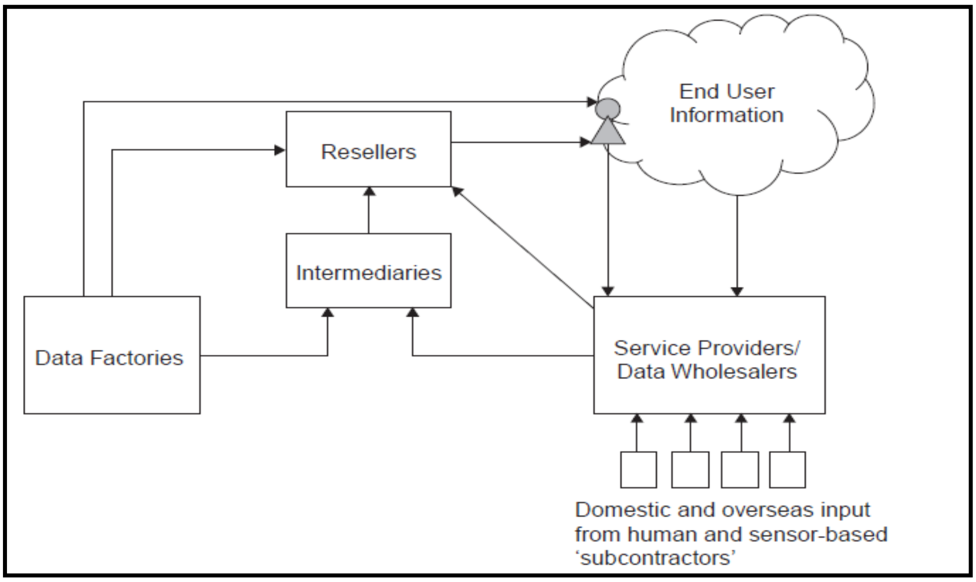

Figure 2.5: The Information Driven Global Chain

2.5.1.1 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.

- **Sensors and Radio frequency identification**

  Sensors and RFID are already found in a multitude of different applications worldwide, 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 information processing system.

  Smartphone's 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. In this sense, the sensor networks, 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 convergence 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.

In fact, the creation of the I-GVC would not be possible without the contribution of many millions 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.

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Every person worldwide that has to use digital technologies to do their banking, their taxes, their information searches, and to communicate with friends and colleagues, are constantly working on behalf of the I-GVC, contributing their individual profile data and knowledge to the value chain.

2.5.1.2 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. Previously, such data factories would create paper-based products 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. 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.
- **Service Providers/data wholesalers**

  Service Providers and Data wholesalers are those entities that collect data from various sources worldwide, and through the creation of massive 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.

- **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.

  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 intermediary 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 transaction costs associated with the establishment of a market for many different companies to participate in.
- **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 communications platform, but they are indicative of the types of corporate entities that are forming within this space.

2.6 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 communications 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 platform is currently being captured, developed, and molded into information products, overwhelmingly by U.S. companies.
- 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 discrimination and a new sort of dependency relationship between large multinationals 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.

2.7 M2M to IoT An Architectural Overview

- Architecture refers to the description of the main conceptual elements, the actual elements of a target system, how they relate to each other, and principles for the design of the architecture. A conceptual element refers to an intended function, a piece of data, or a service.
- An actual element, meanwhile, refers to a technology building block or a protocol.
- The term "reference architecture" relates to a generalized model that contains the richest set of elements and relations that are of relevance to the domain "Internet of Things".
- When looking at solving a particular problem or designing a target application, the reference architecture is to be used as an aid to design an applied architecture.
- The applied architecture is then the blueprint used to develop the actual system solution is as shown in figure 2.6

- Architecture can be described in several different views to capture specific properties that are of relevance to model, they are functional view, deployment view, process view, and information view.

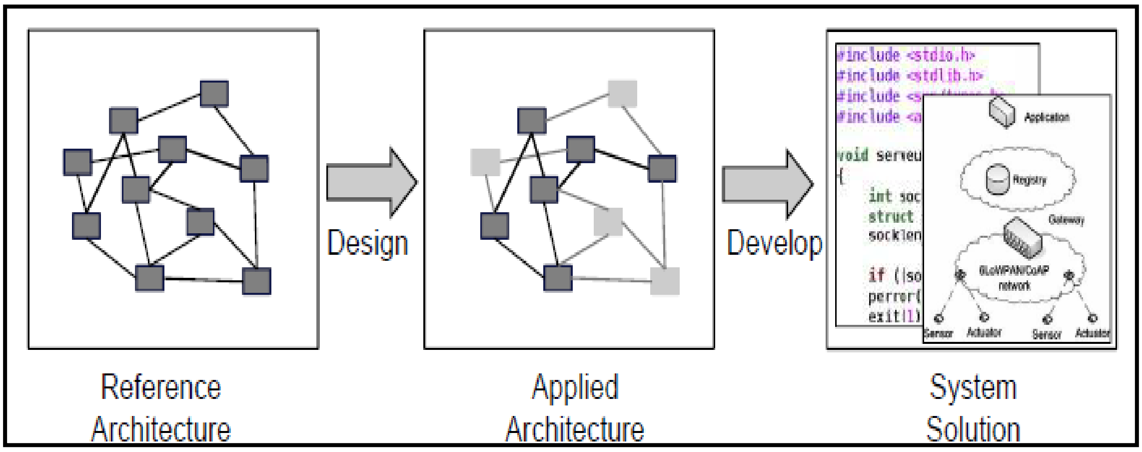

Figure 2.6: From a reference architecture to a system solution.

- When creating a model for the reference architecture, one needs to establish overall objectives for the architecture as well as design principles that come from understanding some of the desired major features of the resulting system solution.
- These objectives and principles have to be derived from a deeper understanding of the actual problem domain, and is typically done by identifying recurring problems or type solutions, and thus by that, extracting common design patterns.
- It is common to partition the architecture work and solution work into two domains, each focusing on specific issues of relevance at the different levels of abstraction is as shown in figure 2.7

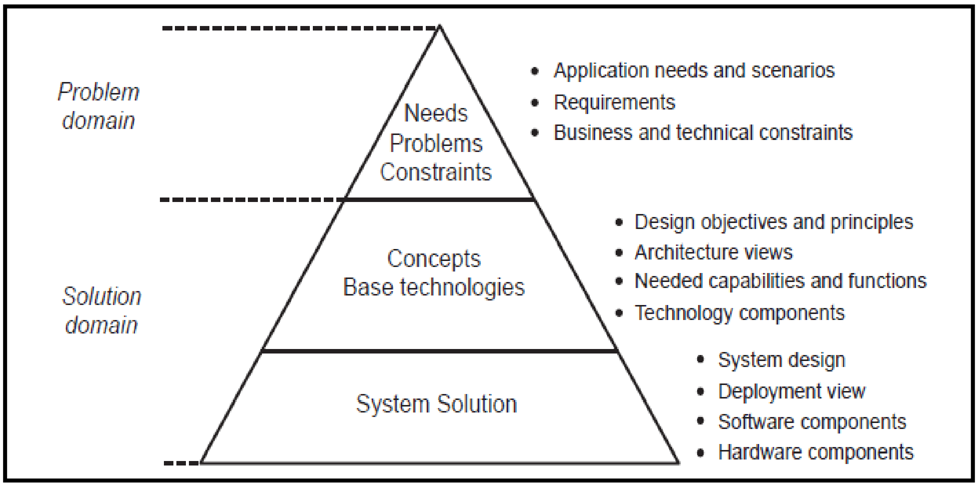

Figure 2.7: Problem and Solution partitioning

- The top level of the triangle is referred to here as the “problem domain” (“domain model” in software engineering). The problem domain about understands the applications of interest, for example, developed through scenario building and use case analysis in order to derive requirements.
- In addition, constraints are typically identified as well. These constraints can be technical, like limited power availability in wireless sensor nodes, or non-technical, like constraints coming from legislation or business.
- The lower level is referred to as the solution domain where design objectives and principles are established, conceptual views are refined, required functions are identified, and where logical partitions of functionality and information are described.
- It is also common to identify suitable technology components such as operating systems and protocols or protocol stacks at this level.
- The actual system solution is finally captured by a system design that typically results in actual software and hardware components, as well as information on how these are to be configured, deployed, and provisioned.

2.8 Main design principles and needed capabilities

Within existing work for deriving requirements and creating architectures or reference models for IoT and M2M, three primary sources can been identified.

- SENSEI
- IoT-A
- The third being the result of a standardization activity driven by ETSI in their Technical Committee (TC) M2M (ETSI M2M TC 2013).

These sources have been selected, as they represent state-of-the-art in terms of creating more complete architectures for the IoT and M2M.

❖ **SENSEI**

- The approach taken in SENSEI was to develop an architecture and technology building blocks that enable“**Real World integration in a future Internet.”**
- Key features include the definition of a real world services interface and the integration of numerous Wireless Sensor and Actuator Network deployments into a common services infrastructure on a global scale.
- The service infrastructure provides a set of services that are common to a vast range of application services.

- The architecture relies on the separation of resources providing sensing and actuation from the actual devices, a set of contextual and real world entity-centric services, and the users of the services.
- SENSEI further relies on an open-ended constellation of providers and users, and also provides a reference model for different business roles.

❖ **ETSI TC M2M**

- The telecommunications industry, meanwhile, has focused on defining a common service core for supporting various M2M applications, and that is agnostic to underlying networks in ETSI TC M2M. The approach taken has been to analyze a set of M2M use cases, derive a set of M2M service requirements, and then to specify an architecture as well as a set of supporting system interfaces.

❖ **IoT-A**

- The approach taken in IoT-A differs from the two approaches above in the sense that instead of defining a single architecture, a reference architecture is created, captured in what the IoT-A refers to as the Architectural Reference Model (ARM).
- The vision of IoT-A is, via the ARM, to establish a means to achieve a high degree of interoperability between different IoT solutions at the different system levels of communication, service, and information.
- IoT-A provides a set of different architectural views, establishes a proposed terminology and a set of Unified Requirements (IoT-A UNI 2013).
- Furthermore, IoT-A proposes a methodology for how to arrive at a concrete architecture based on use cases and requirements.

Comparing these different approaches, a common feature is the focus on a horizontal system approach. There is a clear separation of the underlying communication networks and related technologies from capabilities that enable services. There is also a clear desire to separate logic that is highly application-specific from logic that is common across a large set of applications.

Overall IoT architecture objective is as follows

The overall design objective of IoT architecture shall be to target a horizontal system of real-world services that are open, service-oriented, secure, and offer trust.

- *Design for reuse of deployed IoT resources across application domains. Deployed IoT resources shall be able to be used in a vast range of different applications.* This implies that devices shall be made application independent and that the basic and atomic services they expose in terms of sensing and actuation shall be done in a (to the greatest extent possible) uniform way.

- *Design for a set of support services that provide open service-oriented capabilities and can be used for application development and execution*. These support services shall in general cater to the typical environment of a stakeholder where IoT applications are to be built, such as an open environment, and shall in particular provide support for a few key service capabilities that are central from an IoT perspective.
  - The open environment of IoT will, for instance, require mechanisms for authorized usage of services and resources, authentication, and associated identity management.
  - The key support services that are required from an IoT perspective include the means to access IoT resources, how to publish and discover resources, tools for modeling contextual information and information related to the real world entities that are of interest, and capabilities that provide different levels of abstracted and complex services.
- *Design for different abstraction levels that hide underlying complexities and heterogeneities.*
  - As we have already seen, typical IoT solutions can involve a large number of different devices and associated sensor modalities, and involve a large set of different actors providing services and information that need to be composed and accessed with different levels of aggregation.
  - Again, hiding device-side technologies and providing simple abstractions of the sensing and actuation services is one aspect. Another is the means to perform aggregation of information or knowledge representation.
- *Design for sensing and actors taking on different roles of providing and using services across different business domains and value chains.*
  - IoT solutions can be run across a set of departments within an enterprise, or across a set of enterprises in a value system, or even be provided in a truly open environment. The business contexts can then be viewed as no market (entirely intra organizational), as closed markets (finite and predetermined set of business actors in a specific value system or value chain), or as open markets (undefined and open-ended number of participants).
  - The first thing that needs to be provided is a set of mechanisms that ensure security and trust. Trust and identity management that refer to the different stakeholders is a fundamental requirement.
  - Authentication and authorization of access to use services as well as to be able to provide services is then a second requirement.
- *Design for ensuring trust, security, and privacy. Trust within IoT often implies reliability, which can be both ensuring the availability of services as well as how dependable the services* are, and that data is only used for the purposes the end-user has agreed to. One important aspect of dependability is the accuracy of data or information, as you can have multiple sources of IoT

data. security and privacy are potential barriers for IoT adoption and represent key areas to address when building solutions

- *Design for scalability, performance, and effectiveness. IoT deployments will happen on a global scale and are foreseen to involve billions of deployed nodes.*

  Sensor data will be provided with a wide range of different characteristics. Data may be very infrequent (e.g. alarms or detected abnormal events), or may be coming as real-time data streams, all dependent on the type of data needed or based on application needs. Scalability aspects of importance include the large number of devices and amounts of data produced that needs to be processed or stored. Performance includes consideration of mission-critical applications such as Supervisory Control And Data Acquisition (SCADA) systems with extreme requirements on latency.

- *Design for evolvability, heterogeneity, and simplicity of integration.* Technology is constantly changing, and given the nature of IoT deployments where devices and sensor nodes are expected to be operational and in the field for many years.
- *Design for simplicity of management*. Again going back to one of the potential barriers for IoT adaptation, simplicity of management is an important capability that needs to be properly taken care of when designing IoT solutions.
- *Design for different service delivery models.* For instance, connected vehicles, and Software as a Service (SaaS) as a delivery model. IoT with the wide span of possible applications clearly benefit from elasticity in deployment of solutions, all to meet the long-tail aspect.
- *Design for lifecycle support*. The lifecycle phases are: planning, development, deployment, and execution. Management aspects include deployment efficiency, design time tools, and run-time management.

2.9 An IoT Architecture

The architecture outline is as shown below figure 2.8

- At the lowest level is the **Asset Layer**. This layer is, strictly speaking, not providing any functionality within a target solution, but represents the **raison d'etre** for any IoT application. The assets of interest are the real-world objects and entities that are subject to being monitored and controlled, as well as having digital representations and identities.
  - The typical examples include vehicles and machinery, fixed infrastructures such as buildings and utility systems, homes, and people themselves. Assets can also be of a more virtual character, being subjective representations of parts of the real world that are of

interest to a person or an organization Assets are instrumented with embedded technologies that bridge the digital realm with the physical world, and that provide the capabilities to monitor and control the assets as well as providing identities to the assets.

- **The Resource Layer** provides the main functional capabilities of sensing, actuation, and embedded identities. Sensors and actuators in various devices that may be smartphones or Wireless Sensor Actuator Networks (WSANs), M2M devices like smart meters, or other sensor/actuator nodes, deliver these functions.
    - This is also where gateways of different types are placed that can provide aggregation or other capabilities that are closely related to these basic resources. Identification of assets can be provided by different types of tags; for instance, Radio Frequency Identification Or optical codes like bar codes or Quick Response(QR) codes.
- The purpose of **communication layer** is to provide the means for connectivity between the resources on one end and the different computing instances that host and execute the service support and application logic on the other hand. It can use LAN or WAN.

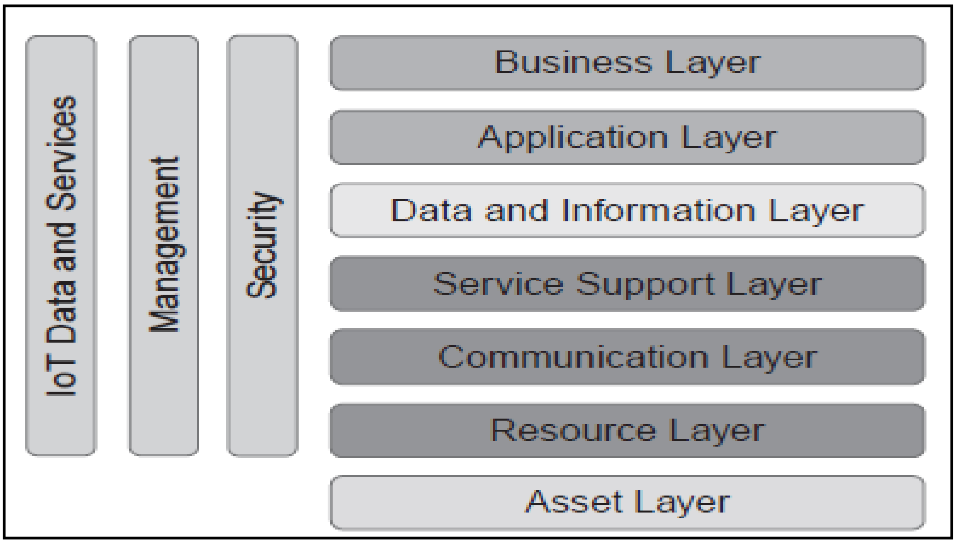

Figure 2.8 Functional Layers and capabilities of an IoT Solution

WAN

- WANs can be realized by different wired or wireless technologies, for instance, fiber or Digital Subscriber Line (DSL) for the former, and cellular mobile networks, satellite, or microwave links for the latter.
- WANs can also be provided by different actors, where some networks can be regarded as public or as private.
- Particularly in the mobile network industry, there are different models for how the communications services are provided that include wholesale of access, and dedicated

virtual network operators that focus on managed M2M connectivity offerings without owning licensed mobile spectrum or actual network resources.

LAN

Prime examples of LANs include Wireless Personal Area Networks (WPANs; also known as Body Area Networks, BANs) for fitness or healthcare applications, Home or Building Area Networks (HANs and BANs, respectively)used in automation and control applications, and Neighborhood Area Networks (NANs), which are used in the Distribution Grid of a Smart Electricity Grid. Communication can also be used in more ad hoc scenarios.Vehicle-to-Vehicle (V2V) is one example that can target safety applications like collision avoidance or car platooning.

LANs use both wired and wireless technologies. General examples of wired LANs include Ethernet and Power Line Communication (PLC), whereas twisted pair (KNX 2013) and (BAC net 2013) over RS-232 are two detailed examples from the building automation industry.

The ZigBee specifications (Zigbee 2013a), the proprietary protocol stack (Z-Wave 2013) for home automation, and ISA100.11a (ISA1002013) for industry automation.

- **Service Support Layer** and are typically executing in data centers or server farms inside organizations or in a cloud environment. These support services can provide uniform handling of the underlying devices and networks, thus hiding complexities in the communications and resource layers.

  Examples include remote device management that can do remote software upgrades, remote diagnostics or recovery, and dynamically reconfigure application processing such as setting event filters. Communication-related functions include selection of communication channels if different networks can be used in parallel, for example, for reliability purposes, and publish_subscribe and message queue mechanisms. Location Based Service (LBS) capabilities and various Geographic Information System (GIS) services are also important for many IoT applications. Of more specific relevance for IoT are services that relate to sensor originating data and actuation services, and services that relate to different tags like RFID.

- **Data and Information Layer** provides a more abstract set of functions as its main purposes are to capture knowledge and provide advanced control logic support Key concepts here include data and information models and knowledge representation in general,and the focus is on the organization of information. We refer to a Knowledge Management Framework (KMF) as a collective term to include data, information, domain-specific knowledge, actionable services descriptions as, for example, represented by single actuators or more complex composite sensing and actuation services, service descriptors, rules,process or workflow descriptions, etc. The The KMF needs to integrate anything from single pieces of data from individual sensors to highly domain-specific expert knowledge into a common knowledge fabric. Key concepts to construct the KMF include semantic annotation, Linked Data, and building different ontologies.

- The **Application Layer** in turn provides the specific IoT applications. There is an open-ended array of different applications, and typical examples include smart metering in the Smart Grid, vehicle tracking, building automation, or participatory sensing (PS).
- The final layer in our architecture outline is the **Business Layer,** which focuses on supporting the core business or operations of any enterprise, organization, or individual that is interested in IoT applications. This is where any integration of the IoT applications into business processes and enterprise systems takes place. The enterprise systems can, for example, be Customer Relationship Management (CRM), Enterprise Resource Planning (ERP), or other Business Support Systems (BSS). The business layer also provides exposure to APIs for third parties to get access to data and information, and can also contain support for direct access to applications by human users; for instance, city portal services for citizens in a smart city context, or providing necessary data visualizations to the human workforce in a particular enterprise.
- In addition to the functional layers, three functional groups cross the different layers, namely Management, Security, and IoT Data and Services. The former two are well known functions of a system solution,whereas the latter one is more specific to IoT.

1) **Management:**

The management group deals with the management of system solution related to maintenance, administration, operation, and provisioning. This includes management of devices, communication networks and general IT infrastructure in the organization.

2) **Security:**

Security is the protection of the system, its information, and services from the external threats and any other harm. Authorization, authentication, identity management, and trust are main capabilities.

3) **Data and services:**

Data and service processing can, from a topological perspective, be done in a very distributed fashion and at different levels of complexity.

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