Unit III
M2M to IOT

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IoT

Unit III: M2M to IOT (05)

- Introduction,
- Basic Concepts,
- Difference between IoT and M2M,
- M2M Value Chains,
- IoT Value Chains,
- Machine to Machine Communication,
- M2M to IoT- Architecture, Design principles and capabilities.

RTMNU Questions S-2023

5.	a)	Explain the difference between IOT and M2M.	6
	b)	Draw and explain M2M communication in detail.	8
		OR	
6.	a)	Discuss the M2M value chain.	6
	b)	Draw and explain M2M to IOT architecture in detail.	8

RTMNU Questions W-2024

5.	(a)	With the help of neat diagram, explain the M2M System architecture.	8
	(b)	Explain the differences between Machines in M2M and things in IOT.	6

OR

6.	(a)	State and explain about M2M Communication (How it works) with example.	7
	(b)	Write short notes on :	
		(i) M2M value chains.	4
		(ii) Applications of M2M Communication System.	3

Introduction: Background

- Both M2M and IoT are results of the technological progress over the last decades, including not just the decreasing costs of semiconductor components, but also the spectacular uptake of the Internet Protocol (IP) and the broad adoption of the Internet.

- The application opportunities for such solutions 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.

Background…

- The Internet has undoubtedly had a profound impact across society and industries over the past two decades. Starting off as ARPANET (Advanced Research Project Agency Network) which was developed in late 1960s under ARPA (Advanced Research Projects Agency) were connecting remote computers together.
- The introduction of the TCP/IP (Transmission control protocol/Internet Protocol) protocol suite which basically allows different networks to interconnect, 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 technologies 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.

Background…

- At the same time that the Internet has been evolving, another technology revolution has been unfolding the use of sensors, electronic tags,and actuators to digitally identify, observe and control objects in the physical 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 communicate 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.

Background…

- The reasons for dramatic increase in M2M and IoT solutions 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.

Background…

- What makes the M2M and IoT markets take off today, therefore, is needs meeting enabling technologies at the right cost.

Basic Concepts: What is M2M ?

- M2M stands for Machine-to-Machine, which refers to the communication between two or more machines or devices without the need for human intervention.
- M2M communication is a key aspect of the Internet of Things (IoT) and involves the exchange of data and information between machines or devices to enable automation and decision-making.

What is M2M ?

- M2M communication is used in various industries and applications, such as smart cities, healthcare, transportation, logistics, and manufacturing.
- For example, in a smart city, sensors in streetlights can communicate with each other to optimize energy consumption and detect faults.
- In healthcare, wearable devices can transmit data to healthcare providers to monitor patient health and prevent diseases.
- In manufacturing, machines can communicate with each other to optimize production processes and reduce downtime.

M2M communication

- M2M communication typically involves a network of devices that communicate with each other through various communication technologies, such as cellular networks, Wi-Fi, Bluetooth, and Zigbee.
- The data exchanged between machines can be in various formats, such as sensor data, location data, and machine status information.
- The data is typically processed and analyzed to enable automation and decision-making, such as triggering actions or sending alerts based on certain conditions.

M2M communication

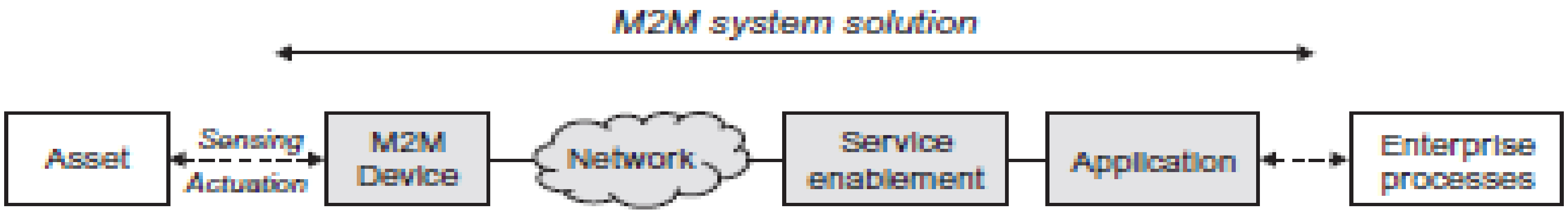
- M2M refers to those solutions that allow communication between devices of the same type and a specific application, all via wired or wireless communication networks.
- M2M solutions allow end-users to capture data about events from assets, such as temperature or inventory levels.
- Typically, M2M is deployed to achieve productivity gains, reduce costs , and increase safety or security.
- M2M has been applied in many different scenarios, including the remote monitoring and control of enterprise assets, or to provide connectivity of remote machine-type devices.
- Remote monitoring and control has generally provided the incentive for industrial applications, whereas connectivity has been the focus in other enterprise scenarios such as connected vending machines or point-of-sales terminals for online credit card transactions.

M2M communication

- M2M solutions, however, do not generally allow for the broad sharing of data or connection of the devices in question directly to the Internet.

A typical M2M solution overview

- A typical M2M system solution consists of M2M devices, Communication networks that provide remote connectivity for the devices, service enablement 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.



FIGURE

A generic M2M system solution.

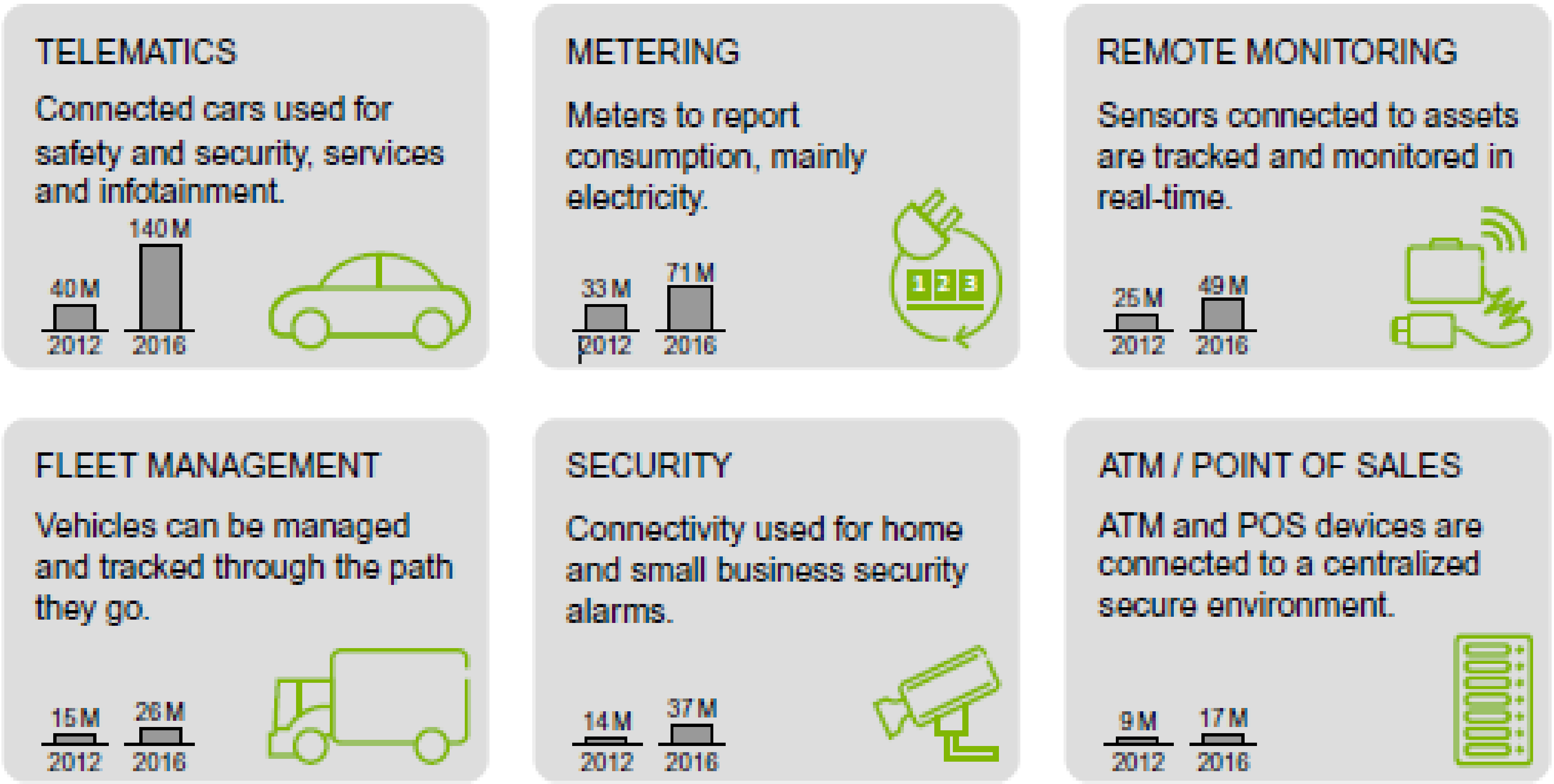
- The system components of an M2M solution are as follows:
- M2M Device. This is the M2M device attached to the asset of interest, and provides sensing and actuation capabilities. The M2M device is here generalized, as there are a number of different realizations of these devices, ranging from low-end 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 functionality that is common across a number of different applications.
- Its primary purpose is to reduce cost for implementation and ease of application development. 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.

Key application areas



FIGURE

Summarized cellular M2M market situation.

Key application areas

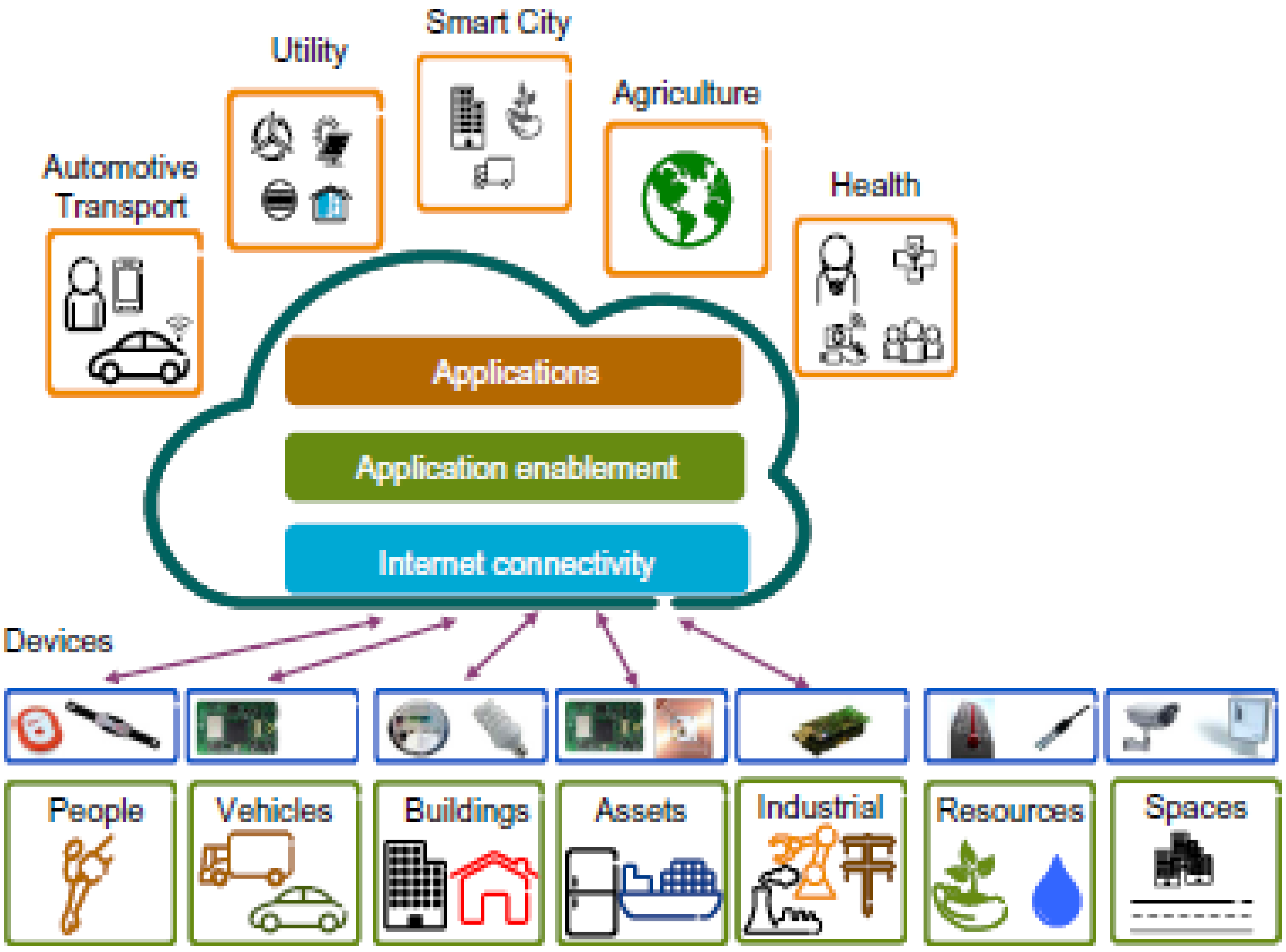
- Metering applications, meanwhile, include primarily remote meter management and data collection for energy consumption in the electricity utility sector, but also for gas and water consumption.
- Remote monitoring is more generalized monitoring of assets, and includes remote patient monitoring as one prime example.
- Fleet management includes a number of different applications, like data logging, goods and vehicle positioning, and security of valuable or hazardous goods.
- Security applications are mainly those related to home alarms and small business surveillance solutions. The final market segment is Automated Teller Machines (ATM) and Point of Sales (POS) terminals.

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) systems 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.

IoT

- 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 processes of enterprises, and creating knowledge (Figure next slide).
- 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 industrial automation.



FIGURE

An IoT.

IoT

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

- Urban Agriculture. Already today, more than 50% of the world’s population lives in urban areas and cities. The increased attention on sustainable 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 example.
- Robots. The mining industry is undergoing a change for the future. Production rates must be increased, cost per produced unit decreased, and the lifetime of mines and sites must be prolonged.
- In addition, human workforce safety must be higher, with fewer or no accidents, and environmental impact must be decreased by reducing energy consumption and carbon emissions. The mining industry answer to this is to turn each mine into a fully automated and controlled operation.

- Food Safety. After several outbreaks of food-related illnesses in the U.S., the U.S. Food and Drug Administration (USFDA) created its Food Safety and Modernization Act (FSMA 2011). The main objective with FSMA is to ensure that the U.S. food supply is safe. Similar food safety objectives have also been declared by the European Union and the Chinese authorities.
- These objectives will have an impact across the entire food supply chain, from the farm to the table, and require a number of actors to integrate various parts of their businesses.
- From the monitoring of farming conditions for plant and animal health, registration of the use of pesticides and animal food, the logistics chain to monitor environmental conditions as produce is being transported, and retailers handling of food

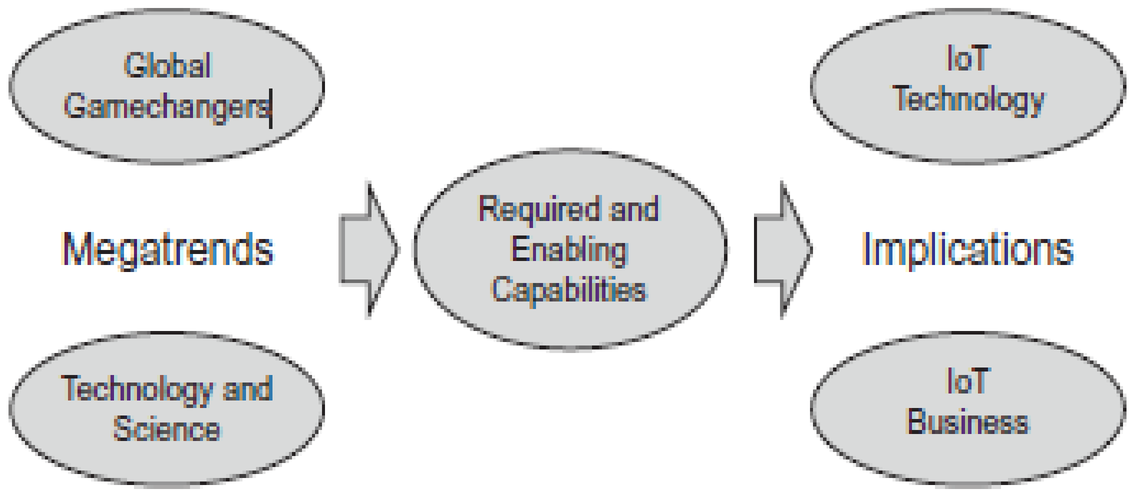
FIGURE :

Emerging IoT applications.

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 decades 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 below.



FIGURE

Megatrends, capabilities, and implications.

Game Changer

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
- Cost rationalization

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

Business
- 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
- Commoditized devices
- Application and user driven

IoT and M2M

- **M2M:**

- Machine-to-Machine (M2M) refers to networking of machines (or devices) for the purpose of remote monitoring and control and data exchange.
- Term which is often synonymous with IoT is Machine-to-Machine (M2M).
- IoT and M2M are often used interchangeably.
- End-to-end architecture of M2M systems comprises of M2M area networks, communication networks and application domain.

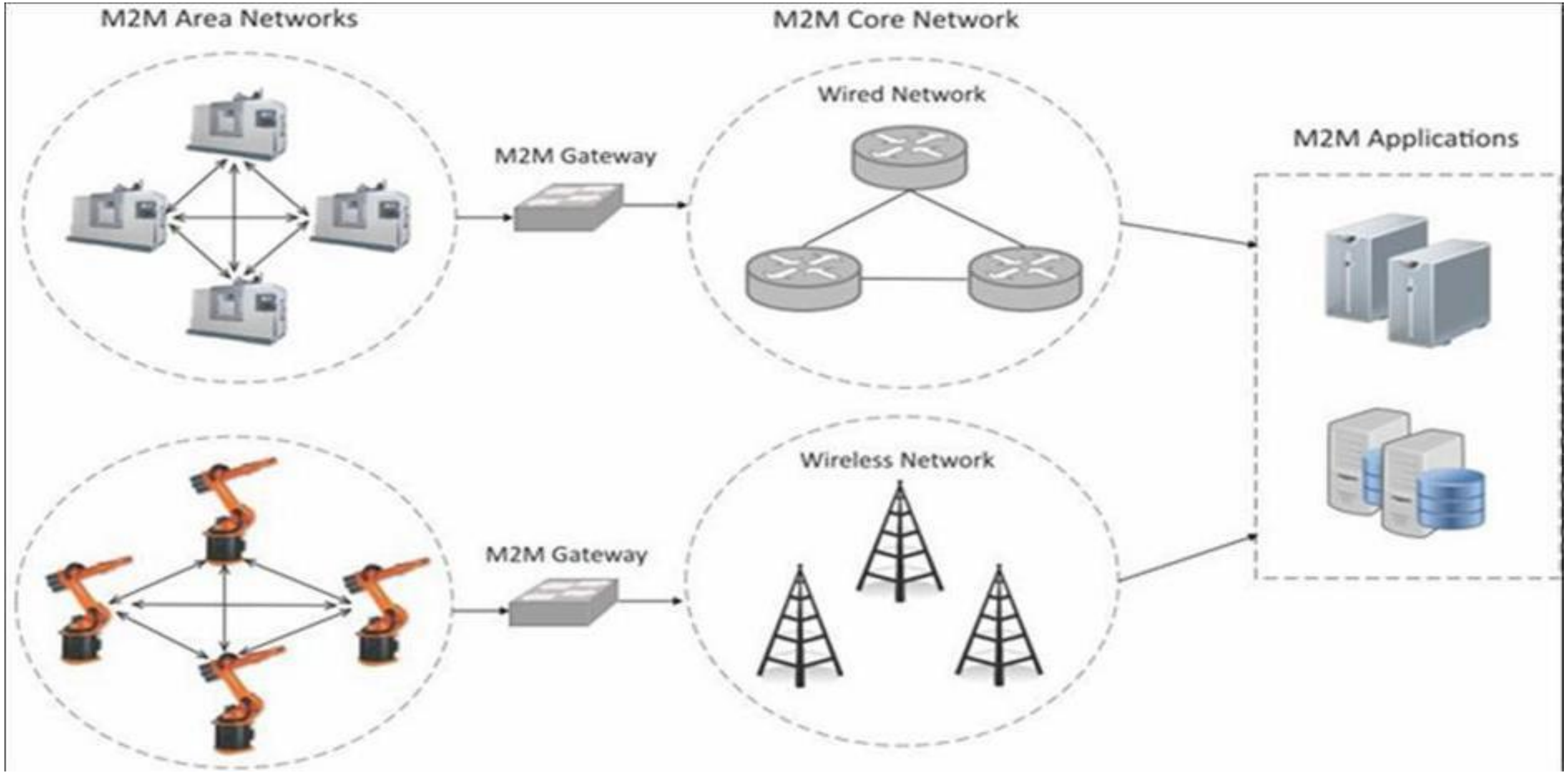


Figure: End-to-end architecture of M2M systems

IoT and M2M…

- An M2M area network comprises of machines (or M2M nodes) which have embedded network modules for sensing, actuation and communicating.
- Various communication protocols can be used for M2M LAN such as ZigBee, Bluetooth, M-bus, Wireless M-Bus etc.,
- These protocols provide connectivity between M2M nodes within an M2M area network.

IoT and M2M…

- The communication network provides connectivity to remote M2M area networks.
- The communication network can use either wired or wireless network (IP based).
- While the M2M networks use either proprietary or non-IP based communication protocols, the communication network uses IP-based network.
- Since non-IP based protocols are used within M2M area network, the M2M nodes within one network cannot communicate with nodes in an external network.

IoT and M2M…

- So to enable the communication between remote M2M area network, M2M gateways are used.
- Fig. (on next slide) Shows a block diagram of an M2M gateway.
- The communication between M2M nodes and the M2M gateway is based on the communication protocols which are naive to the M2M area network.
- M2M gateway performs protocol translations to enable IP-connectivity for M2M area networks.
- M2M gateway acts as a proxy performing translations from/to native protocols to/from Internet Protocol(IP).
- With an M2M gateway, each mode in an M2M area network appears as a virtualized node for external M2M area networks.

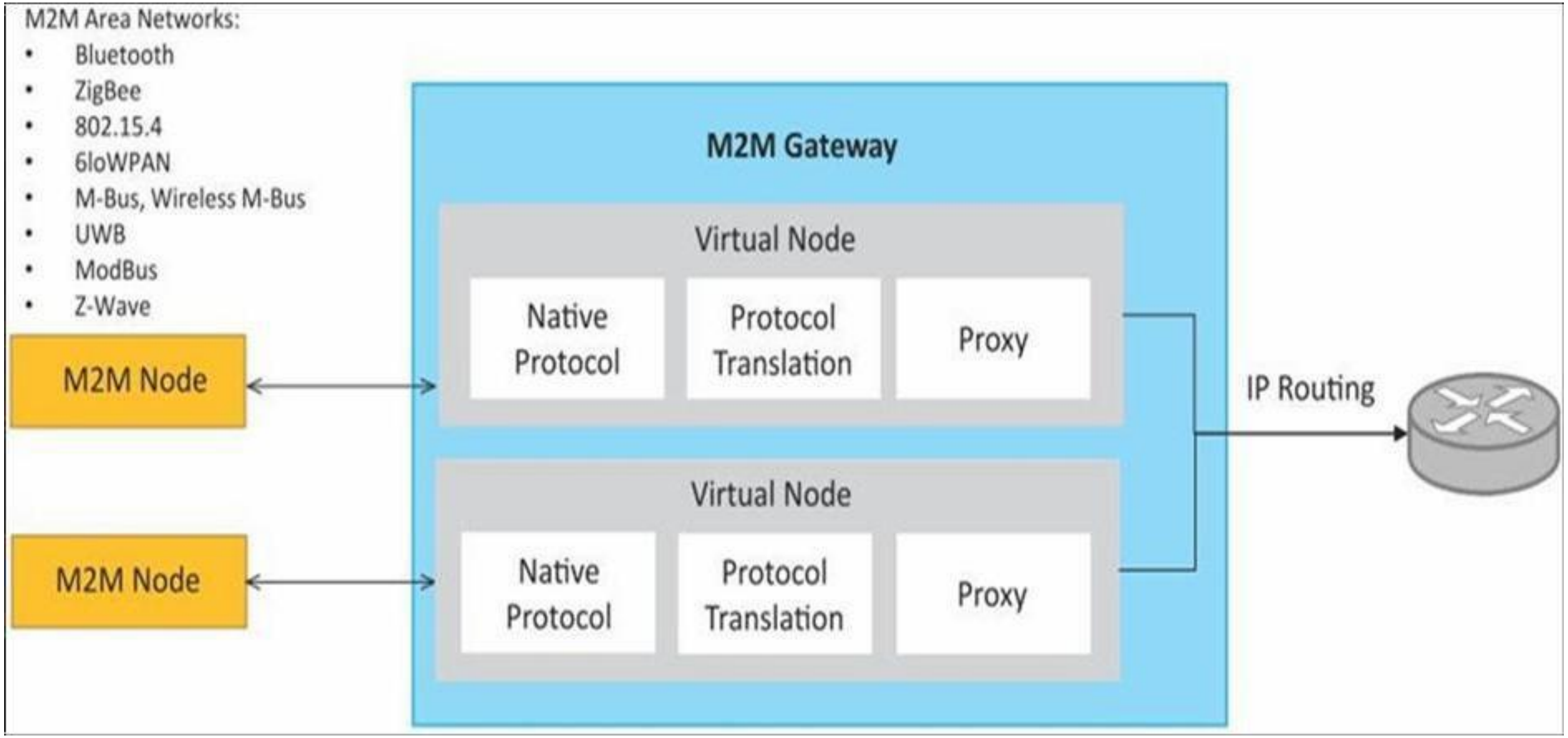


Fig: Block diagram of an M2M Gateway

Differences between IoT and M2M

M2M	VS	IOT
Direct communication between machines	01	Sensors automation and internet platform
Point-to-point communication	02	Support cloud communication
Does not rely on the Internet connection	03	Reply on the Internet connection
Hardware-based technology	04	Uses both hardware and software-based technology
Communicates with a single machine at a time	05	Multiple users can access at one time through the Internet
Device can get connected using the mobile or other network	06	Data delivery depends on the IP network

Differences between IoT and M2M

PARAMETERS	M2M	IOT
Abbreviation for	Machine to Machine	Internet of Things
Philosophy	M2M is Concept where two or more machines can communicate with each other and carry out certain functions without human intervention. Some degree of intelligence can be observed in M2M model.	IOT is an ecosystem of connected devices (via Internet) where the devices have ability to collect and transfer data over a network automatically without human intervention. IOT helps objects to interact with internal and/or external environment which in turn control the decision making.
Connection Type	Point to Point	Through IP Network using various Communication types
Communication protocols	Old proprietary protocols and communication techniques	Internet protocols used commonly
Value Chain	Linear	Multi-sided
Focus Area	For monitoring and control of 1 or few infrastructure/assets.	To address everyday needs of humans.
Sharing of collected data	Data collected is not shared with other applications	Data is shared with other applications (like weather forecasts, social media etc.) improve end user experience
Device dependency	Devices usually don't rely over Internet connection	Devices usually rely over Internet connection
Device in scope	Limited devices in scope	Large number of device sin scope
Scalability	Less scalable than IOT	More scalable due to cloud based architecture
Example	Remote monitoring, fleet control	Smart Cities, smart agriculture etc.
Business Type	B2B	B2B and B2C
Technology Integration	Vertical	Vertical and Horizontal
Open APIs	Not supported	Supported
Related terms	Sensors , Data and Information	End users, devices, wearables, Cloud and Big Data

Differences between IoT and M2M

- IoT (Internet of Things) and M2M (Machine-to-Machine) are two related concepts that involve the interconnectivity of devices and the exchange of data between machines. However, there are some differences between the two.
- Scope: IoT is a broader concept than M2M. IoT refers to the network of physical devices, vehicles, buildings, and other objects that are connected and can exchange data. M2M, on the other hand, refers specifically to the direct communication between two or more machines without human intervention.

Differences between IoT and M2M ….

- Complexity: IoT systems are generally more complex than M2M systems. IoT systems involve multiple devices and sensors that interact with each other and with cloud-based services to enable automation and decision-making. M2M systems, on the other hand, typically involve simpler communication between machines with a more limited scope.
- Application: IoT is generally used in applications that involve complex interactions between devices and systems, such as smart homes, smart cities, and industrial automation. M2M, on the other hand, is typically used in applications that involve direct communication between machines, such as remote monitoring, asset tracking, and industrial control.

Differences between IoT and M2M ……

- Standards: IoT has more established standards and protocols than M2M. IoT uses standard protocols such as MQTT, CoAP, and HTTP to enable interoperability between devices and systems. M2M communication, on the other hand, may use proprietary protocols and technologies.

Differences between IoT and M2M ..

1) Communication Protocols:

- Commonly used M2M protocols include ZigBee, Bluetooth, ModBus, M-Bus, Wireless M-Bus tec.,
- IoT uses Hypertext Transfer Protocol (HTTP) , Constrained application protocol (CoAP), WebSocket , Message Queue Telemetry Transport (MQTT) , Extensible Messaging and Presence Protocol(XMPP) , Data distribution service (DDS) , Advanced Message Queuing protocols (AMQP) etc.,

2) Machines in M2M Vs Things in IoT:

- Machines in M2M will be homogenous whereas Things in IoT will be heterogeneous.

3) Hardware Vs Software Emphasis:

- the emphasis of M2M is more on hardware with embedded modules, the emphasis of IoT is more on software.

Differences between IoT and M2M ….

4) Data Collection &Analysis

- M2M data is collected in point solutions and often in on-premises storage infrastructure.
- The data in IoT is collected in the cloud (can be public, private or hybrid cloud).

5) Applications

- M2M data is collected in point solutions and can be accessed by on-premises applications such as diagnosis applications, service management applications, and on- premises enterprise applications.
- IoT data is collected in the cloud and can be accessed by cloud applications such as analytics applications, enterprise applications, remote diagnosis and management applications, etc.

Differences between IoT and M2M ….

- In summary, while IoT and M2M share many similarities,
- IoT is a broader concept that involves complex interactions between devices and systems, while M2M involves direct communication between machines.
- IoT is also more established and has more standardized protocols than M2M.

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.

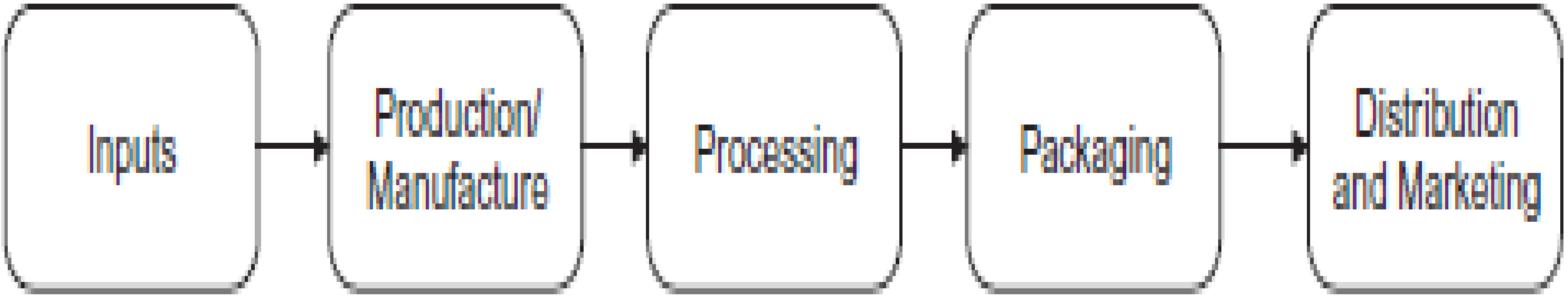
- This is one of the key differences between the M2M and IoT markets how the industrial structures will be formed around these solutions, despite very similar technology implementations.

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 below; it is comprised of five separate activities that work together to create a finalized product.

Global value chains



FIGURE

A simplified global value chain.

Global value chains…

- 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 “focusing on the sequences of tangible and intangible value-adding activities, from conception and production to end use.
- GVC analysis therefore provides 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 particularly useful as such an analysis can help identify the boundaries between existing industrial structures such as M2M solutions and emerging industrial 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 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.

Ecosystems vs. value chains….

- Over time, they co-evolve their capabilities 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 ecosystem leader because it enables members to move toward shared visions to align their investments, and to find mutually supportive roles.”

Ecosystems vs. value chains….

- 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 associated with the creation of value it is the instantiation of exchange by a certain set of companies within an ecosystem.
- This is an important distinction 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.

M2M Value Chains

- M2M (Machine-to-Machine) value chains refer to the various stages involved in delivering an M2M solution, from the development of hardware and software components to the delivery of value-added services to end-users.
- Let’s take a look at the inputs and outputs of an M2M value chain.

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. 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.

M2M Value Chains……

- 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.

M2M Value Chains……

- M2M value chains are internal to one company and cover one solution.
- IoT Value Chains, meanwhile, are about the use and reuse of data across value chains and across solutions.

IoT value chains

- IoT (Internet of Things) value chains refer to the various stages involved in delivering an IoT solution, from the development of hardware and software components to the delivery of value-added services to end-users. See the figure on next slide for typical IoT value chain.
- The IoT value chain typically includes the following stages:
- 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 (next slide) 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. However, the manner in which the data from these devices and sensors is used provides a different and much broader marketplace than M2M does.

IoT Value Chains

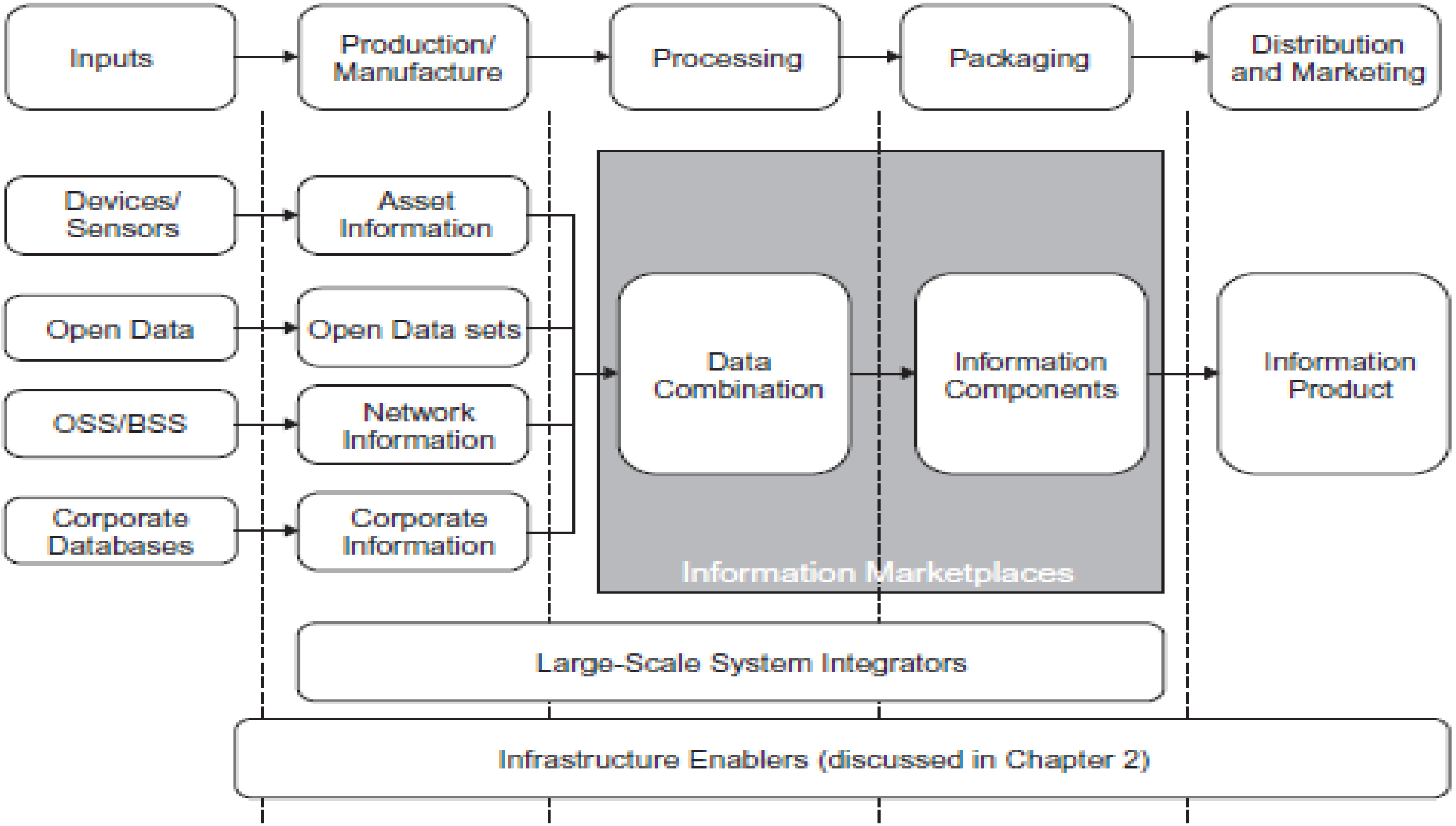


FIGURE .

An Information-Driven Value Chain for IoT.

IoT value chains….

- 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 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.

IoT value chains…

- 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.

IoT value chains…

- 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, are as follows:

IoT value chains…

- 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.

IoT value chains…

- 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.
- This process involves the extensive use of data analytics for M2M and IoT solutions.
- 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 frameworks in order to create not just visualizations of existing information, but to create new knowledge for the enterprise in question.

IoT value chains…

- 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 traceability 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.

IoT value chains…

- 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).

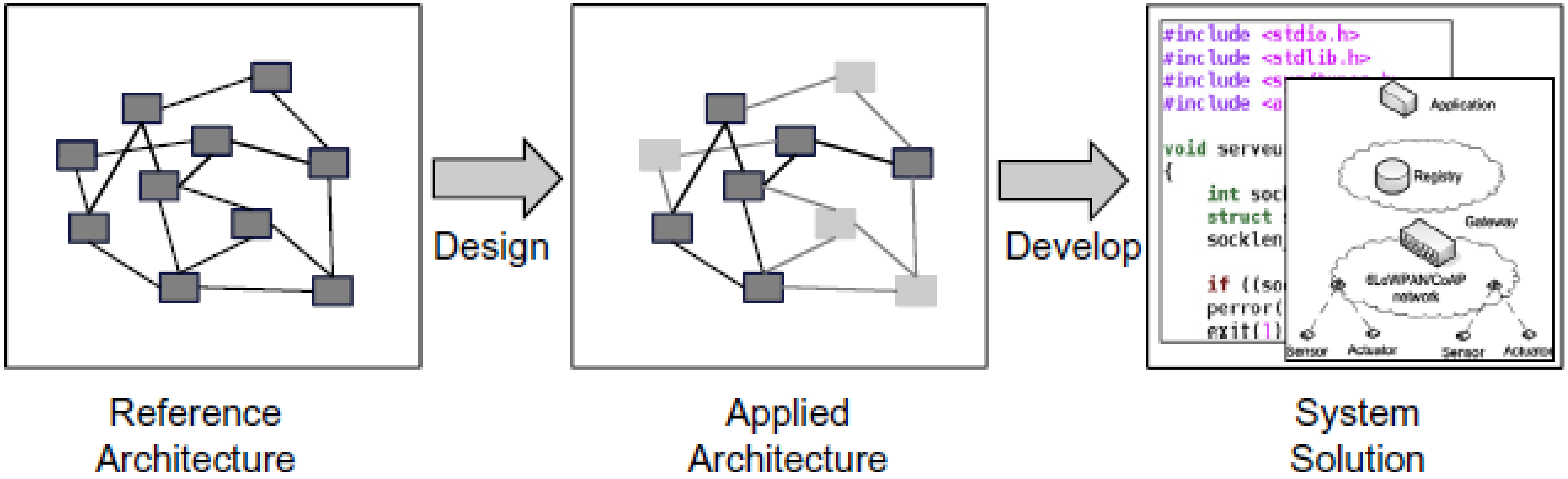
M2M to IoT- Architecture, Design principles and capabilities.

- 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.”

M2M to IoT- Architecture…

- 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, i.e. an instance created out of a subset of the reference architecture.
- The applied architecture is then the blueprint used to develop the actual system solution (Figure on next slide).

M2M to IoT- Architecture…



FIGURE

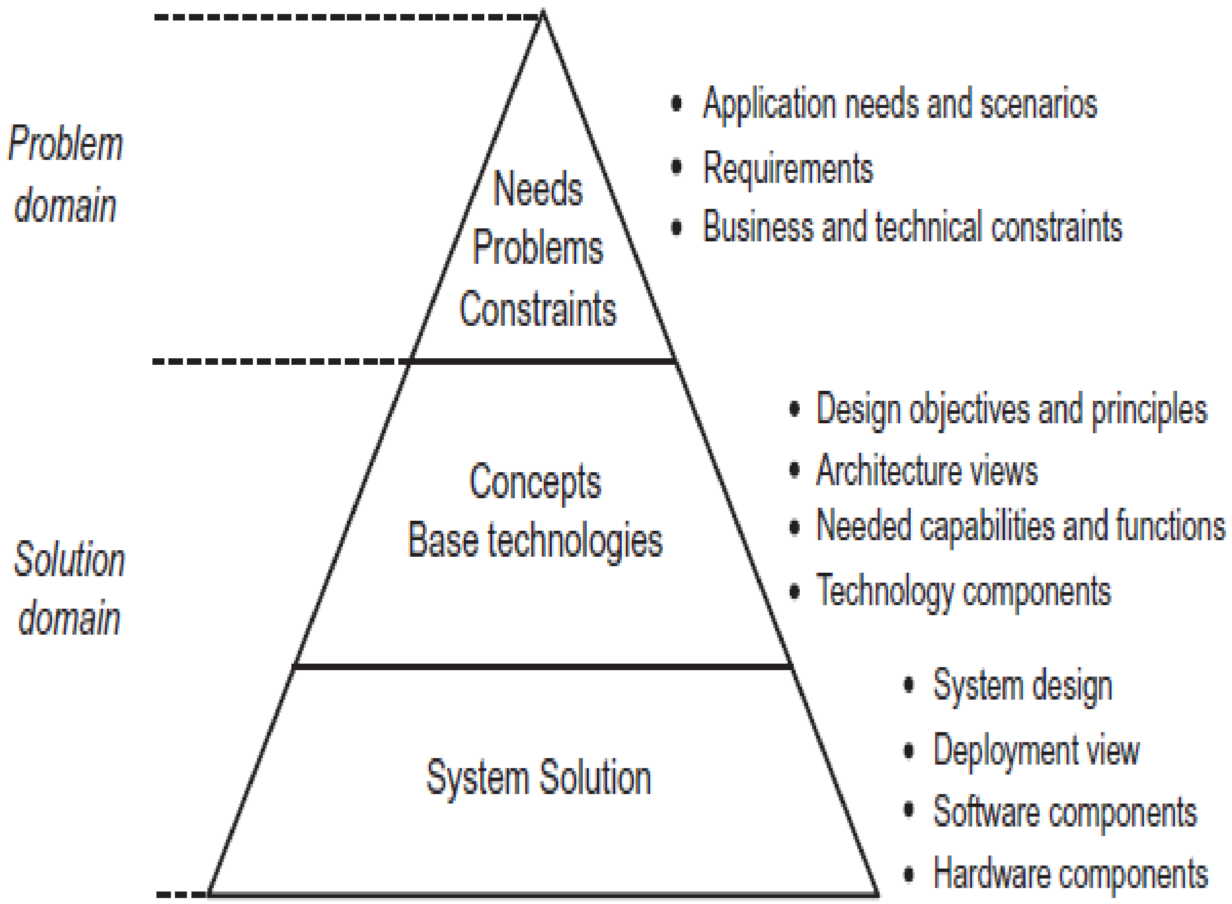
From a reference architecture to a system solution.

M2M to IoT- Architecture…

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

M2M to IoT- Architecture…

- For instance, an overall objective might be to decouple application logic from communication mechanisms, and typical design principles might then be to design for protocol interoperability and to design for encapsulated service descriptions.
- 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.



FIGURE

Problem and Solution domain partitioning.

- The problem domain establishes the foundation for the subsequent solutions.
- 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 (Figure LHS)

M2M to IoT- Architecture…

- The top level of the triangle is referred to here as the "problem domain" ("domain model" in software engineering). The problem domain is about understanding 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.
- These are real-world design constraints.
- The lower level is referred to as the solution domain.

M2M to IoT- Architecture…

- In Solution domain design objectives and principles are established, conceptual views are refined, required functions are identified, and where logical partitions of functionality and information are described.
- Often this is where a logical architecture is defined, or network Architecture in the form of a network topology diagram is produced. 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.

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.
- Two of them are the larger European 7th Framework Program research projects, SENSEI (2013) and IoT-A (2013),
- 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.

Main design principles…

- The approach taken in SENSEI was to develop an architecture and technology building blocks that enable a "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 and is separated from any underlying communication network for which the only assumption made was that it should be based on Internet Protocol (IP).

Main design principles…

- 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. A number of design principles and guidelines are identified, and so is a set of requirements.
- Finally, the architecture itself contains a set of key functional capabilities.

Main design principles…

- 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.
- Similar to SENSEI, there was a clear approach towards a horizontal system with separation of devices, gateways, communications networks, and the creation of a common service core and a set of applications, all separated by defined reference points.

Main design principles…

- Finally, 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.

Main design principles…

- 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. Further analyzing both the referenced existing work as well as both needed capabilities and direct IoT implications,
- we can also derive a set of supporting design principles that target different means to fulfill the overall architecture objective.
- These design principles have a set of interpretations and further expectations on needed technology solutions.

Main design principles…

- Design for reuse of deployed IoT resources across application domains.
- Design for a set of support services that provide open service-oriented capabilities and can be used for application development and execution.
- Design for different abstraction levels that hide underlying complexities and heterogeneities.
- Design for sensing and actors taking on different roles of providing and using services across different business domains and value chains.

Main design principles…

- Design for ensuring trust, security, and privacy.
- Design for scalability, performance, and effectiveness.
- Design for evolvability, heterogeneity, and simplicity of integration.
- Design for simplicity of management.
- Design for different service delivery models.
- Design for lifecycle support.

An IoT architecture outline

- There is a rather widely accepted view of what a typical M2M solution looks like. However, there is no generally accepted M2M systems architecture or universal set of standards that is widely acknowledged.
- What is state of the art today is mainly coming from a few standardization bodies that have specified either protocols as systems components, or system and functional architectures for various parts of a complete end-to-end M2M architecture.

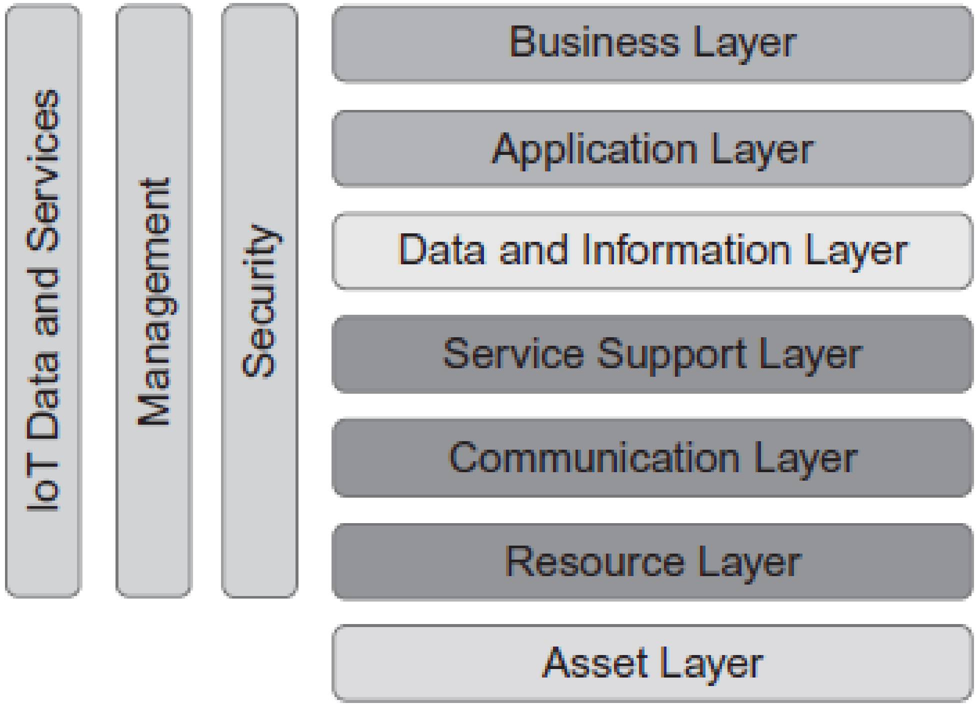
An IoT architecture outline…

- When it comes to IoT, there is today not a single widely accepted view of what a typical IoT solution looks like.
- However, as mentioned, there are a number of research activities on the European level that are converging on defining a reference architecture, and these activities are to be found as projects in the Internet of Things European Research Cluster (IERC 2013).
- The diversity in the possible and sought-after applications, as well as the diversity in deployment scenarios, together produces a large set of different requirements and constraints.

An IoT architecture outline…

- Attempting to produce a single architecture consequently results in a number of optional and conditional requirements, all depending on the particular problem at hand or application in focus.
- Nevertheless, the identified key features that are needed when building an M2M or IoT solution can now be put together into a larger context by proposing a single view of the main functional capabilities (see Figure next slide).
- This is not a strict and formal functional architecture, but provides a conceptual overview. It also follows the approach of looking at the system capabilities from a layered point of view, including highlighting key functions that go across the layers.

An IoT architecture outline…



FIGURE

Functional layers and capabilities of an IoT solution.

An IoT architecture outline…

- Other approaches that are common in describing an architecture are the software approach and network approach that are more focused on how functions are distributed across a network topology.
- For the sake of brevity, we use IoT as a collective term to include both M2M and IoT.
- Here the different proposed functional layers and capabilities provided are discussed.

Acronyms

6LowPAN	IPv6 over Low Powered Personal Area Network
ACM	Automatic Computing Machinery Association
AMQP	Advanced Message Queueing Protocol
ANSI	American National Standards Institute
ANT	A proprietary open access multicast wireless sensor network
ANT+	Interoperability function added to ANT
API	Application Programming Interface
ARIB	Association of Radio Industries and Businesses (Japan)
BACnet	Building Automation and Control Network
CI12.20	ANSI Standard for Electric Meter Accuracy and Performance
CoAP	Constrained Application Protocol
COSEM	Company Specification for Energy Metering
CPS	Cyber Physical Systems
CPU	Central Processing Unit
CTIA	Cellular Telecommunication Industries Association
DARPA	Defense Advance Research Project Agency
DASH7	ISO 18000-7 RFID standard for sensor networks

Acronyms (Cont)

DECT	Digital Enhanced Cordless Communication
DLMS	Device Language Message Specification
DoE	Department of Energy
EC2	Elastic Compute Cloud 2 (by Amazon)
ETSI	European Telecommunications Standards Institute
EU	European Union
FP7	Framework Program 7
GP	GreenPHY
GreenPHY	Green Physical Layer
HomePlug-GP	HomePlug Green PHY
IEEE	Institute for Electrical and Electronic Engineers
IERC	IoT-European Research Cluster
IETF	Internet Engineering Task Force
iOS	iPhone Operating System
IoT	Internet of Things
IP	Internet Protocol

Acronyms (Cont)

IPSO	IP for Smart Objects
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
ISP	Internet Service Provider
ITU	International Telecommunications Union
KNX	Building automation protocol
MB	Mega-byte
MCAD	Multi-Cloud Application Deployment Platform
MQTT	Message Queue Telemetry Transport
NASA	National Aeronautical and Space Administration
NEST	Name of a product
NFC	Near field communication
NIH	National Institute of Health
NITRD	Networking and Info Tech Research and Development
NonIP	Non-Internet Protocol
NSF	National Science Foundation

Acronyms (Cont)

OAuth	Open Authorization protocol from IETF
oneM2M	One Machine to Machine
ONR	Office of Naval Research
PAN	Personal area network
PIN	Personal Identification Number
PLC	Power Line Communication
PoP	Point of Presence
QoI	Quality of information
QR	Quick Response
RFID	Radio Frequency Identifier
RPL	Routing Protocol for Low Power and Lossy Networks
SDN	Software Defined Networking
SIG	Special Interest Group
TLV	Type-Length-Value
TV	Television
UK	United Kingdom

Acronyms (Cont)

ULE	Ultra Low Energy
US	United States
VC	Venture Capital
WAN	Wide Area Network
WiFi	Wireless Fidelity
XML	eXtensible Markup Language
ZB	Ziga-Byte