Internal Assesment Test –I, September 2020

INTERNET OF THINGS	**Code:**	**18MCA542**						
16-09-2020	Duration:	90 mins	Max Marks:	50	Sem	V		MCA

1. Define IoT? Explain emerging IoT application

IOT – definition

- The **Internet of Things** (**IoT**) is the network of physical devices embedded with electronics, software, sensors, actuators, and connectivity which enables these things to connect and exchange data
- 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
- IoT also refers to the connection of such systems and sensors to the broader Internet, as well as the use of general Internet technologies b) With the diagram, Discuss IoT and its emerging applications.

IOT Applications

Urban Agriculture:

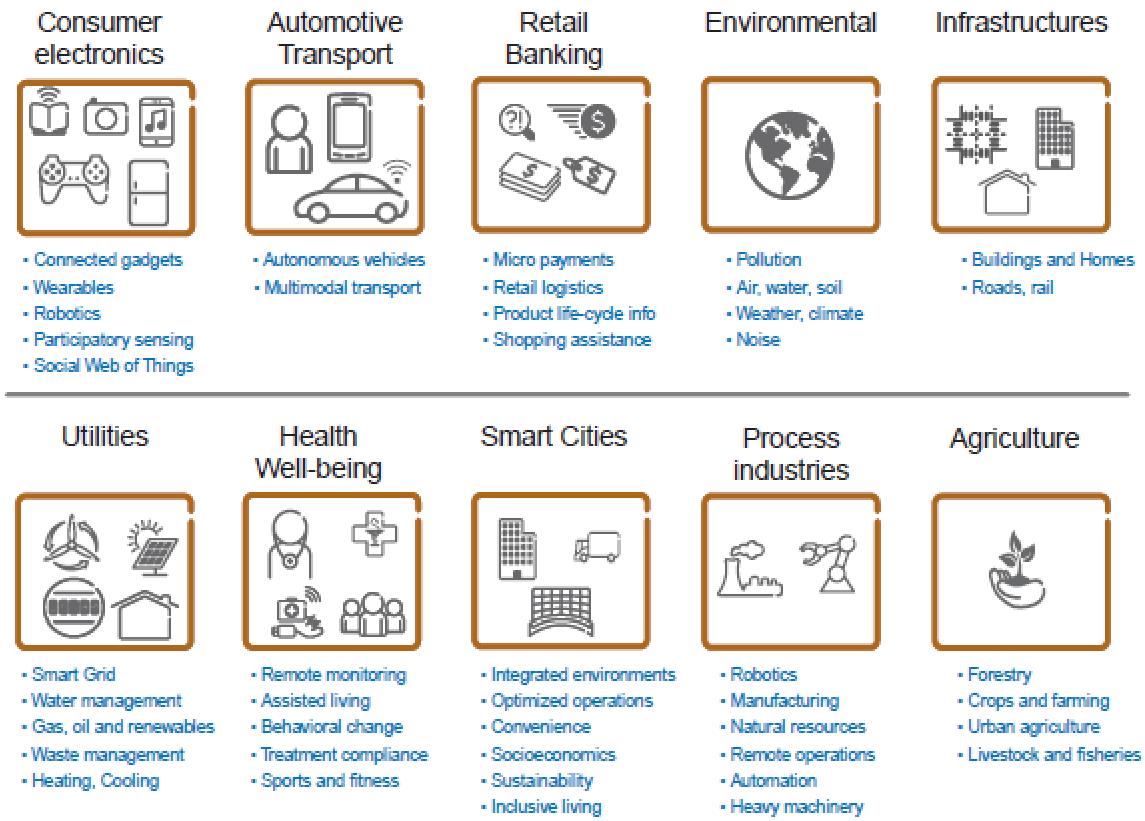
By using IoT technologies, urban agriculture could be highly optimized. Sensors and actuators can monitor and control the plant environment and tailor the conditions according to the needs of the specific specimen. Water supply through a combination of rain collection and remote feeds can be combined on demand. A vision of urban agriculture is to be a self-sustaining system. Urban agriculture can be a mix of highly industrialized deployments with vertical greenhouses, and collective efforts by individuals in apartments by the use of more do-it-yourself style equipment.

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. The process chain of the mine involving blasting, crushing, grinding, and ore processing will be highly automated and interconnected. The heavy machinery used will be remotely controlled and monitored, mine sites will be connected, and shafts monitored in terms of air and gases.

Food Safety:

The main objective with is to ensure that the U.S. food supply is safe. 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-all will be connected.



2. Explain the trends in information and communication technologies.

□□**sensors, actuators, and tags function as the digital interfaces**

o Small-scale and cheap sensors and actuators provide the bridge between the physical realm and ICT systems. Tags using technologies such as RFID provide the means to put electronic identities on any object, and can be cheaply produced.

Embedded processing

o is evolving not only towards higher capabilities and processing speeds, but also extending towards the smallest of applications.

o There is a growing market for small-scale embedded processing such as 8-, 16- , and 32-bit microcontrollers with on-chip RAM and flash memory, I/O capabilities, and networking interfaces such as IEEE 802.15.4 that are integrated on tiny System-on-a-Chip (SoC) solutions.

□□**Instant access to the Internet**

o virtually everywhere today, mainly thanks to wireless and cellular technologies and the rapid deployment of cellular 3G and 4G or Long Term Evolution (LTE) systems on a global scale.

o These systems provide ubiquitous and relatively cheap connectivity with the right characteristics for many applications, including low latency and the capacity to handle large amounts of data with high reliability.

Software Architectures

o Software architectures have undergone several evolutions over the past decades, in particular with the increasing dominance of the web paradigm.

o Software architecture refers to the high level structures of a software system, the discipline of creating such structures, and system. Each structure comprises software elements, relations among them, and properties of both elements and relations

Service Oriented Approach (SOA)

o A service-oriented architecture (SOA) is a style of software design where services are provided to the other components by application components, through a communication protocol over a network.

Open APIs

o Open APIs relate to a common need to create a market between many companies, as is the case in the IoT market. Open APIs permit the creation of a fluid industrial platform, allowing components to be combined together in multiple different ways by multiple developers with little to no interaction with those who developed the platform, or installed the devices.

o Without Open APIs, a developer would need to create contracts with several different companies in order to get access to the correct data to develop the application.

o The transaction costs associated with establishing such a service would be prohibitively expensive for most small development companies; they would need to establish contracts with each company for the data required, and spend time and money on legal fees and business development with each individual company.

Virtualization

o has many different facets and has gained a lot of attention in the past few years, even though it has been around for a rather long time.

Cloud Computing

o Cloud computing allows elasticity in deployment of services and enables reaching long-tail applications in a viable fashion.

o Cloud computing also has the benefit of easing different businesses to interconnect if they are executing on the same platform.

Big Data

o Big data, which refers to the increasing number and size of data sets that are available for companies and individuals to collect and perform analysis on.

Decision support

o Knowledge representation across domains and heterogeneous systems are also important, as are semantics and linked-data.

3. Define the following :
(i) Megatrends (ii) Capabilities (iii) Implications

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.

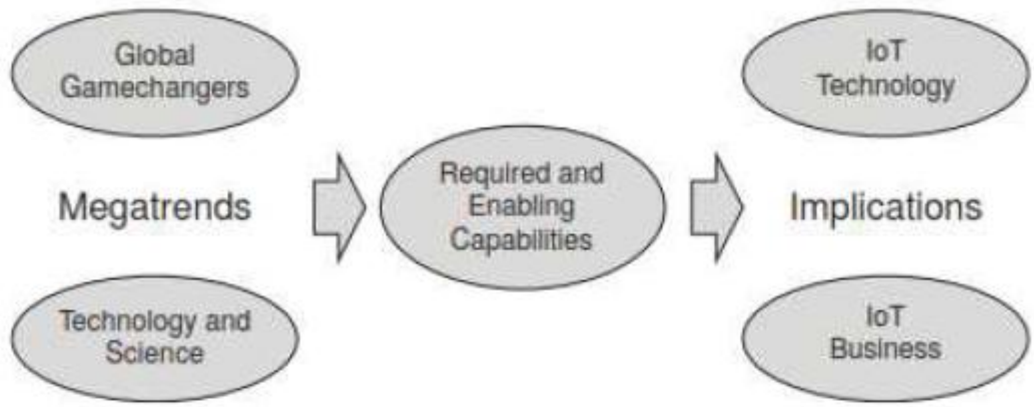


Figure No: 1.3 Megatrends, Capabilities and Implications

Game Changers
The game changers come from a set of social, economic, and environmental 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, controlling, 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 technology evolution required to face these challenges. Some of the global significant game changers
o **Natural Resource Constraint**
o **Economic Shifts**
o **Changing Demographics**
o **Socioeconomic Expectations**
o **Climate Change and Environment Impacts**
o **Safety and Security**
o **Urbanization**
1.3.2 General technology and scientific trend
o **Material Science**
has a large impact across a vast range of industries, from pharmaceutical and cosmetics to electronics. MicroElectroMechanical Systems (MEMS) can be used to build advanced micro-sized sensors like accelerometers and gyroscopes.
Emerging flexible and printable electronics will enable a new range of innovations for embedding technology in the real world.
From an IoT perspective, these advances in material science will see an increasing range of applications and also a broader definition of what is meant by a sensor.
o **Complex and Advanced Machinery**
o **Energy Production and Storage**
is relevant to IoT for two reasons.
Firstly, it relates to the global interest of securing the availability of electricity while reducing climate and environmental impacts. Smart Grids, for example, imply micro-generation of electricity using affordable photovoltaic panels. smart grids also require new types of energy storage, both for the grid itself and for emerging technologies such as Electric Vehicles (EVs) that rely on increasingly efficient battery technologies.

- Secondly, powering embedded devices in Wireless Sensor Networks (WSNs) will increasingly rely on different energy harvesting technologies and also rely on new miniaturized battery technologies and ultra capacitors.

1.3.3.1 Capabilities

- These capabilities address several aspects such as cost efficiency, effectiveness and convenience; being lean and reducing environmental impact; encouraging innovation; and in general, applying technology to create more intelligent systems, enterprises, and societies.
- The aforementioned ICT developments provide us with a rich toolbox to address these different aspects in general, and as part of that, IoT in particular.
- While M2M today targets specific problems with tailored, siloed solutions, it is clear that emerging IoT applications will address the much more complex scenarios of large scale distributed monitor and control applications.
- For example, Smart City solutions: here there is a clear need for integration of multiple disparate infrastructures such as utilities, including district heating and cooling, water, waste, and energy, as well as transportation such as road and rail.
- Each of these infrastructures has multiple stakeholders and separate ownership even though they operate in the same physical spaces of buildings, road networks, and so on.
- The optimization of entire cities requires the opening up of data and information, business processes, and services at different levels of the disjoint silos, creating a common fabric of services and data relating to the different infrastructures.
- IoT will allow more assets of enterprises and organizations to be connected, thus allowing a tighter and more prompt integration of the assets into business processes and expert systems.
- Simple machines can be used in a more controlled and intelligent manner, often called "Smart Objects." These connected assets will generate more data and information, and will expose more service capabilities to ICT systems. As society operations involve a large number of actors taking on different roles in providing services, and as enterprises and industries increasingly rely on efficient operations across ecosystems, cross value chain and value system integration is a growing need.
- These sorts of collaboration scenarios will become increasingly important as industries, individuals, and government organizations work together to solve complex problems involving multiple stakeholders.
- The open and collaborative nature of IoT means methods are required to publish and discover data and services, as well as means to achieve semantic interoperability, but also that care needs to be given to trust, security, and privacy.
- As we come to increasingly rely on ICT solutions to monitor and control assets, physical properties of the real world require not just increased levels of cybersecurity, but what can be referred to as cyber-physical security. In the use of the Internet today, it is possible to exact financial damage via breaking into information technology (IT) systems of companies or bank accounts of individuals.
- This raises requirements for trust and security to be correctly implemented in IoT systems.

Implications for IoT

- Having gained a better understanding of capabilities needed, as well as how technology evolution can support these needs.

- There is already a trend of moving away from vertically oriented systems, or application-specific silos, towards a horizontal systems approach.
- The use of the TCP/IP stack towards IoT devices represents another horizontal point in an M2M and IoT system solution, and is something driven by organizations like the IETF and the IP for Smart Objects (IPSO) Alliance.
- In the M2M device area, there is an emerging consolidation of technologies where solutions across different industry segments traditionally rely on legacy and proprietary technologies.
- Currently within industry segments there is technology fragmentation, one example being Building and Home Automation and Control with legacy technologies like BACnet, Lonworks, KNX, Z-Wave, and ZigBee.
- Where there is a requirement for integration across multiple infrastructures and of a large set of different devices, as well as data and information sharing across multiple domains, there is a clear benefit from a horizontal systems approach with at least a common conceptual interoperability made available, and a reduced set of technologies and protocols being used.
- M2M is point problem-oriented, resulting in point solutions where devices and applications are highly dedicated to solving a single task.
- M2M devices are for this reason many times highly application-specific, and reuse of devices beyond the M2M application at hand is difficult, if at all possible. Benefits will be achieved if an existing device can be used in a variety of applications, and likewise if a specific application can use a number of different deployed devices.
- Here we see a shift from application-specific devices towards application-independent devices
- Clear benefits come from relying on the web services paradigm, as it allows easy integration in SOAs and attracts a larger application developer community.
- Even though M2M has been around for many years, recent years have seen a tremendous interest in M2M across industries, primarily the telecom industry.
- This comes from the fact that both devices and connectivity have become viable for many different applications, and M2M today is centered on devices and connectivity.
- For IoT there will be a shift of focus away from device- and connectivity-centricity towards services, data, and intelligence.

4.a) Differentiate M2M and IOT

Aspect	M2M	IoT
Applications and Services	Point problem driven	Innovation driven
	Single application-single device	Multiple applications-multiple devices
	Communication and device centric	Information and service centric
	Asset management driven	Data and information driven
Business	Closed business operations	Open market place
	Business objective driven	Participatory community driven
	B2B	B2B, B2C
	Established value chains	Emerging ecosystems
	Consultancy and Systems Integration enabled	Open Web and as-a-Service enabled
	In-house deployment	Cloud deployment
Technology	Vertical system solution approach	Horizontal enabler approach
	Specialized device solutions	Generic commodity devices
	De facto and proprietary	Standards and open source
	Specific closed data formats and service descriptions	Open APIs and data specifications
	Closed specialized software Development	Open software development
	SOA enterprise integration	Open APIs and web development

4.b Explain with a neat diagram a typical M2M solution overview

A typical M2M system solution consists of
o M2M devices
o communication networks that provide remote connectivity for the devices,
o service enablement, application logic,
o Integration of the M2M application into the business processes provided by an Information Technology (IT) illustrated in the below figure 1.1
□□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 electricity meter), all depending on the enterprise.

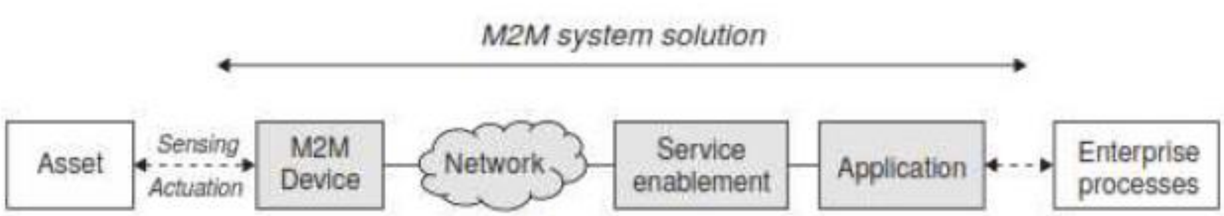


Figure 1.1 A Generic M2M system solution

The system components of an M2M solution are as follows:
o ***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.

o ***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). Examples of WANs are public cellular mobile networks, fixed private networks, or even satellite links.

o ***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.

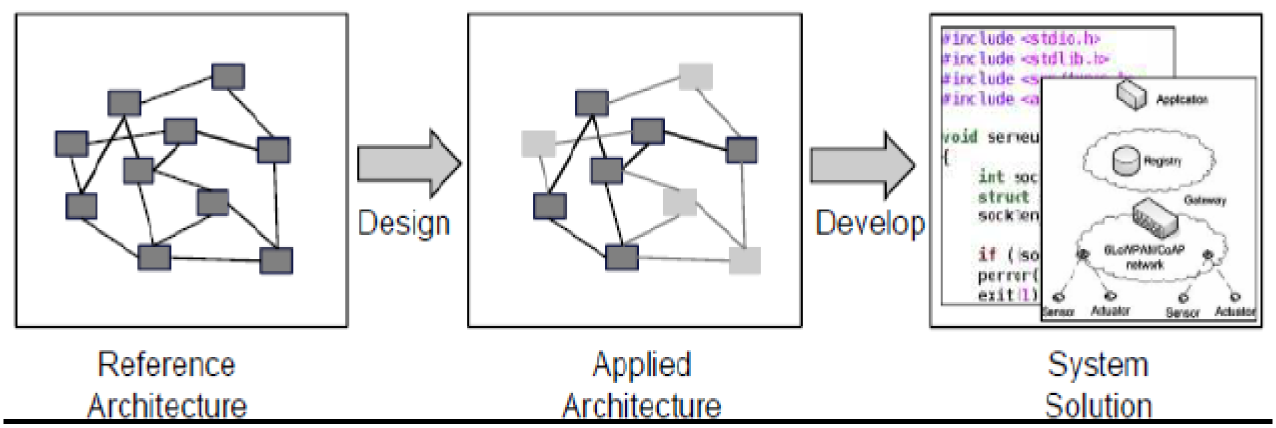
o ***M2M Application***. The application component of the solution is a realization of the highly specific monitor and control process. The application is further integrated into the overall business process system of the enterprise. The process of remotely monitoring and controlling assets can be of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

5.a)Define Reference and applied architecture with diagram

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.

Applied architecture is then the blueprint used to develop the actual system solution is as shown in figure



5.b) Explain 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

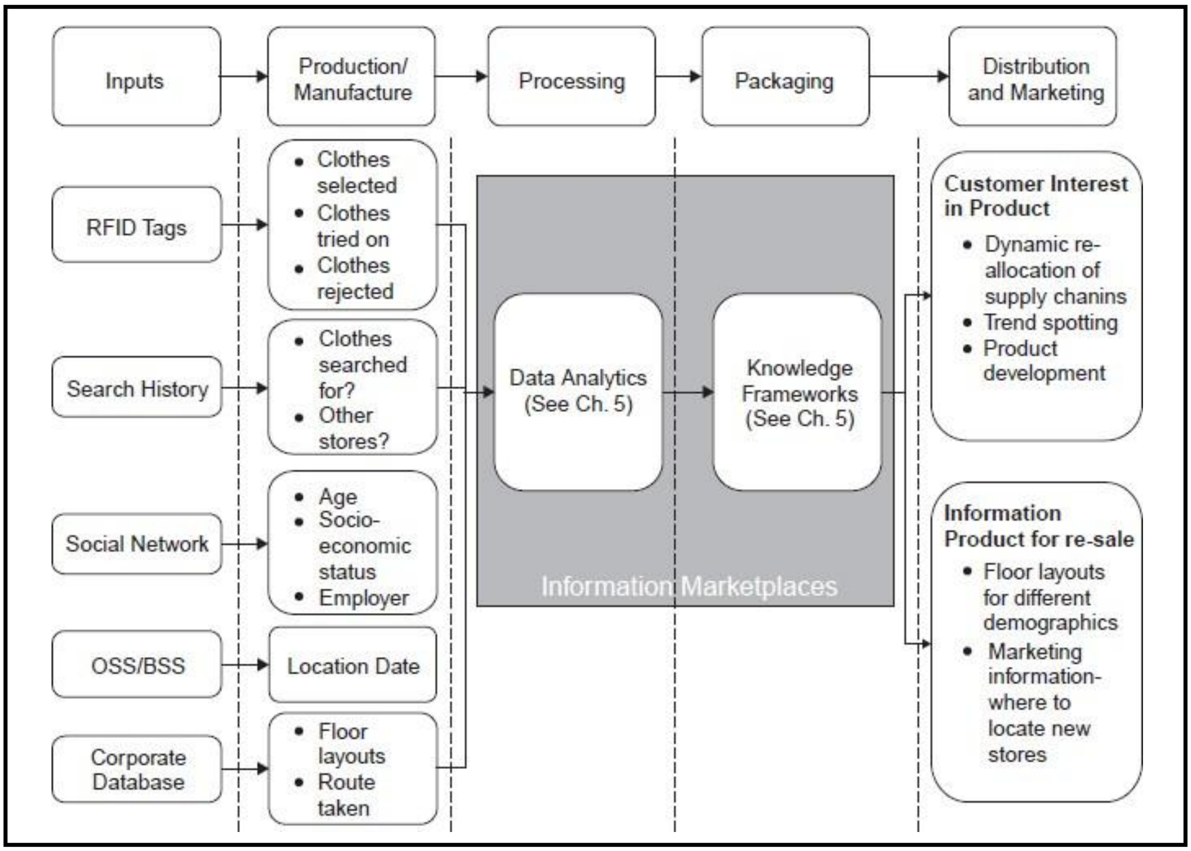


Figure 2.4: An Information Drive Value chain for Retail

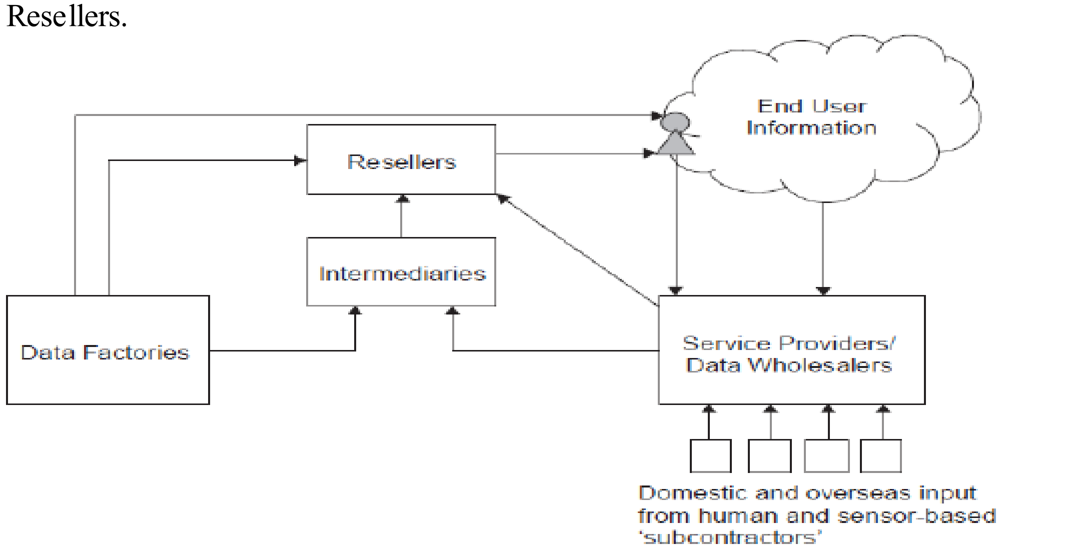
Similarly, if I was in a clothing store searching for a new outfit for work, through a combination of information about myself and the RFID tags on the different clothes, I could be guided to the correct clothing selection for my age group, my education level, and also my current employer. Information 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.

6) List and explain the fundamental roles of information-driven global value chain (I-GVC)

- 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.

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. 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. 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

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.

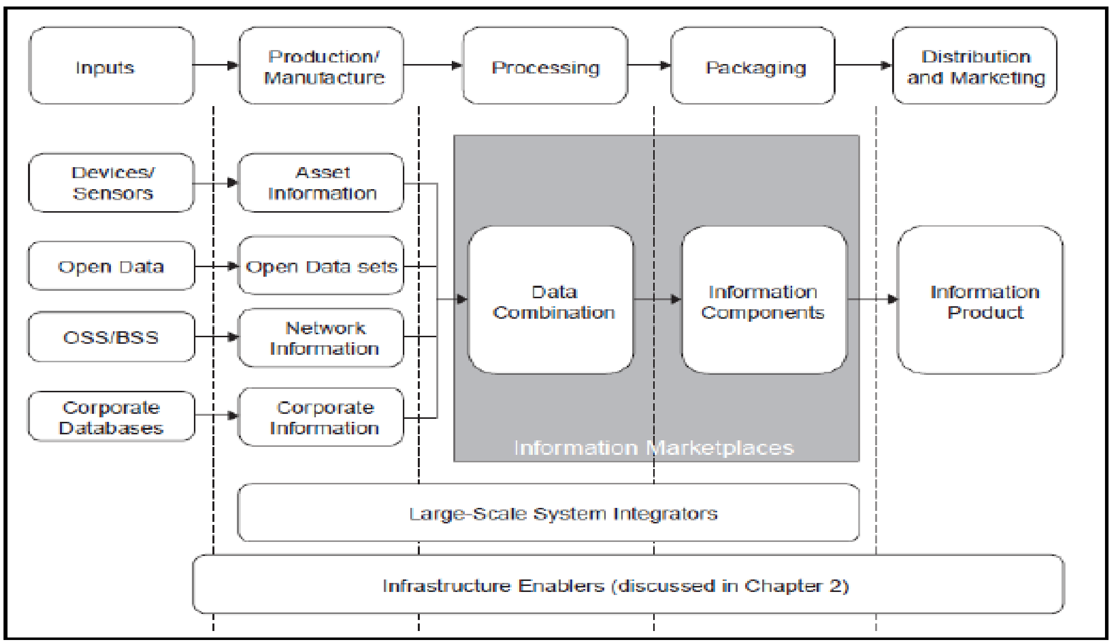
- **Intermediaries**

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.

7) Summarize the steps involved in 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.

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:

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.

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.

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).

8) With a neat diagram, explain IoT architecture outline

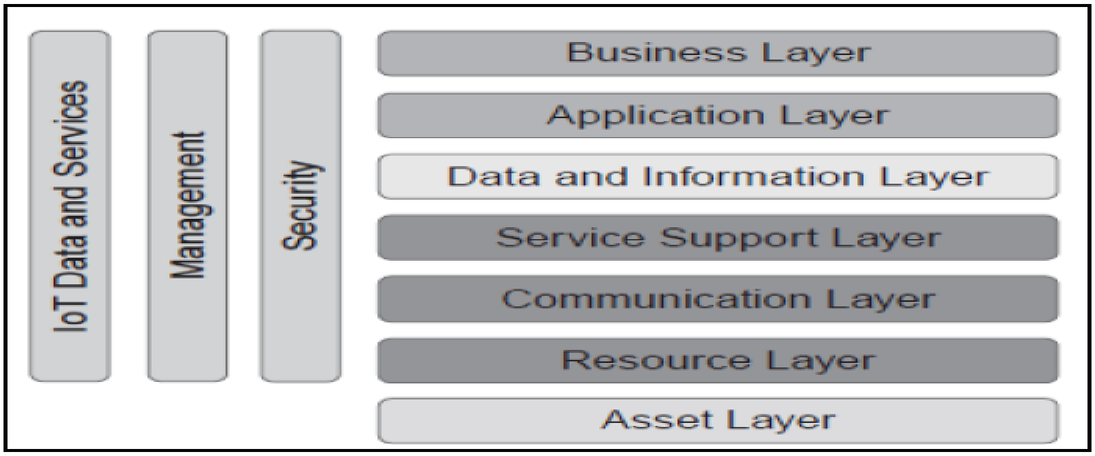


Figure 2.8 Functional Layers and capabilities of an IoT Solution

Asset Layer.

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.

o 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.

o 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.

Communication layer

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.

WAN
o 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.

o WANs can also be provided by different actors, where some networks can be regarded as public or as private.

o 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

- 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.

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.

- 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 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.

Application Layer

- 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).

Business Layer

- 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.