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MODULE 1

CHAPTER 1

Introduction to Internet of Things (IoT)

Syllabus

What is IoT? - IoT and Digitization. IoT Impact - Connected Roadways, Connected Factory, Smart Connected Buildings, Smart Creatures, Convergence of IT and OT, IoT Challenges, The oneM2M IoT Standardized Architecture, The IoT World Forum (IoTWF) Standardized Architecture, IoT Data Management and Compute Stack - Design considerations and Data related problems, Fog Computing, Edge Computing, The Hierarchy of Edge, Fog and Cloud.

GQ ⇒ 1-32 ⇒ (QB)

1.1 IOT AND DIGITIZATION

What is IOT?

GQ. What is IOT Digitization ? **(4 Marks)**

- The **Internet of Things** (IoT) describes the network of physical objects "things" that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet.
- *IoT* and *digitization* are terms that are often used interchangeably. In most contexts, this duality is fine, but there are key differences to be aware of.
- At a high level, IoT focuses on connecting "things," such as objects and machines, to a computer network, such as the Internet. IoT is a well-understood term used across the industry as a whole. On the other hand, digitization can mean different things to different people but generally encompasses the connection of "things" with the data they generate and the business insights that result.
- For example, in a shopping mall where Wi-Fi location tracking has been deployed, the "things" are the Wi-Fi devices. Wi-Fi location tracking is simply the capability of knowing where a consumer is in a retail environment through his or her smart phone's connection to the retailer's Wi-Fi network.
- While the value of connecting Wi-Fi devices or "things" to the Internet is obvious and appreciated by shoppers, tracking real-time location of Wi-Fi clients provides a specific business benefit to the mall and shop owners. In this case, it helps the business understand where shoppers tend to congregate and how much time they spend in different parts of a mall or store.
- Analysis of this data can lead to significant changes to the locations of product displays and advertising, where to place certain types of shops, how much rent to charge, and even where to station security guards.

Note

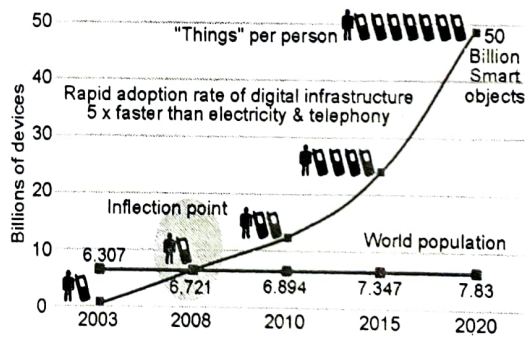
- For several years the term *Internet of Everything*, or *IoE*, was used extensively. Over time, the term IoE has been replaced by the term *digitization*.
- Although technical terms tend to evolve over time, the words *IoE* and *digitization* have roughly the same definition. IoT has always been a part of both, but it is important to note that IoT is a subset of both IoE and digitization.

- Digitization, as defined in its simplest form, is the conversion of information into a digital format. Digitization has been happening in one form or another for several decades.
- For example, the whole photography industry has been digitized. Pretty much everyone has digital cameras these days, either standalone devices or built into their mobile phones. Almost no one buys film and takes it to a retailer to get it developed. The digitization of photography has completely changed our experience when it comes to capturing images.
- In the context of IoT, digitization brings together things, data, and business process to make networked connections more relevant and valuable. A good example of this that many people can relate to is in the area of home automation with popular products, such as Nest.
- With Nest, sensors determine your desired climate settings and also tie in other smart objects, such as smoke alarms, video cameras, and various third-party devices.

1.2 IOT IMPACT

G.Q. Explain IOT Impact ? **(4 Marks)**

- Projections on the potential impact of IoT are impressive. About 14 billion, or just 0.06%, of "things" are connected to the Internet today. Cisco Systems predicts that by 2020, this number will reach 50 billion.
- A UK government report speculates that this number could be even higher, in the range of 100 billion objects connected. Cisco further estimates that these new connections will lead to $19 trillion in profits and cost savings.
- Fig. 1.2.1 provides a graphical look at the growth in the number of devices being connected.



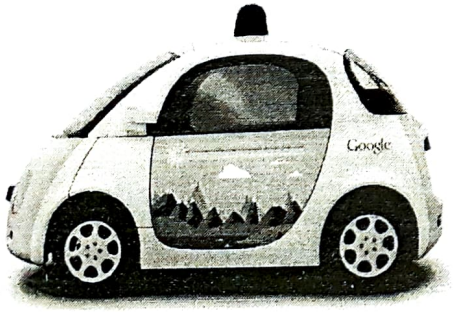
(1A1)**Fig. 1.2.1 : The Rapid Growth in the Number of Devices Connected to the Internet**

- What these numbers mean is that IoT will fundamentally shift the way people and businesses interact with their surroundings. Managing and monitoring smart objects using real-time connectivity enables a whole new level of data-driven decision making. This in turn results in the optimization of systems and processes and delivers new services that save time for both people and businesses while improving the overall quality of life.

1.2.1 Connected Roadways

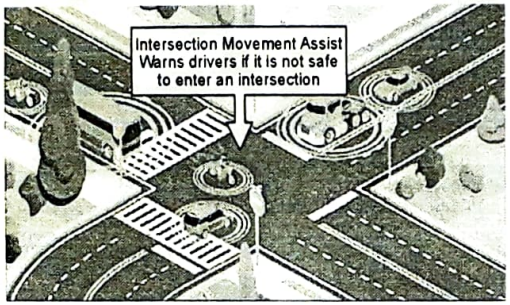
GQ. Write a short note on Connected Roadways.

- People have been fantasizing about the self-driving car, or autonomous vehicle, in literature and film for decades. While this fantasy is now becoming a reality with well-known projects like Google's self-driving car, IoT is also a necessary component for implementing a fully connected transportation infrastructure.
- IoT is going to allow self-driving vehicles to better interact with the transportation system around them through bidirectional data exchanges while also providing important data to the riders.
- Self-driving vehicles need always-on, reliable communications and data from other transportation-related sensors to reach their full potential. Connected roadways is the term associated with both the driver and driverless cars fully integrating with the surrounding transportation infrastructure.
- Fig. 1.2.2 shows a self-driving car designed by Google.



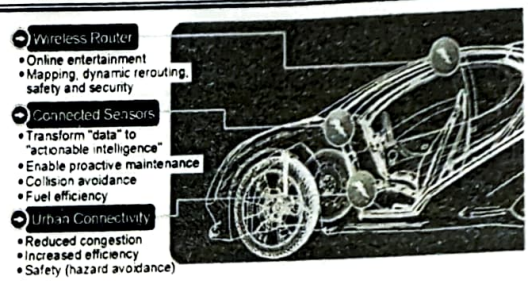
(1A2)**Fig. 1.2.2 : Google's Self-Driving Car**

- Basic sensors reside in cars already. They monitor oil pressure, tire pressure, temperature, and other operating conditions, and provide data around the core car functions.
- From behind the steering wheel, the driver can access this data while also controlling the car using equipment such as a steering wheel, pedals, and so on. The need for all this sensory information and control is obvious.
- The driver must be able to understand, handle, and make critical decisions while concentrating on driving safely. The Internet of Things is replicating this concept on a much larger scale.
- Today, we are seeing automobiles produced with thousands of sensors, to measure everything from fuel consumption to location to the entertainment your family is watching during the ride.
- As automobile manufacturers strive to reinvent the driving experience, these sensors are becoming IP-enabled to allow easy communication with other systems both inside and outside the car.
- In addition, new sensors and communication technologies are being developed to allow vehicles to "talk" to other vehicles, traffic signals, school zones, and other elements of the transportation infrastructure. We are now starting to realize a truly connected transportation solution.
- Connected roadways will bring many benefits to society. These benefits include reduced traffic jams and urban congestion, decreased casualties and fatalities, increased response time for emergency vehicles, and reduced vehicle emissions.
- For example, with IoT-connected roadways, a concept known as Intersection Movement Assist (IMA) is possible. This application warns a driver (or triggers the appropriate response in a self-driving car) when it is not safe to enter an intersection due to a high probability of a collision perhaps because another car has run a stop sign or strayed into the wrong lane.
- Thanks to the communications system between the vehicles and the infrastructure, this sort of scenario can be handled quickly and safely.
- See Fig. 1.2.3 for a graphical representation of IMA.
- IMA is one of many possible roadway solutions that emerge when we start to integrate IoT with both traditional and self-driving vehicles. Other solutions include automated vehicle tracking, cargo management, and road weather communications.



(1A3)**Fig. 1.2.3 : Application of Intersection Movement Assist**

- With automated vehicle tracking, a vehicle's location is used for notification of arrival times, theft prevention, or highway assistance. Cargo management provides precise positioning of cargo as it is enroute so that notification alerts can be sent to a dispatcher and routes can be optimized for congestion and weather. Road weather communications use sensors and data from satellites, roads, and bridges to warn vehicles of dangerous conditions or inclement weather on the current route.
- Today's typical road car utilizes more than a million lines of code and this only scratches the surface of the data potential. As cars continue to become more connected and capable of generating continuous data streams related to location, performance, driver behavior, and much more, the data generation potential of a single car is staggering. It is estimated that a fully connected car will generate more than 25 gigabytes of data per hour, much of which will be sent to the cloud.
- To put this in perspective, that's equivalent to a dozen HD movies sent to the cloud every hour by your car! Multiply that by the number of hours a car is driven per year and again by the number of cars on the road, and you see that the amount of connected car data generated, transmitted, and stored in the cloud will be in the zettabytes range per year (more than a billion petabytes per year).
- Fig. 1.2.4 provides an overview of the sort of sensors and connectivity that you will find in a connected car.
- Another area where connected roadways are undergoing massive disruption is in how the data generated by a car will be used by third parties.
- Clearly, the data generated by your car needs to be handled in a secure and reliable way, which means the network needs to be secure, it must provide authentication and verification of the driver and car, and it needs to be highly available. But who will use all this data?



(1A4)**Fig. 1.2.4 : The Connected Car**

- Automobile data is extremely useful to a wide range of interested parties. For example, tire companies can collect data related to use and durability of their products in a range of environments in real time.
- Automobile manufacturers can collect information from sensors to better understand how the cars are being driven, when parts are starting to fail, or whether the car has broken down details that will help them build better cars in the future. This becomes especially true as autonomous vehicles are introduced, which are sure to be driven in a completely different way than the traditional family car.
- In the future, car sensors will be able to interact with third-party applications, such as GPS/maps, to enable dynamic rerouting to avoid traffic, accidents, and other hazards. Similarly, Internet-based entertainment, including music, movies, and other streaming or downloads, can be personalized and customized to optimize a road trip.
- This data will also be used for targeted advertising. As GPS navigation systems become more integrated with sensors and wayfinding applications, it will become possible for personalized routing suggestions to be made.
- For example, if it is known that you prefer a certain coffee shop, through the use of a cloud-based data connector, the navigation system will be able to provide routing suggestions that have you drive your car past the right coffee shop.
- All these data opportunities bring into play a new technology: the IoT data broker. Imagine the many different types of data generated by an automobile and the plethora of different parties interested in this data. This poses a significant business opportunity.
- In a very real sense, the data generated by the car and driver becomes a valuable commodity that can be bought and sold. While the data transmitted from the car will likely go to one initial location in the cloud, from there the data can be separated and sold selectively by the data broker.

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- For example, tire companies will pay for information from sensors related to your tires, but they won't get anything else. While information brokers have been around a long time, the technology used to aggregate and separate the data from connected cars in a secure and governed manner is rapidly developing and will continue to be a major focus of the IoT industry for years to come.
- Connected roadways are likely to be one of the biggest growth areas for innovation. Automobiles and the roads they use have seen incredible change over the past century, but the changes ahead of us are going to be just as astonishing.
- In the past few years alone, we have seen highway systems around the world adopt sophisticated sensors systems that can detect seismic vibrations, car accidents, severe weather conditions, traffic congestion, and more.
- Recent advancements in roadway fiber-optic sensing technology is now able to record not only how many cars are passing but their speed and type. Due to the many reasons already discussed, connected cars and roadways are early adopters of IoT technology.
- For a more in-depth discussion of IoT use cases and architectures in the transportation industry, "Transportation."

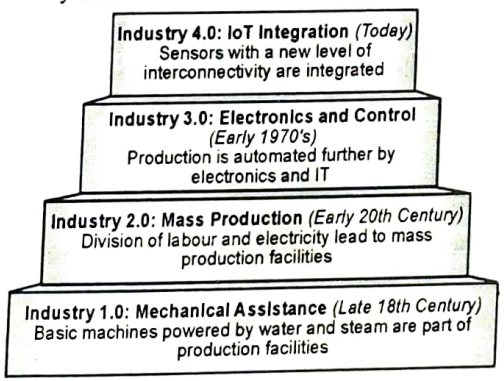
1.2.2 Connected Factory

GQ. Write short note on Connected factory ? **(2 Marks)**

- For years, traditional factories have been operating at a disadvantage, impeded by production environments that are "disconnected" or, at the very least, "strictly gated" to corporate business systems, supply chains, and customers and partners. Managers of these traditional factories are essentially "flying blind" and lack visibility into their operations. These operations are composed of plant floors, front offices, and suppliers operating in independent silos. Consequently, rectifying downtime issues, quality problems, and the root causes of various manufacturing inefficiencies is often difficult.
- The main challenges facing manufacturing in a factory environment today include the following :
  - Image Accelerating new product and service introductions to meet customer and market opportunities.
  - Image Increasing plant production, quality, and uptime while decreasing cost.
- Adding another level of complication to these challenges is the fact that they often need to be addressed at various levels of the manufacturing business.

- For example, executive management is looking for new ways to manufacture in a more cost-effective manner while balancing the rising energy and material costs. Product development has time to market as the top priority. Plant managers are entirely focused on gains in plant efficiency and operational agility. The controls and automation department looks after the plant networks, controls, and applications and therefore requires complete visibility into all these systems.
- Industrial enterprises around the world are retooling their factories with advanced technologies and architectures to resolve these problems and boost manufacturing flexibility and speed. These improvements help them achieve new levels of overall equipment effectiveness, supply chain responsiveness, and customer satisfaction.
- A convergence of factory-based operational technologies and architectures with global IT networks is starting to occur, and this is referred to as the connected factory.
- As with the IoT solutions for the connected roadways previously discussed, there are already large numbers of basic sensors on factory floors.
- However, with IoT, these sensors not only become more advanced but also attain a new level of connectivity. They are smarter and gain the ability to communicate, mainly using the Internet Protocol (IP) over an Ethernet infrastructure.
- In addition to sensors, the devices on the plant floor are becoming smarter in their ability to transmit and receive large quantities of real-time informational and diagnostic data. Ethernet connectivity is becoming pervasive and spreading beyond just the main controllers in a factory to devices such as the robots on the plant floor. In addition, more IP-enabled devices, including video cameras, diagnostic smart objects, and even personal mobile devices, are being added to the manufacturing environment.
- For example, a smelting facility extracts metals from their ores. The facility uses both heat and chemicals to decompose the ore, leaving behind the base metal. This is a multistage process, and the data and controls are all accessed via various control rooms in a facility.
- Operators must go to a control room that is often hundreds of meters away for data and production changes. Hours of operator time are often lost to the multiple trips to the control room needed during a shift. With IoT and a connected factory solution, true "machine-to-people" connections are implemented to bring sensor data directly to operators on the floor via mobile devices.
- Time is no longer wasted moving back and forth between the control rooms and the plant floor. In addition, because the operators now receive data in real time, decisions can be made immediately to improve production and fix any quality problems.

- Another example of a connected factory solution involves a real-time location system (RTLS). An RTLS utilizes small and easily deployed Wi-Fi RFID tags that attach to virtually any material and provide real-time location and status.
- These tags enable a facility to track production as it happens. These IoT sensors allow components and materials on an assembly line to "talk" to the network. If each assembly line's output is tracked in real time, decisions can be made to speed up or slow production to meet targets, and it is easy to determine how quickly employees are completing the various stages of production. Bottlenecks at any point in production and quality problems are also quickly identified.
- While we tend to look at IoT as an evolution of the Internet, it is also sparking an evolution of industry. In 2016 the World Economic Forum referred to the evolution of the Internet and the impact of IoT as the "fourth Industrial Revolution."
  - The first Industrial Revolution occurred in Europe in the late eighteenth century, with the application of steam and water to mechanical production.
  - The second Industrial Revolution, which took place between the early 1870s and the early twentieth century, saw the introduction of the electrical grid and mass production.
  - The third revolution came in the late 1960s/early 1970s, as computers and electronics began to make their mark on manufacturing and other industrial systems.
  - The fourth Industrial Revolution is happening now, and the Internet of Things is driving it. Fig. 1.2.5 summarizes these four Industrial Revolutions as Industry 1.0 through Industry 4.0.



(1A5)**Fig. 1.2.5 : The Four Industrial Revolutions**

- The IoT wave of Industry 4.0 takes manufacturing from a purely automated assembly line model of production to a model where the machines are intelligent and communicate with one another.
- IoT in manufacturing brings with it the opportunity for inserting intelligence into factories. This starts with creating smart objects, which involves embedding sensors, actuators, and controllers into just about everything related to production. Connections tie it all together so that people and machines work together to analyze the data and make intelligent decisions. Eventually this leads to machines predicting failures and self-healing and points to a world where human monitoring and intervention are no longer necessary.

1.2.3 Smart Connected Buildings

- Another place IoT is making a disruptive impact is in the smart connected buildings space. In the past several decades, buildings have become increasingly complex, with systems overlaid one upon another, resulting in complex intersections of structural, mechanical, electrical, and IT components. Over time, these operational networks that support the building environment have matured into sophisticated systems; however, for the most part, they are deployed and managed as separate systems that have little to no interaction with each other.
- The function of a building is to provide a work environment that keeps the workers comfortable, efficient, and safe. Work areas need to be well lit and kept at a comfortable temperature. To keep workers safe, the fire alarm and suppression system needs to be carefully managed, as do the door and physical security alarm systems.
- While intelligent systems for modern buildings are being deployed and improved for each of these functions, most of these systems currently run independently of each other and they rarely take into account where the occupants of the building actually are and how many of them are present in different parts of the building.
- However, many buildings are beginning to deploy sensors throughout the building to detect occupancy. These tend to be motion sensors or sensors tied to video cameras. Motion detection occupancy sensors work great if everyone is moving around in a crowded room and can automatically shut the lights off when everyone has left, but what if a person in the room is out of sight of the sensor? It is a frustrating matter to be at the mercy of an unintelligent sensor on the wall that wants to turn off the lights on you.
- Similarly, sensors are often used to control the heating, ventilation, and air-conditioning (HVAC) system.

- Temperature sensors are spread throughout the building and are used to influence the building management system's (BMS's) control of air flow into a room.
- Another interesting aspect of the smart building is that it makes them easier and cheaper to manage. Considering the massive costs involved in operating such complex structures, not to mention how many people spend their working lives inside a building, managers have become increasingly interested in ways to make buildings more efficient and cheaper to manage.
- Have you ever heard people complain that they had too little working space in their office, or that the office space wasn't being used efficiently? When people go to their managers and ask for a change to the floor plan, such as asking for an increase in the amount of space they work in, they are often asked to prove their case. But workplace floor efficiency and usage evidence tends to be anecdotal at best.
- When smart building sensors and occupancy detection are combined with the power of data analytics it becomes easy to demonstrate floor plan usage and prove your case.
- Alternatively, the building manager can use a similar approach to see where the floor is not being used efficiently and use this information to optimize the available space. This has brought about the age of building automation, empowered by IoT.
- While many technical solutions exist for looking after building systems, until recently they have all required separate overlay networks, each responsible for its assigned task. In an attempt to connect these systems into a single framework, the Building Automation System (BAS) has been developed to provide a single management system for the HVAC, lighting, fire alarm, and detection systems, as well as access control.
- All these systems may support different types of sensors and connections to the BAS. How do you connect them together so the building can be managed in a coherent way? This highlights one of the biggest challenges in IoT, which is discussed throughout this book : the heterogeneity of IoT systems.
- Before you can bring together heterogeneous systems, they need to converge at the network layer and support a common services layer that allows application integration. The value of converged networks is well documented.
- For example, in the early 2000s, Cisco and several other companies championed the convergence of voice and video onto single IP networks that were shared with other IT applications.

- The economies of scale and operational efficiencies gained were so massive that VoIP and collaboration technologies are now the norm. However, the convergence to IP and a common services framework for buildings has been slower.
- For example, the de facto communication protocol responsible for building automation is known as BACnet (Building Automation and Control Network). In a nutshell, the BACnet protocol defines a set of services that allow Ethernet-based communication between building devices such as HVAC, lighting, access control, and fire detection systems. The same building Ethernet switches used for IT may also be used for BACnet. This standardization also makes possible an intersection point to the IP network (which is run by the IT department) through the use of a gateway device. In addition, BACnet/IP has been defined to allow the "things" in the building network to communicate over IP, thus allowing closer consolidation of the building management system on a single network.

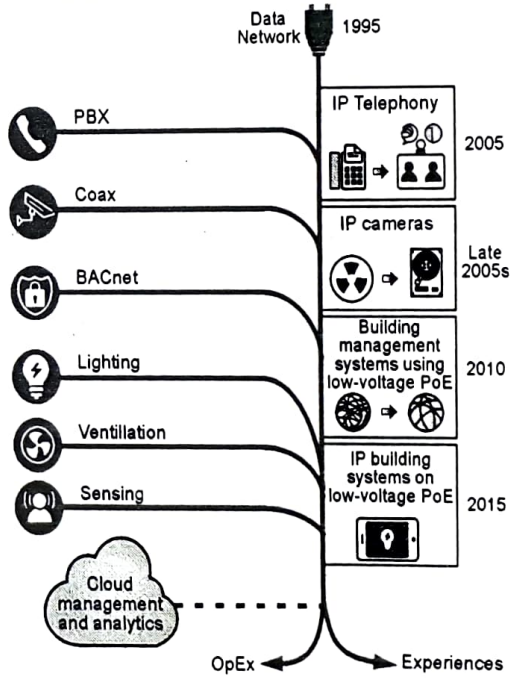
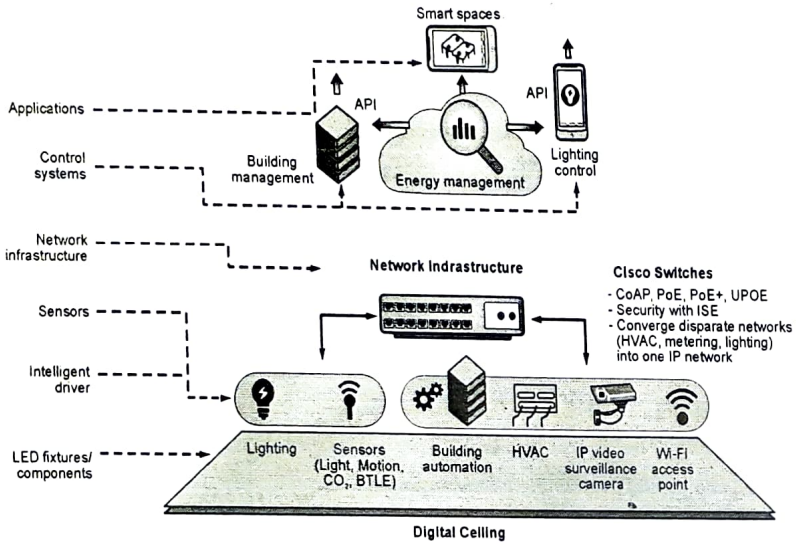


Fig. 1.2.6 illustrates the conversion of building protocols to IP over time.

- Another promising IoT technology in the smart connected building, and one that is seeing widespread adoption, is the "digital ceiling."

- The digital ceiling is more than just a lighting control system. This technology encompasses several of the building's different networks including lighting, HVAC, blinds, CCTV (closed-circuit television), and security systems and combines them into a single IP network.



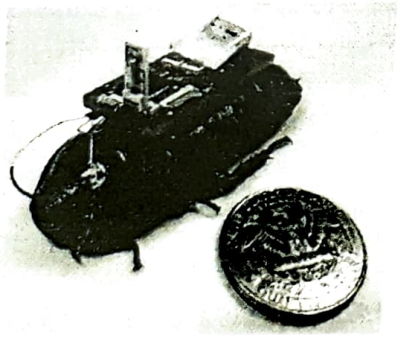
(1A7)**Fig. 1.2.7 : A Framework for the Digital Ceiling**

- Central to digital ceiling technology is the lighting system. As you are probably aware, the lighting market is currently going through a major shift toward light-emitting diodes (LEDs). Compared to traditional lighting, LEDs offer lower energy consumption and far longer life. The lower power requirements of LED fixtures allow them to run on Power over Ethernet (PoE), permitting them to be connected to standard network switches.
- In a digital ceiling environment, every luminaire or lighting fixture is directly network-attached, providing control and power over the same infrastructure. This transition to LED lighting means that a single converged network is now able to encompasses luminaires that are part of consolidated building management as well as elements managed by the IT network, supporting voice, video, and other data applications.
- The next time you look at the ceiling in your office building, count the number of lights. The quantity of lights easily outnumbers the number of physical wired ports by a hefty margin.

- Obviously, supporting the larger number of Ethernet ports and density of IP addresses requires some redesign of the network, and it also requires a quiet, fanless PoE-capable switch in the ceiling. That being said, the long-term business case supporting reduced energy costs from LED luminaries versus traditional fluorescent or halogen lights is so significant that the added initial investment in the network is almost inconsequential.
- The business case for the digital ceiling becomes even stronger when a building is being renovated or a new structure is being built. In these cases, the cost benefit of running CAT 6/5e cables in the ceiling versus plenum-rated electrical wiring to every light is substantial.
- The energy savings value of PoE-enabled LED lighting in the ceiling is clear. However, having an IP-enabled sensor device in the ceiling at every point people may be present opens up an entirely new set of possibilities. For example, most modern LED ceiling fixtures support occupancy sensors.
- These sensors provide high-resolution occupancy data collection, which can be used to turn the lights on and off, and this same data can be combined with advanced analytics to control other systems, such as HVAC and security.
- Unlike traditional sensors that use rudimentary motion detection, modern lighting sensors integrate a variety of occupancy-sensing technologies, including Bluetooth low energy (BLE) and Wi-Fi. The science here is simple.
- Because almost every person these days carries a smart device that supports BLE and Wi-Fi, all the sensor has to do is detect BLE or Wi-Fi beacons from a nearby device.
- When someone walks near a light, the person's location is detected, and the wireless system can send information to control the air flow from the HVAC system into that zone in real time, maximizing the comfort of the office worker. Figure shows an example of an occupancy sensor in a digital ceiling light.
- You can begin to imagine the possibilities that IoT smart lighting brings to a workplace setting.
- Not only does it provide for optimized levels of lighting based on actual occupancy and building usage, it allows granular control of temperature, management of smoke and fire detection, video cameras, and building access control.
- IoT allows all this to run through a single network, requiring less installation time and a lower total cost of system ownership.

1.2.4 Smart Creatures

- When you think about IoT, you probably picture only inanimate objects and machines being connected. However, IoT also provides the ability to connect living things to the Internet. Sensors can be placed on animals and even insects just as easily as on machines, and the benefits can be just as impressive.
- One of the most well-known applications of IoT with respect to animals focuses on what is often referred to as the "connected cow." Sparked, a Dutch company, developed a sensor that is placed in a cow's ear. The sensor monitors various health aspects of the cow as well as its location and transmits the data wirelessly for analysis by the farmer.
- The data from each of these sensors is approximately 200 MB per year, and you obviously need a network infrastructure to make the connection with the sensors and store the information.
- Once the data is being collected, however, you get a complete view of the herd, with statistics on every cow. You can learn how environmental factors may be affecting the herd as a whole and about changes in diet. This enables early detection of disease as cows tend to eat less days before they show symptoms. These sensors even allow the detection of pregnancy in cows.
- Another application of IoT to organisms involves the placement of sensors on roaches. While the topic of roaches is a little unsettling to many folks, the potential benefits of IoT-enabled roaches could make a life-saving difference in disaster situations.
- Researchers at North Carolina State University are working with Madagascar hissing cockroaches in the hopes of helping emergency personnel rescue survivors after a disaster.



(1A8)**Fig. 1.2.8 : IoT-Enabled Roach Can Assist in Finding Survivors After a Disaster (Photo courtesy of Alper Bozkurt, NC State University)**

- As shown in Fig. 1.2.8, an electronic backpack attaches to a roach. This backpack communicates with the roach through parts of its body.
- Low-level electrical pulses to an antenna on one side makes the roach turn to the opposite side because it believes it is encountering an obstacle. The cerci of the roach are sensory organs on the abdomen that detect danger through changing air currents. When the backpack stimulates the cerci, the roach moves forward because it thinks a predator is approaching.
- The electronic backpack uses wireless communication to a controller and can be "driven" remotely. Imagine a fleet of these roaches being used in a disaster scenario, such as searching for survivors in a collapsed building after an earthquake. The roaches are naturally designed to efficiently move around objects in confined spaces. Technology has also been tested to keep the roaches in the disaster area; it is similar to the invisible fencing that is often used to keep dogs in a yard. The use of roaches in this manner allows for the mapping of spaces that rescue personnel cannot access, which helps search for survivors.
- To help with finding a person trapped in the rubble of a collapsed building, the electronic backpack is equipped with directional microphones that allow for the detection of certain sounds and the direction from which they are coming.
- Software can analyze the sounds to ensure that they are from a person rather than from, say, a leaking pipe. Roaches can then be steered toward the sounds that may indicate people who are trapped. In addition, the microphones provide the ability for rescue personnel to listen in on whatever sounds are detected.
- These examples show that IoT often goes beyond just adding sensors and more intelligence to nonliving "things." Living "things" can also be connected to the Internet and this connection can provide important results.

1.3 CONVERGENCE OF IT AND OT

GQ. Explain Converence of IT and OT. **(4 Marks)**

- Until recently, Information Technology (IT) and Operational Technology (OT) have for the most part lived in separate worlds. IT supports connections to the Internet along with related data and technology systems and is focused on the secure flow of data across an organization.

- OT monitors and controls devices and processes on physical operational systems. These systems include assembly lines, utility distribution networks, production facilities, roadway systems, and many more. Typically, IT did not get involved with the production and logistics of OT environments.
- Specifically, the IT organization is responsible for the information systems of a business, such as email, file and print services, databases, and so on.
- In comparison, OT is responsible for the devices and processes acting on industrial equipment, such as factory machines, meters, actuators, electrical distribution automation devices, SCADA (supervisory control and data acquisition) systems, and so on.
- Traditionally, OT has used dedicated networks with specialized communications protocols to connect these devices, and these networks have run completely separately from the IT networks.
- Management of OT is tied to the lifeblood of a company. For example, if the network connecting the machines in a factory fails, the machines cannot function, and production may come to a standstill, negatively impacting business on the order of millions of dollars. On the other hand, if the email server (run by the IT department) fails for a few hours, it may irritate people, but it is unlikely to impact business at anywhere near the same level.
- Table 1.3.1 highlights some of the differences between IT and OT networks and their various challenges.

Table 1..3.1 : Comparing Operational Technology (OT) and Information Technology (IT)

Criterion	Industrial OT Network	Enterprise IT Network
Operational focus	Keep the business operating 24 × 7	Manage the computers, data, and employee communication system in a secure way
Priorities	1. Availability	1. Security
	2.. Integrity	2. Integrity
	3. Security	3. Availability
Types of data	Monitoring, control, and supervisory data	Voice, video, transactional, and bulk data
Security	Controlled physical access to devices	Devices and users authenticated to the network

Challenges in IT & OT.

Failure Impact

Criterion	Industrial OT Network	Enterprise IT Network
Implication of failure	OT network disruption directly impacts business	Can be business impacting, depending on industry, but workarounds may be possible
Network upgrades (software or hardware)	Only during operational maintenance windows	Often requires an outage window when workers are notonsite; impact can be mitigated
Security vulnerability	Low: OT networks are isolated and often use proprietary protocols	High: continual patching of hosts is required, and the network is connected to Internet and requires vigilant protection

- With the rise of IoT and standards-based protocols, such as IPv6, the IT and OT worlds are converging or, more accurately, OT is beginning to adopt the network protocols, technology, transport, and methods of the IT organization, and the IT organization is beginning to support the operational requirements used by OT.
- When IT and OT begin using the same networks, protocols, and processes, there are clear economies of scale. Not only does convergence reduce the amount of capital infrastructure needed but networks become easier to operate, and the flexibility of open standards allows faster growth and adaptability to new technologies.
- However, as you can see from Table 1.3.1, the convergence of IT and OT to a single consolidated network poses several challenges. There are fundamental cultural and priority differences between these two organizations. IoT is forcing these groups to work together, when in the past they have operated rather autonomously.
- For example, the OT organization is baffled when IT schedules a weekend shutdown to update software without regard to production requirements. On the other hand, the IT group does not understand the prevalence of proprietary or specialized systems and solutions deployed by OT.
- Take the case of deploying quality of service (QoS) in a network. When the IT team deploys QoS, voice and video traffic are almost universally treated with the highest level of service.
- However, when the OT system shares the same network, a very strong argument can be made that the real-time OT traffic should be given a higher priority than even voice because any disruption in the OT network could impact the business.

- With the merging of OT and IT, improvements are being made to both systems. OT is looking more toward IT technologies with open standards, such as Ethernet and IP. At the same time, IT is becoming more of a business partner with OT by better understanding business outcomes and operational requirements.
- The overall benefit of IT and OT working together is a more efficient and profitable business due to reduced downtime, lower costs through economy of scale, reduced inventory, and improved delivery times. When IT/OT convergence is managed correctly, IoT becomes fully supported by both groups. This provides a "best of both worlds" scenario, where solid industrial control systems reside on an open, integrated, and secure technology foundation.6

☞ IoT Challenges

GQ. Explain different IOT challenges. **(4 Marks)**

- While an IoT-enabled future paints an impressive picture, it does not come without significant challenges.
- Many parts of IoT have become reality, but certain obstacles need to be overcome for IoT to become ubiquitous throughout industry and our everyday life.
- Table 1.3.2 highlights a few of the most significant challenges and problems that IoT is currently facing.

Table 1.3.2 : IoT Challenges

Privacy	As sensors become more prolific in our everyday lives, much of the data they gather will be specific to individuals and their activities. This data can range from health information to shopping patterns and transactions at a retail establishment. For businesses, this data has monetary value. Organizations are now discussing who owns this data and how individuals can control whether it is shared and with whom.
Big data and data analytics	IoT and its large number of sensors is going to trigger a deluge of data that must be handled, This data will provide critical information and insights if it can be processed in an efficient manner. The challenge, however, is evaluating massive amounts of data arriving from different sources in various forms and doing so in a timely mariner.

Interoperability	As with any other nascent technology, various protocols and architectures are jockeying for market share and standardization within IoT. Some of these protocols and architectures are based on proprietary elements, and others are open. Recent IoT standards arc helping minimize this problem, but there are often various protocols and implementations available for la networks. The prominent protocols and architectures especially open, standards-based implementations are the subject of this book.

☞ Summary

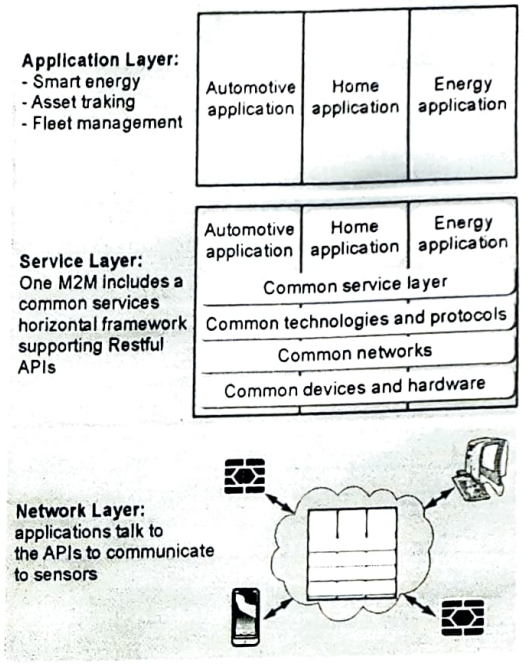
- This chapter provides an introductory look at the Internet of Things and answers the question "What is IoT?" IoT is about connecting the unconnected, enabling smart objects to communicate with other objects, systems, and people.
- The end result is an intelligent network that allows more control of the physical world and the enablement of advanced applications.
- This chapter also provides a historical look at IoT, along with a current view of IoT as the next evolutionary phase of the Internet. This chapter details a few high-level use cases to show the impact of IoT and some of the ways it will be changing our world.
- A number of IoT concepts and terms are defined throughout this chapter.
- The differences between IoT and digitization are discussed, as well as the convergence between IT and OT. The last section details the challenges faced by IoT.

⏭ 1.4 THE ONEM2M IOT STANDARDIZED ARCHITECTURE

GQ. Explain M2M IOT standardization Architecture. **(4 Marks)**

- In an effort to standardize the rapidly growing field of machine-to-machine (M2M) communications, the European Telecommunications Standards Institute (ETSI) created the M2M Technical Committee in 2008.

- The goal of this committee was to create a common architecture that would help accelerate the adoption of M2M applications and devices. Over time, the scope has expanded to include the Internet of Things.
- Other related bodies also began to create similar M2M architectures, and a common standard for M2M became necessary.
- Recognizing this need, in 2012 ETSI and 13 other founding members launched oneM2M as a global initiative designed to promote efficient M2M communication systems and IoT.
- The goal of oneM2M is to create a common services layer, which can be readily embedded in field devices to allow communication with application servers.1 oneM2M's framework focuses on IoT services, applications, and platforms.
- These include smart metering applications, smart grid, smart city automation, e-health, and connected vehicles.
- One of the greatest challenges in designing an IoT architecture is dealing with the heterogeneity of devices, software, and access methods. By developing a horizontal platform architecture, oneM2M is developing standards that allow interoperability at all levels of the IoT stack.
- For example, you might want to automate your HVAC system by connecting it with wireless temperature sensors spread throughout your office. You decide to deploy sensors that use LoRaWAN technology (discussed in Chapter 4, "Connecting Smart Objects").
- The problem is that the LoRaWAN network and the BACnet system that your HVAC and BMS run on are completely different systems and have no natural connection point. This is where the oneM2M common services architecture comes in. oneM2M's horizontal framework and RESTful APIs allow the LoRaWAN system to interface with the building management system over an IoT network, thus promoting end-to-end IoT communications in a consistent way, no matter how heterogeneous the networks.
- Fig. 1.4.1 illustrates the oneM2M IoT architecture.
- The oneM2M architecture divides IoT functions into three major domains: the application layer, the services layer, and the network layer.
- While this architecture may seem simple and somewhat generic at first glance, it is very rich and promotes interoperability through IT-friendly APIs and supports a wide range of IoT technologies.



(1A9)**Fig. 1.4.1 : The Main Elements of the oneM2M IoT Architecture**

Let's examine each of these domains in turn

(1) Image Applications layer

- The oneM2M architecture gives major attention to connectivity between devices and their applications.
- This domain includes the application-layer protocols and attempts to standardize northbound API definitions for interaction with business intelligence (BI) systems.
- Applications tend to be industry-specific and have their own sets of data models, and thus they are shown as vertical entities.

(2) Image Services layer

- This layer is shown as a horizontal framework across the vertical industry applications. At this layer, horizontal modules include the physical network that the IoT applications run on, the underlying management protocols, and the hardware. Examples include backhaul communications via cellular, MPLS networks, VPNs, and so on. Riding on top is the common services layer.

- This conceptual layer adds APIs and middleware supporting third-party services and applications. One of the stated goals of oneM2M is to "develop technical specifications which address the need for a common M2M Service Layer that can be readily embedded within various hardware and software nodes, and rely upon connecting the myriad of devices in the field area network to M2M application servers, which typically reside in a cloud or data center."
- A critical objective of oneM2M is to attract and actively involve organizations from M2M-related business domains, including telematics and intelligent transportation, healthcare, utility, industrial automation, and smart home applications, to name just a few.

(3) Image Network layer

- This is the communication domain for the IoT devices and endpoints. It includes the devices themselves and the communications network that links them. Embodiments of this communications infrastructure include wireless mesh technologies, such as IEEE 802.15.4, and wireless point-to-multipoint systems, such as IEEE 801.11ah. Also included are wired device connections, such as IEEE 1901 power line communications
- In many cases, the smart (and sometimes not-so-smart) devices communicate with each other. In other cases, machine-to-machine communication is not necessary, and the devices simply communicate through a field area network (FAN) to use-case-specific apps in the IoT application domain. Therefore, the device domain also includes the gateway device, which provides communications up into the core network and acts as a demarcation point between the device and network domains.
- Technical Specifications and Technical Reports published by oneM2M covering IoT functional architecture and other aspects can be found at www.onem2m.org.

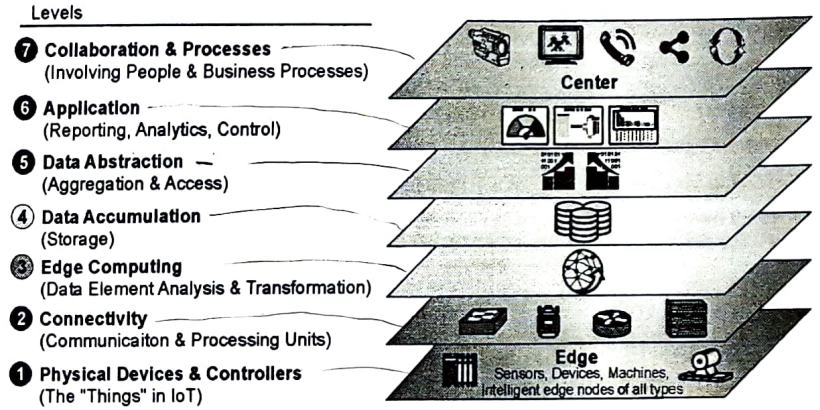
1.5 THE IOT WORLD FORUM (IOTWF) STANDARDIZED ARCHITECTURE

GQ. Explain IoTWF architecture in details. **(4 Marks)**

- In 2014 the IoTWF architectural committee (led by Cisco, IBM, Rockwell Automation, and others) published a seven-layer IoT architectural reference model.
- While various IoT reference models exist, the one put forth by the IoT World Forum offers a clean, simplified perspective on IoT and includes edge computing, data storage,

and access. It provides a succinct way of visualizing IoT from a technical perspective. Each of the seven layers is broken down into specific functions, and security encompasses the entire model.

- Fig. 1.5.1 details the IoT Reference Model published by the IoTWF.



(1A10)**Fig. 1.5.1 : IoT Reference Model Published by the IoT World Forum**

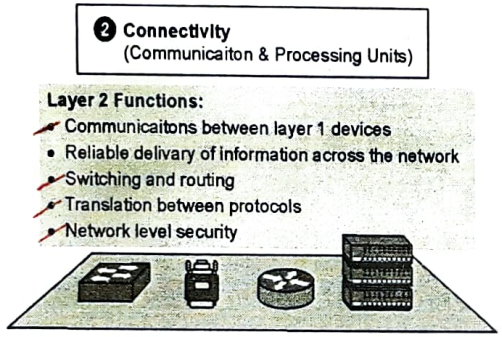
- As shown in Fig. 1.5.1, the IoT Reference Model defines a set of levels with control flowing from the center (this could be either a cloud service or a dedicated data center), to the edge, which includes sensors, devices, machines, and other types of intelligent end nodes.
- In general, data travels up the stack, originating from the edge, and goes northbound to the center. Using this reference model, we are able to achieve the following:
- The following sections look more closely at each of the seven layers of the IoT Reference Model.

Layer 1 : Physical Devices and Controllers Layer

- The first layer of the IoT Reference Model is the physical devices and controllers layer. This layer is home to the "things" in the Internet of Things, including the various endpoint devices and sensors that send and receive information.
- The size of these "things" can range from almost microscopic sensors to giant machines in a factory. Their primary function is generating data and being capable of being queried and/or controlled over a network.

Layer 2 : Connectivity Layer

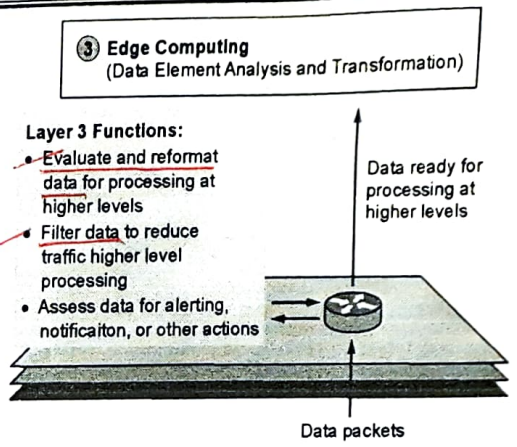
- In the second layer of the IoT Reference Model, the focus is on connectivity. The most important function of this IoT layer is the reliable and timely transmission of data. More specifically, this includes transmissions between Layer 1 devices and the network and between the network and information processing that occurs at Layer 3 (the edge computing layer).
- As you may notice, the connectivity layer encompasses all networking elements of IoT and doesn't really distinguish between the last-mile network (the network between the sensor/endpoint and the IoT gateway, discussed later in this chapter), gateway, and backhaul networks. Functions of the connectivity layer are detailed in Fig. 1.5.2.



(1A11)**Fig. 1.5.2 : IoT Reference Model Connectivity Layer Functions**

Layer 3 : Edge Computing Layer

- Edge computing is the role of Layer 3. Edge computing is often referred to as the "fog" layer and is discussed in the section "Fog Computing," later in this chapter.
- At this layer, the emphasis is on data reduction and converting network data which flows into information that is ready for storage and processing by higher layers. One of the basic principles of this reference model is that information processing is initiated as early and as close to the edge of the network as possible.
- Fig. 1.5.3 highlights the functions handled by Layer 3 of the IoT Reference Model.
- Another important function that occurs at Layer 3 is the evaluation of data to see if it can be filtered or aggregated before being sent to a higher layer. This also allows for data to be reformatted or decoded, making additional processing by other systems easier. Thus, a critical function is assessing the data to see if predefined thresholds are crossed and any action or alerts need to be sent.



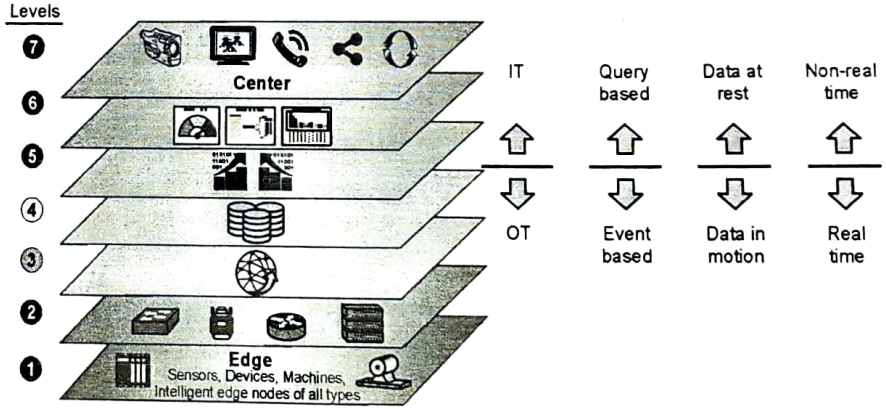
(1A12)**Fig. 1.5.3 : IoT Reference Model Layer 3 Functions**

Upper Layers: Layers 4–7

- The upper layers deal with handling and processing the IoT data generated by the bottom layer.
- For the sake of completeness, Layers 4–7 of the IoT Reference Model are summarized

IT and OT Responsibilities in the IoT Reference Model

- An interesting aspect of visualizing an IoT architecture this way is that you can start to organize responsibilities along IT and OT lines. Fig. 1.5.4 illustrates a natural demarcation point between IT and OT in the IoT Reference Model framework.



(1A13)**Fig. 1.5.4 : IoT Reference Model Separation of IT and OT**

- As demonstrated in Fig. 1.5.4, IoT systems have to cross several boundaries beyond just the functional layers. The bottom of the stack is generally in the domain of OT. For an industry like oil and gas, this includes sensors and devices connected to pipelines, oil rigs, refinery machinery, and so on. The top of the stack is in the IT area and includes things like the servers, databases, and applications, all of which run on a part of the network controlled by IT.
- In the past, OT and IT have generally been very independent and had little need to even talk to each other. IoT is changing that paradigm.
- At the bottom, in the OT layers, the devices generate real-time data at their own rate-sometimes vast amounts on a daily basis.
- Not only does this result in a huge amount of data transiting the IoT network, but the sheer volume of data suggests that applications at the top layer will be able to ingest that much data at the rate required. To meet this requirement, data has to be buffered or stored at certain points within the IoT stack.
- Layering data management in this way throughout the stack helps the top four layers handle data at their own speed.

IOT Data Management And Compute Stack

- This model also has limitations. As data volume, the variety of objects connecting to the network, and the need for more efficiency increase, new requirements appear, and those requirements tend to bring the need for data analysis closer to the IoT system.
- These new requirements include the following :

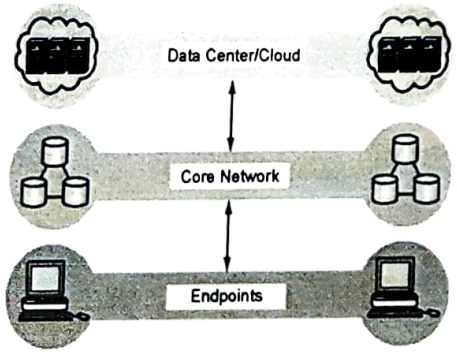
(1) **Minimizing latency :** Milliseconds matter for many types of industrial systems, such as when you are trying to prevent manufacturing line shutdowns or restore electrical service. Analyzing data close to the device that collected the data can make a difference between averting disaster and a cascading system failure.

(2) Conserving network bandwidth : Offshore oil rigs generate 500 GB of data weekly. Commercial jets generate 10 TB for every 30 minutes of flight. It is not practical to transport vast amounts of data from thousands or hundreds of thousands of edge devices to the cloud. Nor is it necessary because many critical analyses do not require cloud-scale processing and storage.

(3) **Increasing local efficiency :** Collecting and securing data across a wide geographic area with different environmental conditions may not be useful. The environmental conditions in one area will trigger a local response independent from the conditions of

another site hundreds of miles away. Analyzing both areas in the same cloud system may not be necessary for immediate efficiency.

☞ The Traditional IT Cloud Computing Model



(1A14)**Fig. 1.5.5 Cloud Computing Model**

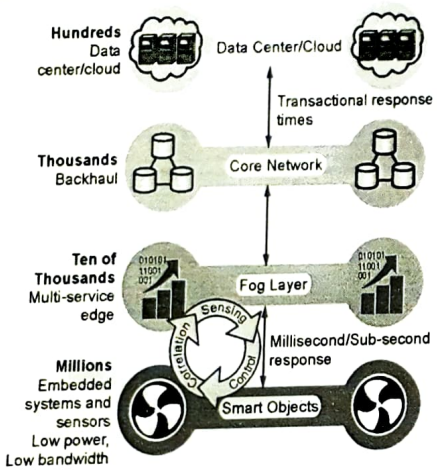
- IoT systems function differently. Several data-related problems need to be addressed
- Bandwidth in last-mile IoT networks is very limited. When dealing with thousands/millions of devices, available bandwidth may be on order of tens of Kbps per device or even less.
- Latency can be very high. Instead of dealing with latency in the milliseconds range, large IoT networks often introduce latency of hundreds to thousands of milliseconds.
- Network backhaul from the gateway can be unreliable and often depends on 3G/LTE or even satellite links. Backhaul links can also be expensive if a per-byte data usage model is necessary.
- The volume of data transmitted over the backhaul can be high, and much of the data may not really be that interesting (such as simple polling messages).
- Big data is getting bigger. The concept of storing and analyzing all sensor data in the cloud is impractical. The sheer volume of data generated makes real-time analysis and response to the data almost impossible.

☞ Fog Computing

GQ. Explain Fog Computing. **(4 Marks)**

- The solution to the challenges mentioned in the previous section is to distribute data management throughout the IoT system, as close to the edge of the IP network as possible. The best-known embodiment of edge services in IoT is fog computing.

- Any device with computing, storage, and network connectivity can be a fog node. Examples include industrial controllers, switches, routers, embedded servers, and IoT gateways. Analyzing IoT data close to where it is collected minimizes latency, offloads gigabytes of network traffic from the core network, and keeps sensitive data inside the local network.



(1A15)**Fig. 1.5.6 : The IoT Data Management and Compute Stack with Fog Computing**

- Fog services are typically accomplished very close to the edge device, sitting as close to the IoT endpoints as possible. One significant advantage of this is that the fog node has contextual awareness of the sensors it is managing because of its geographic proximity to those sensors.
- For example, there might be a fog router on an oil derrick that is monitoring all the sensor activity at that location.
- Because the fog node is able to analyze information from all the sensors on that derrick, it can provide contextual analysis of the messages it is receiving and may decide to send back only the relevant information over the backhaul network to the cloud.
- In this way, it is performing distributed analytics such that the volume of data sent upstream is greatly reduced and is much more useful to application and analytics servers residing in the cloud.

- Fog applications are as diverse as the Internet of Things itself. What they have in common is data reduction monitoring or analyzing real-time data from network-connected things and then initiating an action, such as locking a door, changing equipment settings, applying the brakes on a train, zooming a video camera, opening a valve in response to a pressure reading, creating a bar chart, or sending an alert to a technician to make a preventive repair.
- The defining characteristic of fog computing are as follows:
  (1) **Contextual location awareness and low latency :** The fog node sits as close to the IoT endpoint as possible to deliver distributed computing.
  (2) **Geographic distribution :** In sharp contrast to the more centralized cloud, the services and applications targeted by the fog nodes demand widely distributed deployments.
  (3) **Deployment near IoT endpoints :** Fog nodes are typically deployed in the presence of a large number of IoT endpoints. For example, typical metering deployments often see 3000 to 4000 nodes per gateway router, which also functions as the fog computing node.
  (4) **Wireless communication between the fog and the IoT endpoint :** Although it is possible to connect wired nodes, the advantages of fog are greatest when dealing with a large number of endpoints, and wireless access is the easiest way to achieve such scale.
  (5) **Use for real-time interactions :** Important fog applications involve real-time interactions rather than batch processing. Preprocessing of data in the fog nodes allows upper-layer applications to perform batch processing on a subset of the data.

☞ Edge Computing

GQ. Explain Edge Computing. **(4 Marks)**

- Fog computing solutions are being adopted by many industries, and efforts to develop distributed applications and analytics tools are being introduced at an accelerating pace.
- The natural place for a fog node is in the network device that sits closest to the IoT endpoints, and these nodes are typically spread throughout an IoT network.

Note : Edge computing is also sometimes called "mist" computing. If clouds exist in the sky, and fog sits near the ground, then mist is what actually sits on the ground. Thus, the concept of mist is to extend fog to the furthest point possible, right into the IoT endpoint device itself.

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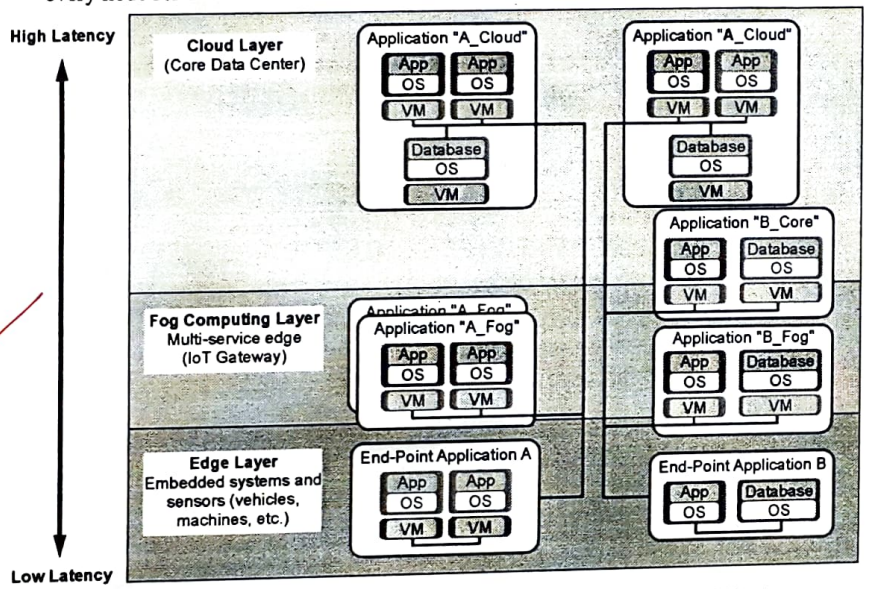
The Hierarchy of Edge, Fog, and Cloud

- It is important to stress that edge or fog computing in no way replaces the cloud. Rather, they complement each other, and many use cases actually require strong cooperation between layers.
- In the same way that lower courts do not replace the supreme court of a country, edge and fog computing layers simply act as a first line of defense for filtering, analyzing, and otherwise managing data endpoints. This saves the cloud from being queried by each and every node for each event.



(1A16)**Fig. 1.5.7 : Distributed Compute and Data Management Across an IoT System**

- From an architectural standpoint, fog nodes closest to the network edge receive the data from IoT devices.
- The fog IoT application then directs different types of data to the optimal place for analysis:
- The most time-sensitive data is analyzed on the edge or fog node closest to the things generating the data.
- Data that can wait seconds or minutes for action is passed along to an aggregation node for analysis and action.

- Data that is less time sensitive is sent to the cloud for historical analysis, big data analytics, and long-term storage. For example, each of thousands or hundreds of thousands of fog nodes might send periodic summaries of data to the cloud for historical analysis and storage.
- In summary, when architecting an IoT network, you should consider the amount of data to be analyzed and the time sensitivity of this data. Understanding these factors will help you decide whether cloud computing is enough or whether edge or fog computing would improve your system efficiency.
- Fog computing accelerates awareness and response to events by eliminating a round trip to the cloud for analysis. It avoids the need for costly bandwidth additions by offloading gigabytes of network traffic from the core network. It also protects sensitive IoT data by analyzing it inside company walls.

...Chapter ends

□□□

	M2M	IoT Frameworks
1.	M2M means direct machine to Machine communication	IoT - means Int. of Things a network of connected devices able to sensor, collect & exchange information
2.	Hardware based.	H/W & S/W based.
3.	Does not require internet connection.	Requires internet connection
4.	Supports point-to-point comm^n.	supports cloud comm^n.
5.	Best for small scale applications	Easy to large scale appl^n.
6.	Communicates through a proprietary cellular or wired N/W.	communicates on standards based IP n/ws.
7.	Applications :- vending machines, ATMs, smart meters.	Applications :- smart cities, connected cars, & EV charging networks.