Module-1

- **What is IoT?**
- **IoT Network Architecture and Design**

Chapter-1

What is IoT?

- If we imagine a world where anything can be online and communicating to other things and people in order to enable new services that enhance our lives.

- From self-driving drones delivering your grocery order to sensors in your clothing monitoring your health, the world you know is set to undergo a major technological shift forward. This shift is known collectively as the **Internet of Things (IoT).**

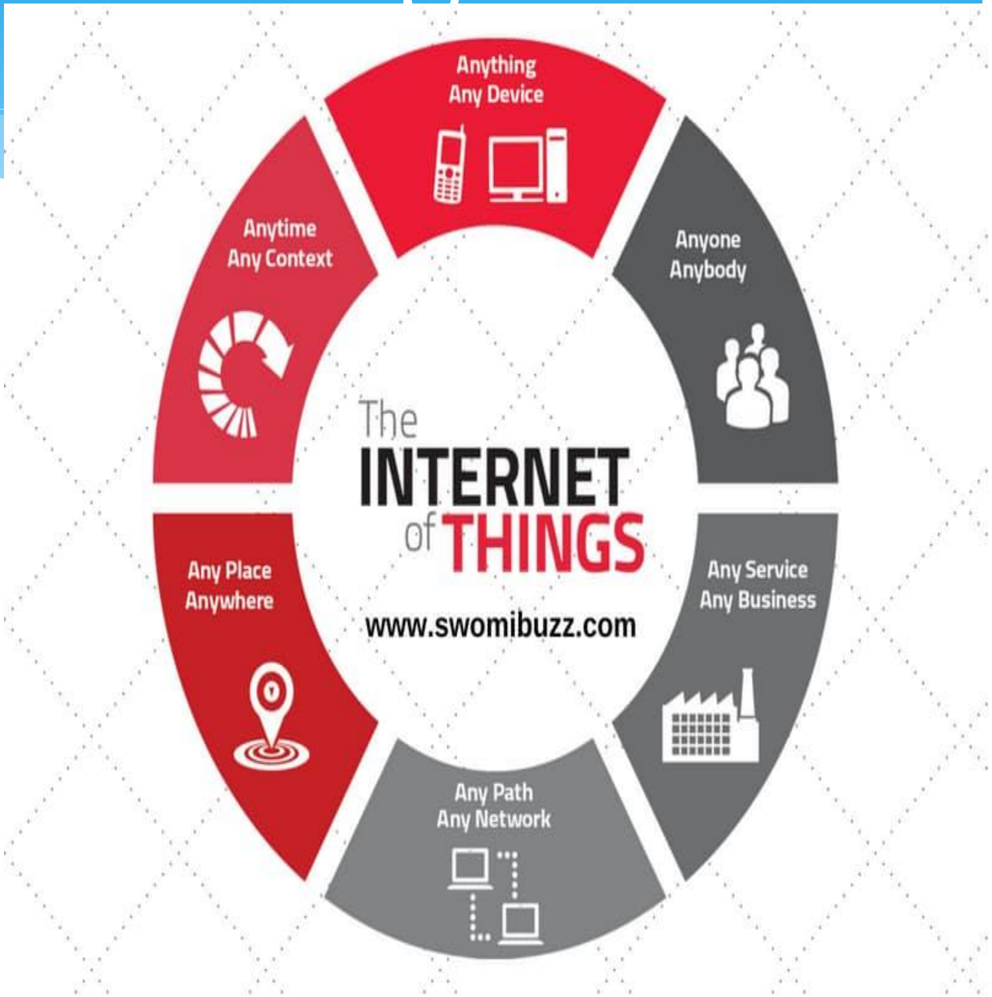
- The basic premise and goal of IoT is to

"connect the unconnected."

- This means that objects that are not currently joined to a computer network, namely the Internet, will be connected so that they can communicate and interact with people and other objects.

Internet of Things

* System of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.



* **Genesis of IoT**
* **IoT and Digitization**
* **IoT Impact**
* **Convergence of IT and OT**
* **IoT Challenges**

Genesis of IoT

- The age of IoT is often said to have started between the years 2008 and 2009.During this time period, the number of devices connected to the Internet eclipsed the world’s population.
- With more **“things”** connected to the Internet than people in the world, a new age was upon us, and the **Internet of Things** was born.
- The person credited with the creation of the term **“Internet of Things”** is Kevin Ashton.

Genesis of IoT

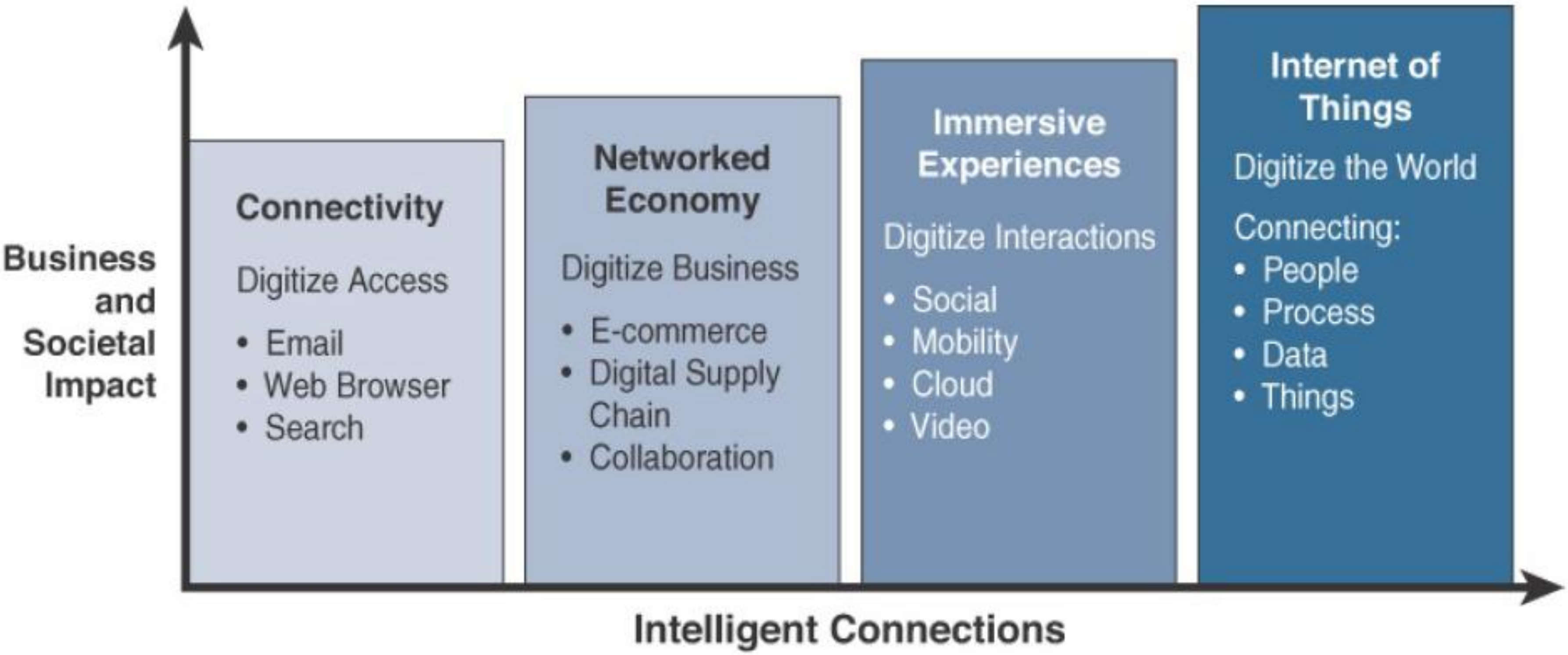


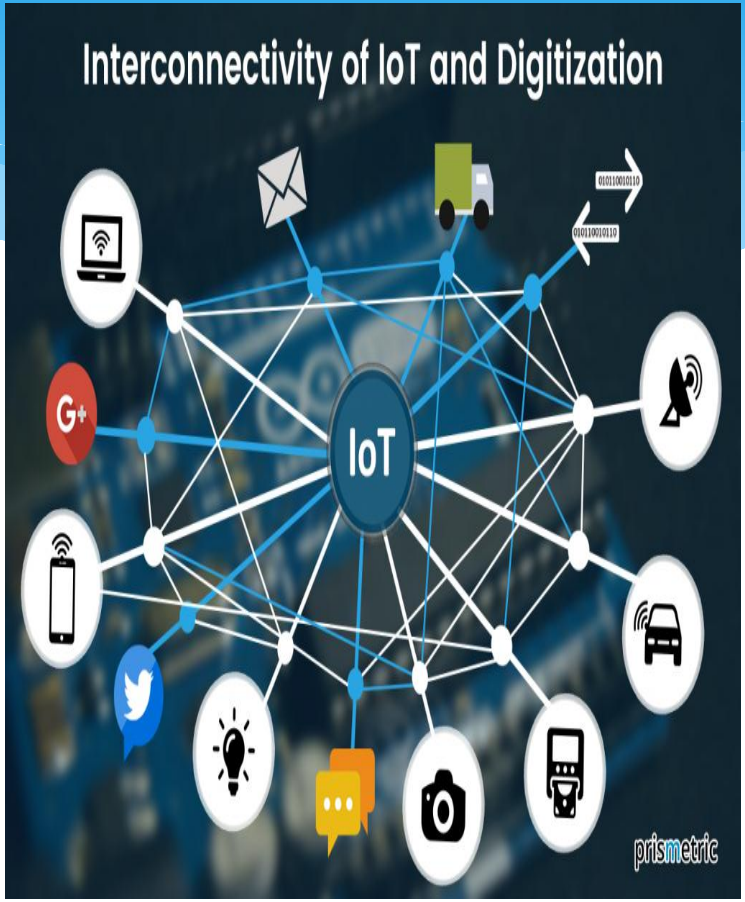
Figure 1.1 : Evolutionary Phases of the Internet

Evolutionary phases of the Internet

Internet Phase	Definition
Connectivity (Digitize access)	This phase connected people to email, web services and search so that information is easily accessed.
Networked Economy (Digitized business)	This phase enabled e-commerce and supply chain enhancements along with collaborative engagement to drive increased effectively in business processes
Immersive Experiences (Digitize interaction)	This phase extended the internet experience to encompass widespread video and social media while always being connected through mobility. More and more applications are moved into the cloud.
Internet of Things (Digitize the world)	This phase is adding connectivity to objects and machines in the world around us to enable new services and experiences.it is connecting the unconnected.

IoT and Digitization

* **IoT** focuses on connecting "things,"
  * objects and machines, to a computer network,
    * such as the Internet.



* **digitization**


Smart Mall

* Digitization, as defined in its simplest form, is the conversion of information into a digital format.

* Examples:
* The digitization of photography has completely changed our experience when it comes to capturing images.

* digitization include the video rental industry and transportation.

* The transportation industry is currently undergoing digitization in the area of taxi services

IoT Impact

- 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

IoT Impact

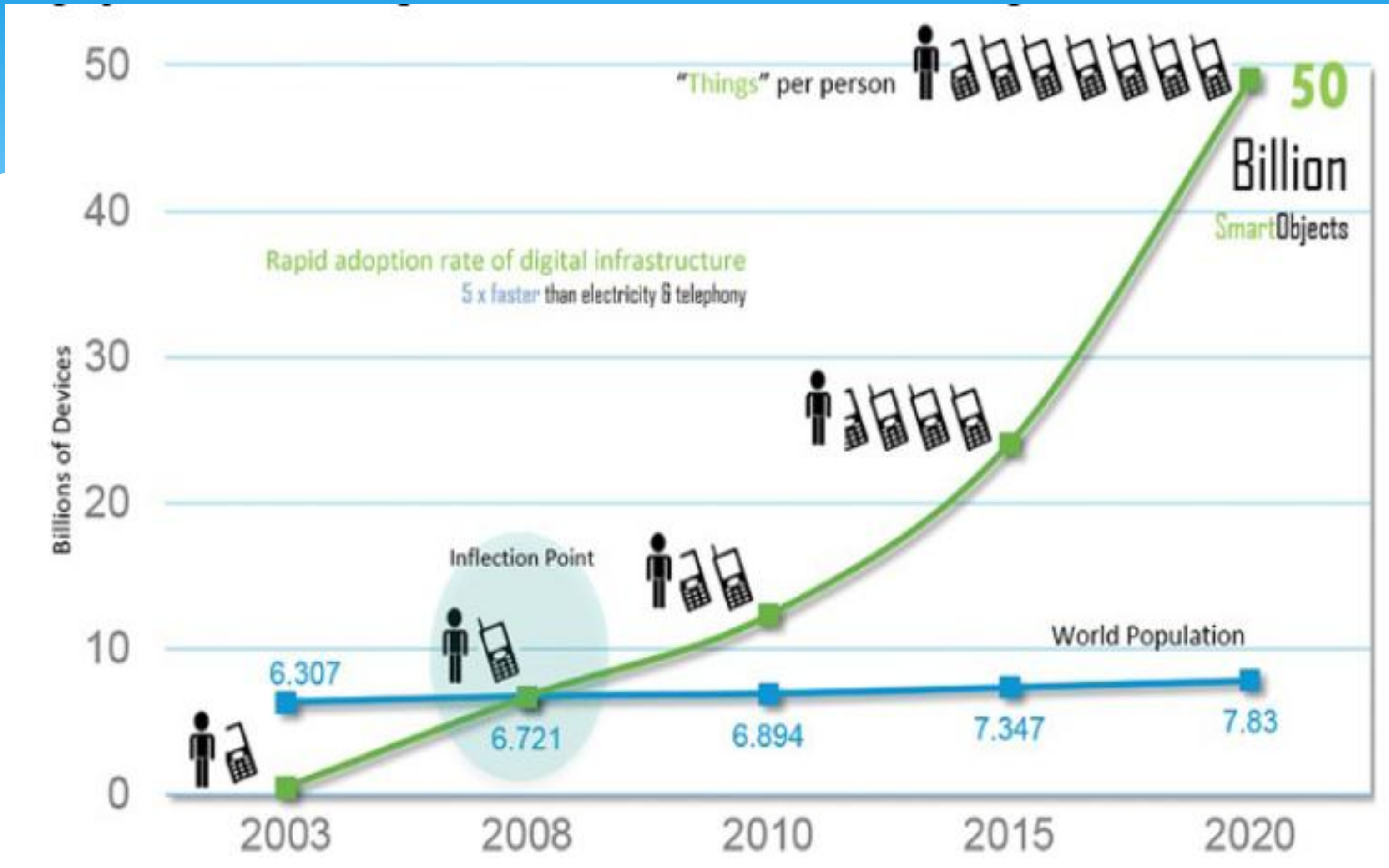


Figure 1.2 : The Rapid Growth in the Number of Devices Connected to the Internet

Illustration of IoT Use cases

* Connected Roadways

* Connected Factory

* Smart Connected Buildings

* Smart Creatures

Illustration of IoT Use cases

* **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

Figure 1.3 : Google's Self-Driving Car

Challenge	Supporting Data
Safety	IoT and the enablement of connected vehicle technologies will empower drivers with the tools they need to anticipate potential crashes and significantly reduce the no of lives lost each year.
Mobility	More than a billion cars are on the roads worldwide. Connected vehicle mobility applications can enable system operators and drivers to make informed decisions, which can, in turn, reduce travel delays. In addition, communication between mass transit, emergency response vehicles and traffic management infrastructures help optimizing routing of vehicles, further reducing potential delays.
Environment	Connected vehicle environmental applications will give all travellers the real-time information they need to make **"green"** transportation choices

Table 1.2: Current Challenges Being Addressed by Connected Roadways

* connected roadways will bring many **benefits to society.**

* reduced traffic jams
* Urban congestion
* decreased casualties and fatalities
* increased response time for emergency vehicles
* reduced vehicle emissions.

* **IoT-Connected Roadways : Intersection Movement Assist (IMA)**

- 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.

- Figure 1.4 shows 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.

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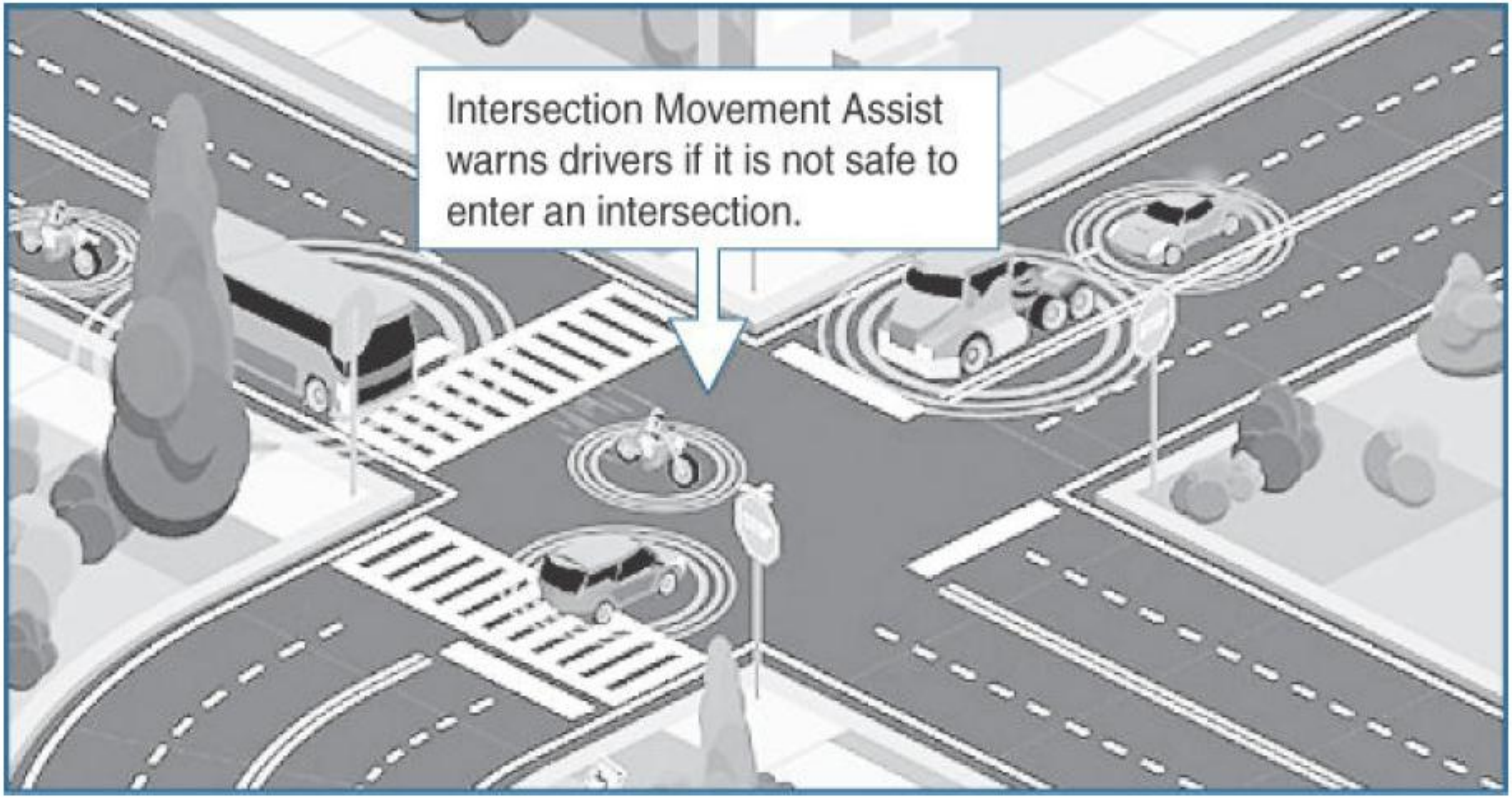


Figure 1.4: Application of Intersection Movement Assist

- **Other solutions: Connected Roadways**

    - Automated Vehicle Tracking
    - Cargo management
    - Road weather communications

- 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 en route 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.

- As cars continue to become more connected and capable of generating continuous data streams related to location, performance, driver behaviour, 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.

- Figure 1.5 provides an overview of the sort of sensors and connectivity that you will find in a connected car.

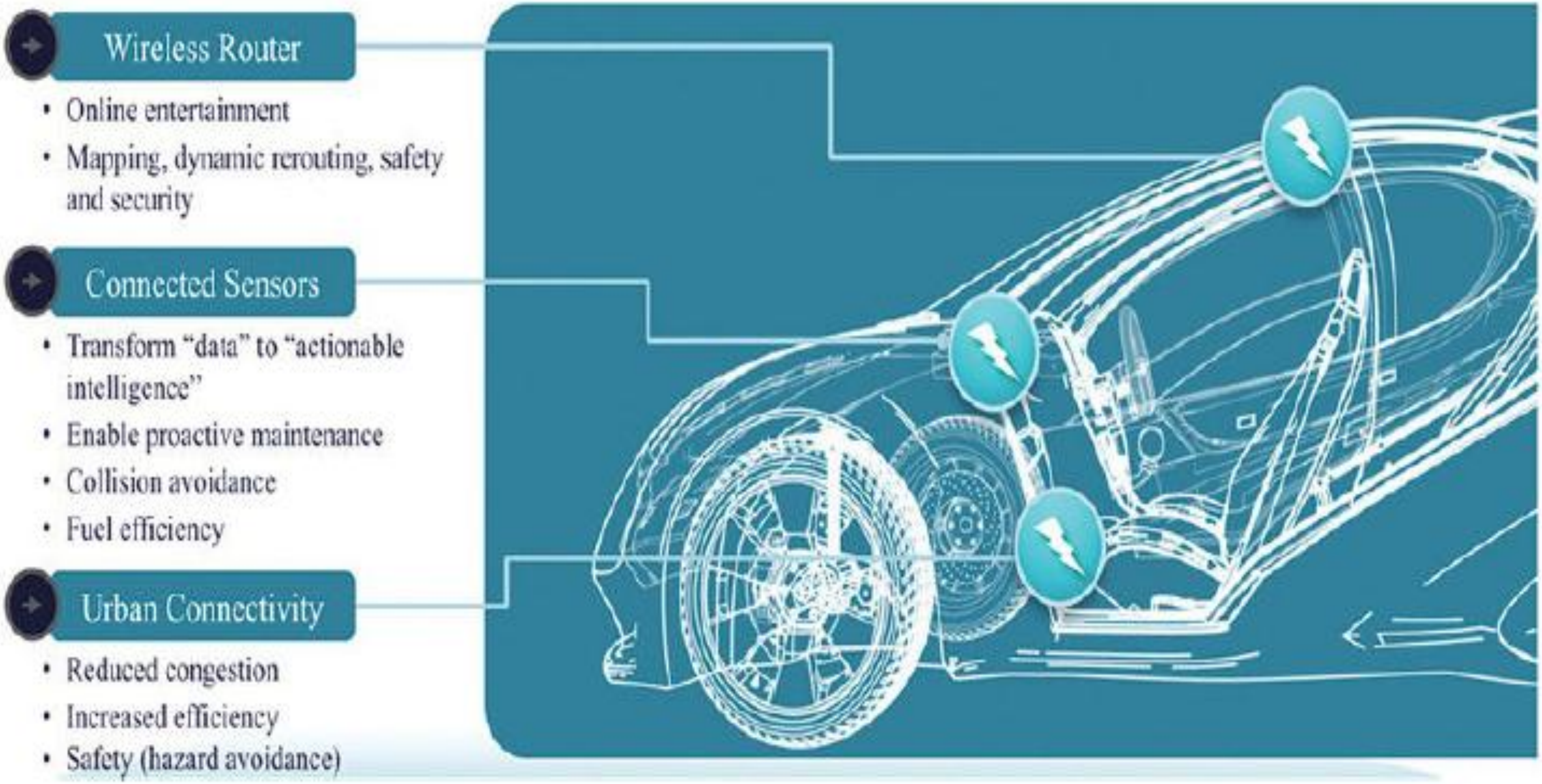


Figure 1.5 : The Connected Car

Third Parties accessing the data generated by 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.

- Automobile data is extremely useful to a wide range of interested parties.

  - For ex : tire companies can collect data related to use and durability of their products in a range of environments in real time.

* 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

Connected Factory

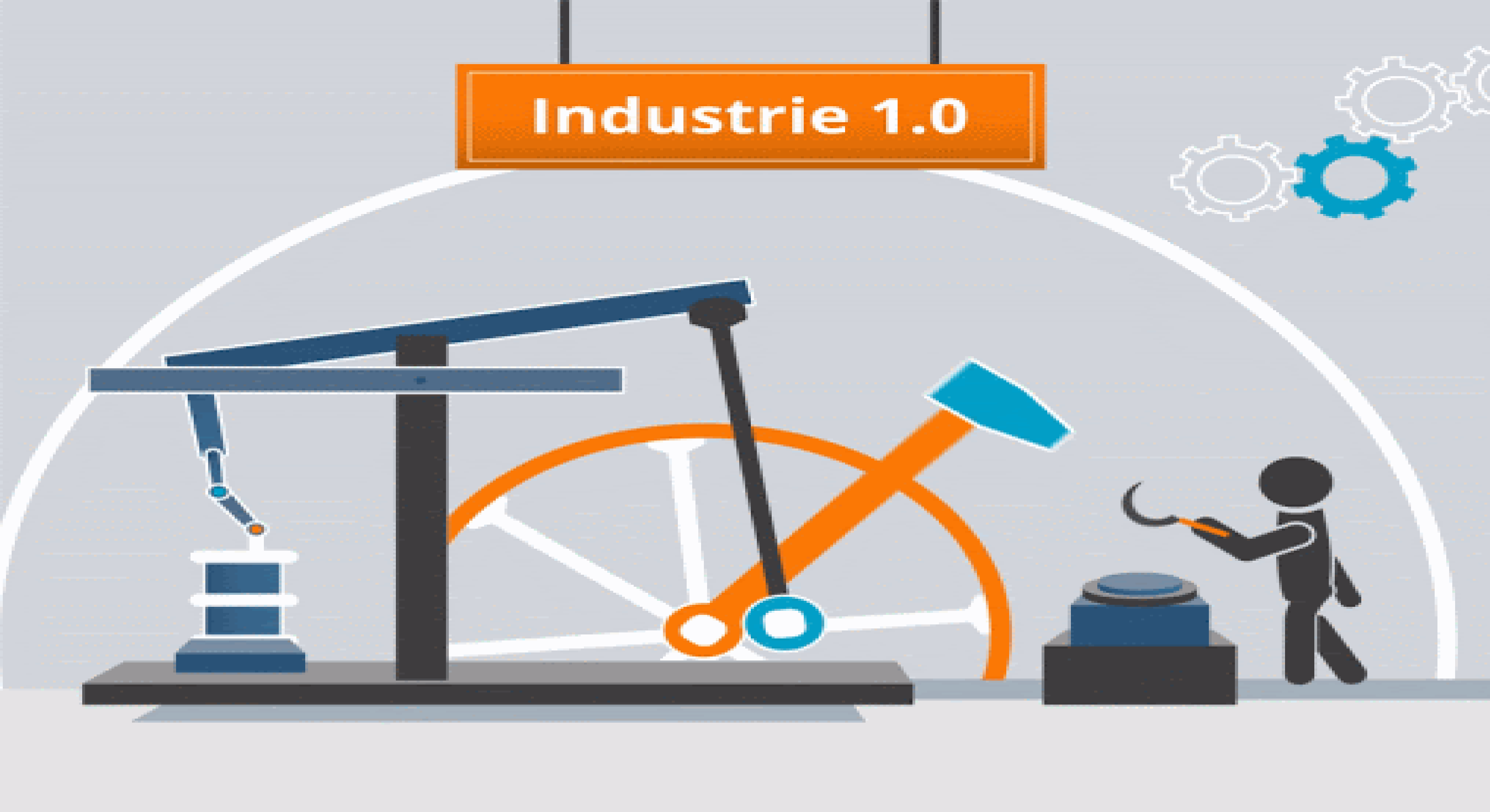
* Main challenges facing manufacturing in a factory environment

* Accelerating new product and service introductions to meet customer and market opportunities.
* Increasing quality and uptime while decreasing cost.
* Securing factories from cyber threats.
* Decreasing high cabling and re-cabling costs.
* Improving worker productivity and safety.

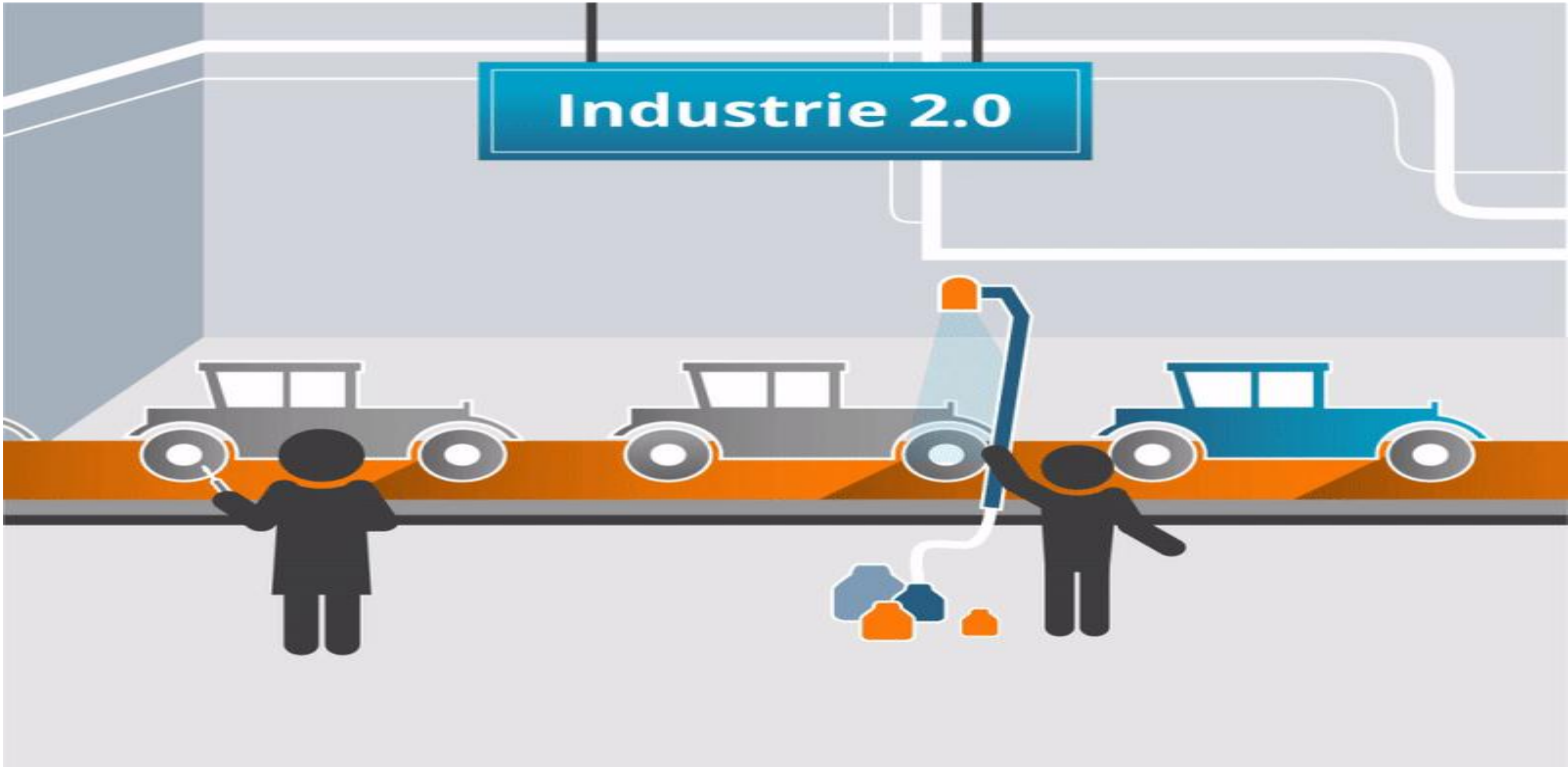
- A convergence of factory-based operational technologies and architectures with global IT networks is starting to occur, and this is referred to as the **connected factory**.

- With IoT, a large number of sensors deployed in the factory floors has not only become more advanced but has also attained a new level of connectivity.

- They are smarter and gain the ability to communicate, mainly using **the Internet Protocol (IP) over an Ethernet infrastructure**.

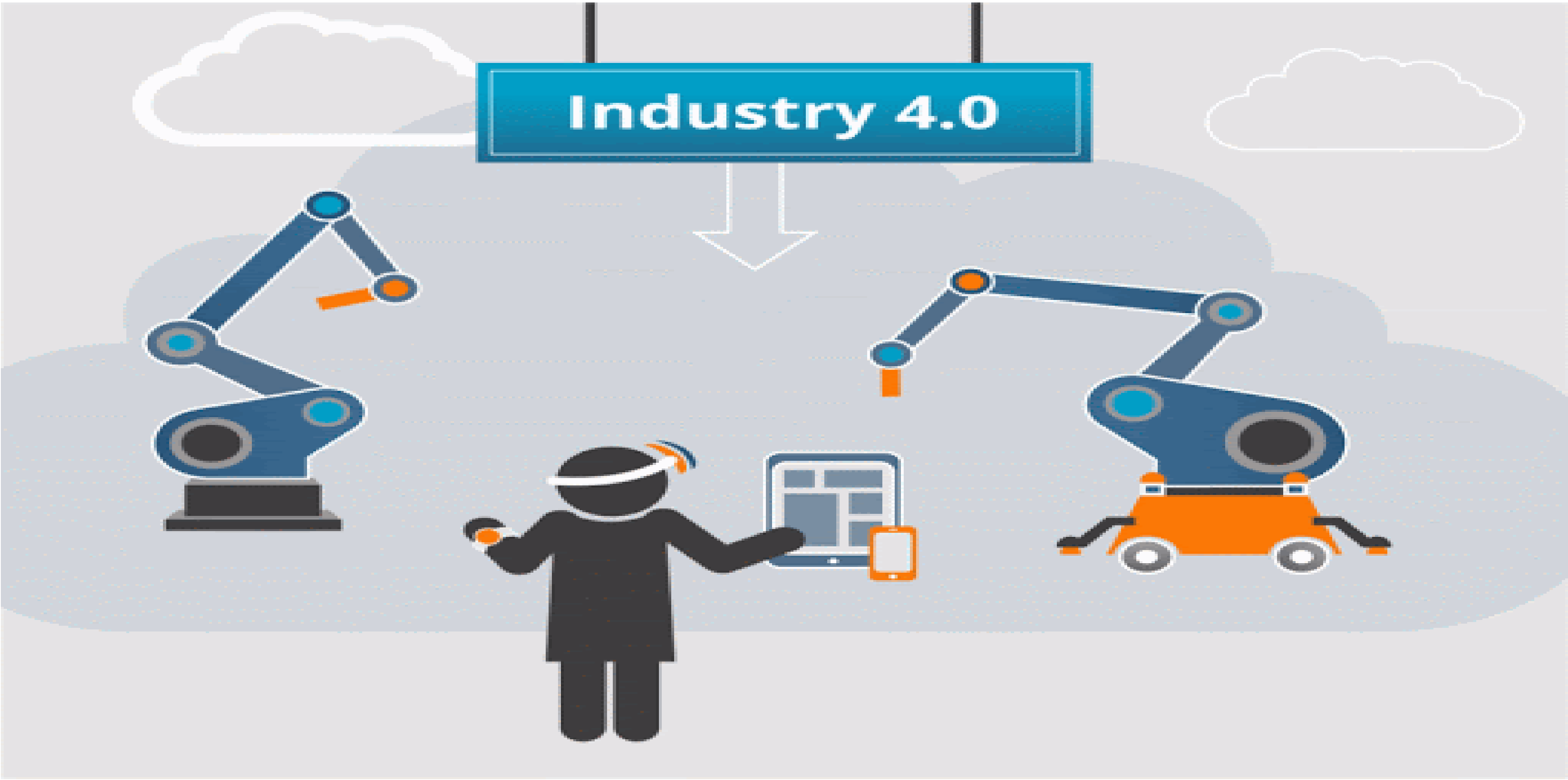


In the 1800s, water- and steam-powered machines were developed to aid workers. As production capabilities increased, business also grew from individual cottage owners taking care of their own — and maybe their neighbors' — needs to organizations with owners, managers and employees serving customers.



By the beginning of the 20th century, electricity became the primary source of power. It was easier to use than water and steam and enabled businesses to concentrate power sources to individual machines. Eventually machines were designed with their own power sources, making them more portable

* *I*n the last few decades of the 20th century, the invention and manufacture of electronic devices, such as the transistor and, later, integrated circuit chips, made it possible to more fully automate individual machines to supplement or replace operators



In the 21st century, Industry 4.0 connects the internet of things (IOT) with manufacturing techniques to enable systems to share information, analyze it and use it to guide intelligent actions.

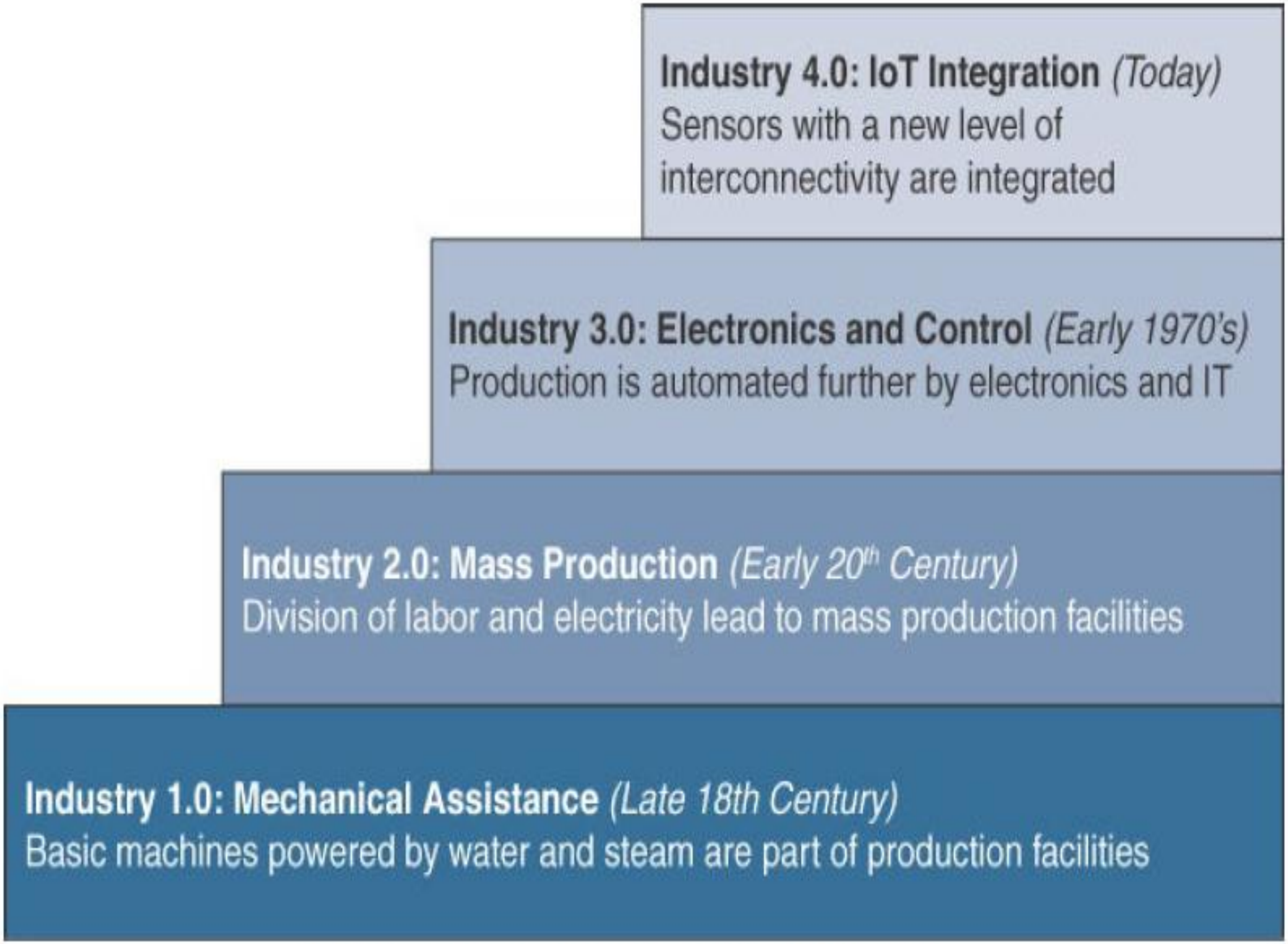


Figure 1-6 *The Four Industrial Revolutions*

Deploy a Connected Factory Network with the Internet of Everything

* **Smart Connected Buildings**

3. Smart Connected Buildings

* **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 control of air flow into a room.

* interesting aspect of the smart building is that it makes them **easier and cheaper to manage**

* communication protocol responsible for building automation is known as **BACnet.**
* 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.
* 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.

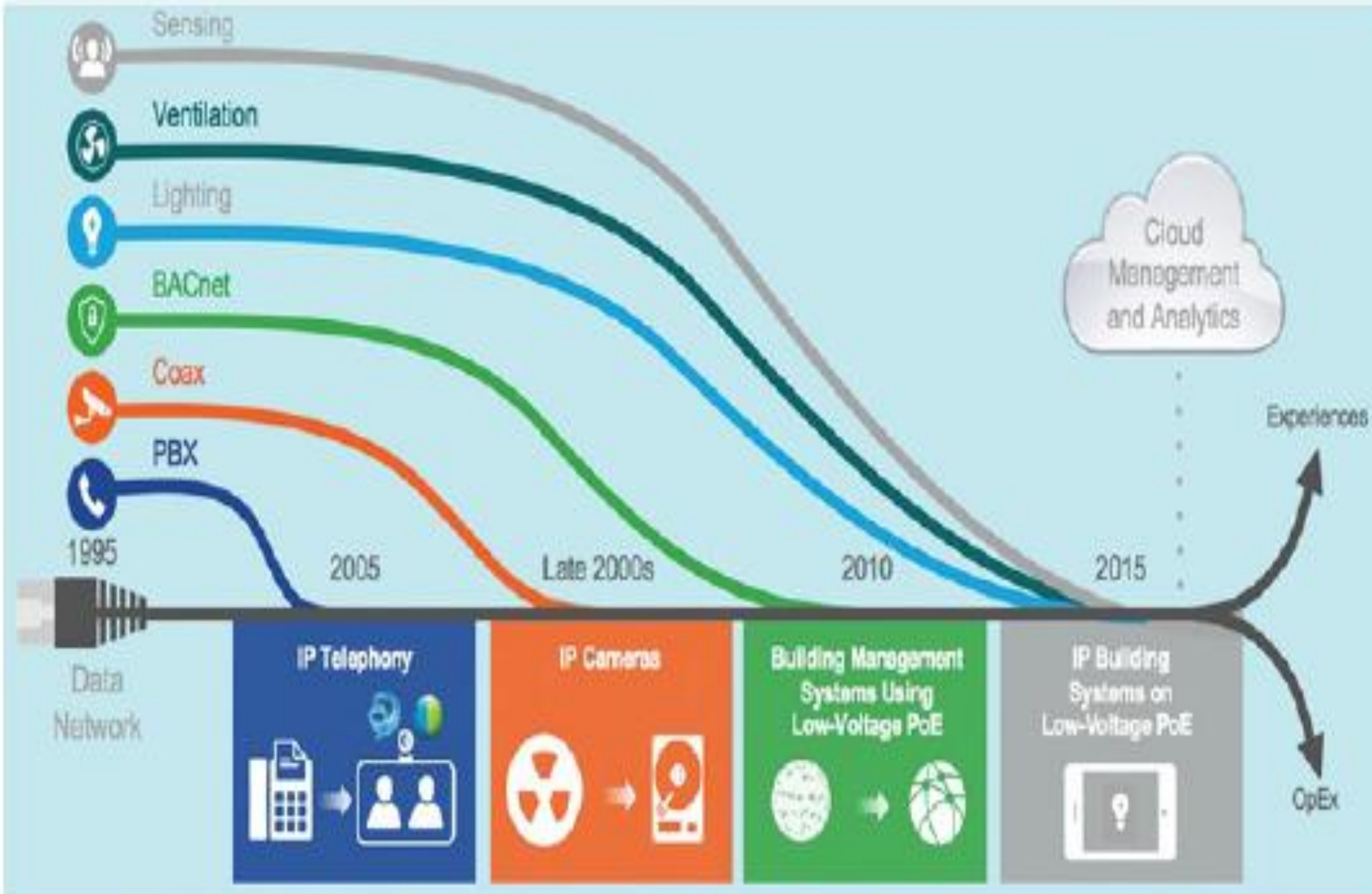


Figure 1-7 *Convergence of Building Technologies to IP*

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
  * CCTV
  * security systems

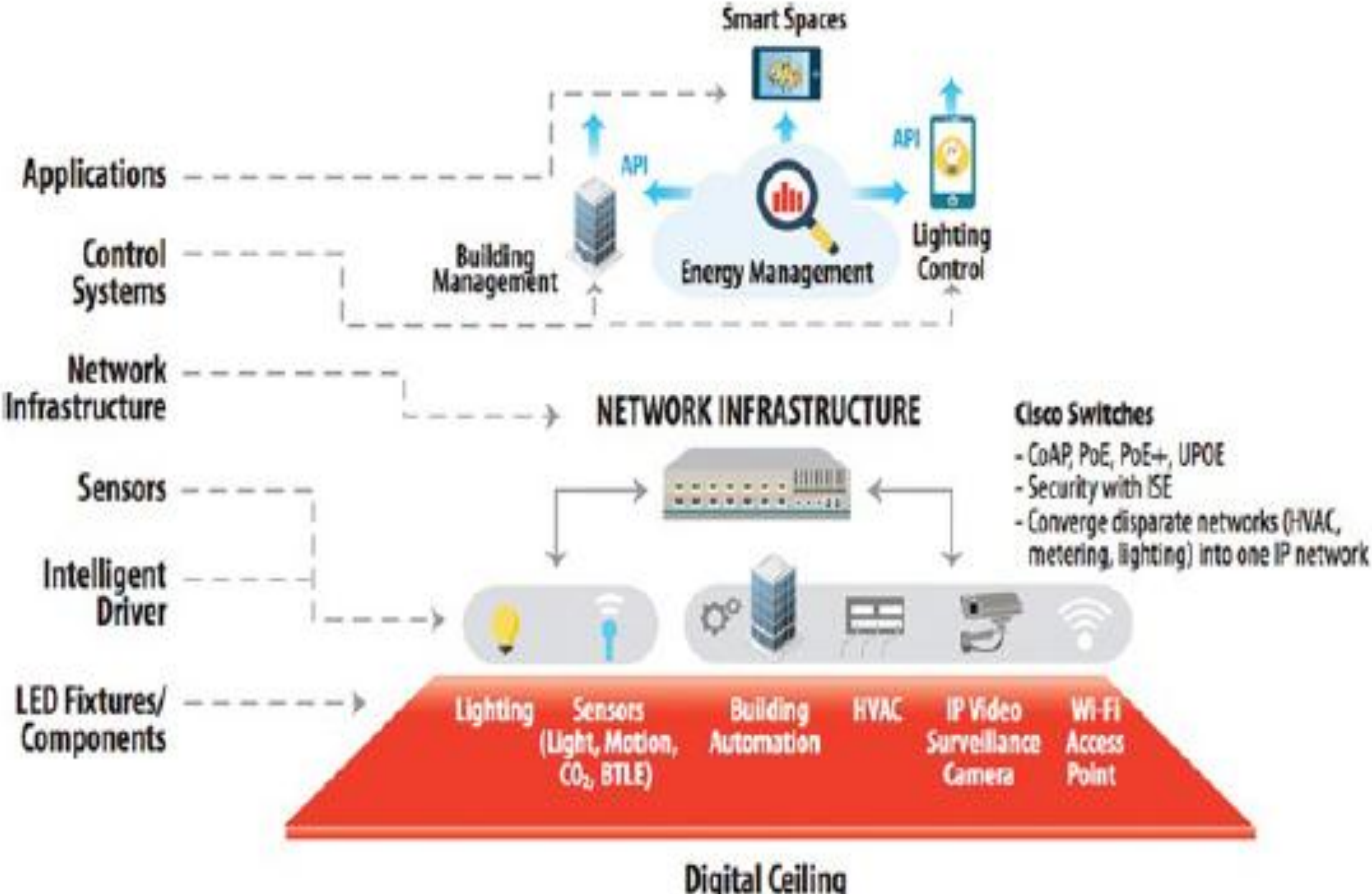


Figure 1-8 *A Framework for the Digital Ceiling*

- 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.

- For ex : most modern LED ceiling fixtures support occupancy sensors.

- 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.

- Figure 1.9 shows an example of an occupancy sensor in a digital ceiling light.

Figure 1-9 *An LED Digital Ceiling Light with Occupancy Sensor*

Smart Creatures

- When we think about IoT, we 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.

- obviously need a network infrastructure to make the connection with the sensors and store the information.

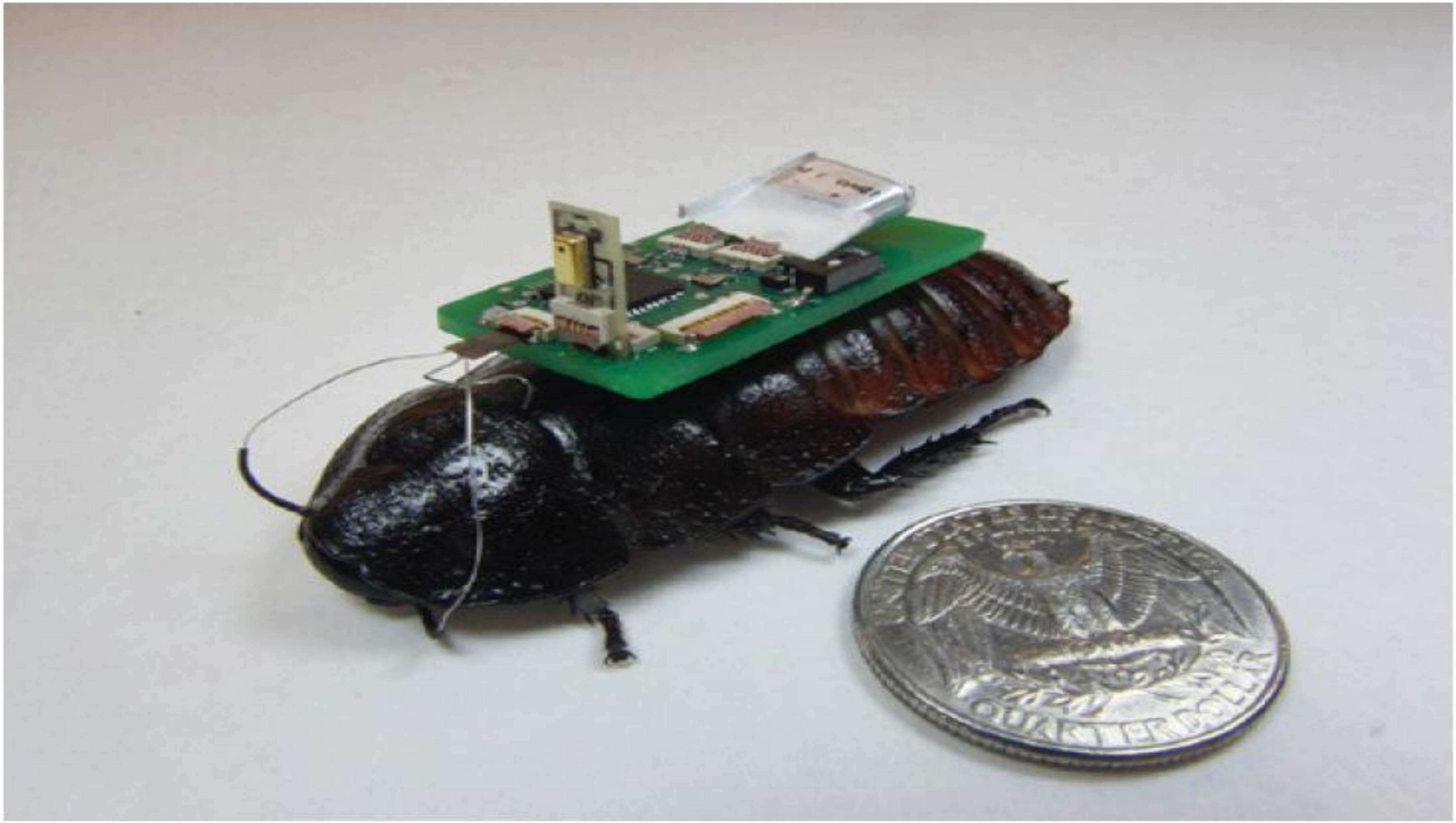
- Once the data is being collected, however, you get a complete view of the herd, with statistics on every cow.

* We 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

- Another application of IoT to organisms involves the **placement of sensors on roaches**.

- the potential benefits of IoT-enabled roaches could make a life-saving difference in disaster situations



* **Figure 1.10 :** IoT-Enabled Roach can assist in finding survivors after a disaster

- The little electronic backpack fitted onto the Madagascar hissing cockroaches and featuring a microcontroller interacts with the insects' antennae and cerci (sensory organs on their abdomens) to direct their movement.

- The electronic backpack uses wireless communication to a controller and can be **“driven”** remotely.

- A fleet of these roaches can be used in a disaster scenario, such as searching for survivors in a collapsed building after an earthquake

Convergence of IT and OT

* **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.

* Specifically, the IT organization is responsible for the information systems of a business, such as email, file and print services, databases, and so on.

* 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 ex :
  - 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 highlights some of the differences between IT and OT networks and their various challenges.

Criterion	Industrial OT Network	Enterprise IT Network
Operational Focus	Keep the business operating 24x7	Manage the computers, data and employee communication system in a secure way
Priorities	1. Availability 2. Integrity 3. Security	1. Security 2. Integrity 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

Implication of failure	OT network disruption directly impacts business	Can be business impacting, depending on industry, but workarounds may be possible
Network Upgrades(software/hardware)	Only during operational maintenance windows	Often requires an outage window when workers are not onsite; 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

Table 1.3: Comparing Operational Technology(OT) and Information Technology(IT)

IoT Challenges

* the most significant challenges and problems that IoT is currently facing.

- **Scale**
- **Security**
- **Privacy**
- **Big data and data analytics**
- **Interoperability**

Challenge	Description
Scale	While scale of IT networks can be large, the scale of OT can be several orders of magnitude larger For ex : one large electrical utility in Asia recently began deploying IPv6-based smart meters on its electrical grid. While this utility company has tens of thousands of employees(which can be considered IP nodes in the network), the number of meters in the service area is tens of millions. This means the scale of the network the utility is managing has increased by more than 1,000 fold.
Security	With more **“things”** becoming connected with other **“things”** and people security is an increasingly complex issue for IoT. The threat surface has now been greatly expanded and if a device gets hacked, its connectivity is a major concern. A compromised device can serve as a launching point to attack other devices and systems.
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 a efficient manner. The challenge, however is evaluating a massive amounts of data arriving from different sources in various forms and doing so in timely manner.
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 are helping minimize this problem, but there are often various protocols and implementations available for IoT networks.

Table 1.4 : IoT Challenges