Chapter Four

Internet of Things (IoT)

Learning outcomes

- **After completing this lesson you should be able to**
  - **Describe IoT**
  - **Understand the idea of IoT**
  - **Explain the history of IoT**
  - **List advantages and challenges of IoT**
  - **Explain How IoT works**
  - **Explain the architecture of IoT**
  - **Describe IoT tools and platforms**
  - **Describe some of the application areas of IoT**

Overview of Internet of Things (IoT)

* The IoT, refers to the set of devices and systems that interconnect real-world **sensors and actuators** to the Internet.
* IoT is a network of devices which can sense, accumulate and transfer data over the internet without any human intervention.
* IoT is here to change the world we know.
  - Smart cars, smart homes, smart cities, everything around us can be turned into a smart device with the help of Internet of Thing
  - IoT surely brings the coolness factor to technology.

Definition from International Bodies

* **Internet Architecture Board (IAB):**
  - The networking of smart objects, meaning a huge number of devices intelligently communicating in the presence of internet protocol that cannot be directly operated by human beings but exist as components in buildings, vehicles or the environment
* **Internet Engineering Task Force (IETF):**
  - The networking of smart objects in which smart objects have some constraints such as limited bandwidth, power, and processing accessibility for achieving interoperability among smart objects

Cont..

- **IEEE Communications**:
  - A framework of all things that have a representation in the presence of the internet in such a way that new applications and services enable the interaction in the physical and virtual world in the form of Machine-to-Machine (M2M) communication in the cloud
- **Oxford dictionary:**
  - The interaction of everyday object's computing devices through the Internet that enables the sending and receiving of useful data

Cont. ..

* The most important features of IoT include **artificial intelligence**, **connectivity**, **sensors**, **active engagement**, and **small device** use.
* A brief review of these features is given below:
  - AI – IoT essentially makes virtually anything “smart”, meaning it enhances every aspect of life with the power of **data collection**, **artificial intelligence algorithms**, and **networks**.
  - This can mean something as simple as enhancing your refrigerator and cabinets to detect when milk and your favorite cereal run low, and to then place an order with your preferred grocer.

Cont. ..

- **Connectivity** – New enabling technologies for networking and specifically IoT networking, mean networks are no longer exclusively tied to major providers.
  - Networks can exist on a much smaller and cheaper scale while still being practical. IoT creates these small networks between its system devices.
- **Sensors** – IoT loses its distinction without sensors.
  - They act as defining instruments that transform IoT from a standard passive network of devices into an active system capable of real-world integration.

Cont. ..

- **Active Engagement** – Much of today's interaction with connected technology happens through passive engagement.
- IoT introduces a new paradigm for active content, product, or service engagement.

Small Devices – Devices, as predicted, have become smaller, cheaper, and more powerful over time.

- IoT exploits purpose-built small devices to deliver its precision, scalability, and versatility.

Conceptual Framework (2020) of IoT

- **IoT** is a network of devices which can sense, accumulate and transfer data over the internet without any human intervention.
  - **IoT= Services + Data + Networks + Sensors**
  - A **thing** in the internet of things can be **natural or man-made** object **assigned a Unique IP address** and able to ***transfer data over a network***
- The Internet of Things means **taking all the things in the world and connecting them to the internet**.
- The IoT is more than a buzzword; it is a system that is influencing how humans interact with technology, and how human beings behave.

Cont..

* IoT is also considered as a worldwide network of intelligent objects that are interconnected and uniquely representable on the basis of communication-based protocols
* According to the Gartner report, by 2020 connected devices across all technologies will reach 20.6 billion.
* By end-2022, 29 billion connected devices, of which around 18 billion will be related to IoT.
* And by 2025, we will have 41.6 billion connected IoT devices
* The number of IoT devices surpassed the global human population in 2010.

What IoT Include

* **IoT includes many different systems, including**
  - **Internet-connected cars**
  - **wearable devices including health and fitness monitoring devices, watches, and even human implanted devices;**
  - **Smartphones, smart meters and smart objects;**
  - **home automation systems and lighting controls;**
  - **wireless sensor networks that measure weather, flood defenses, tides and more**

IoT Enablers

* **The IoT four key technological enablers are: -**
  - **RFID technology used for tagging the things**
  - **Sensor technology used for sensing the things**
  - **Smart technology used for thinking the things**
  - **Nanotechnology used for shrinking the things**
* Generally speaking, IOT is just more than **M2M** communication, with technologies including:
  - Wireless sensor networks, sensor networks , 2G/3G/4G,GSM,GPRS,RFID, WI-FI, GPS, microcontroller, microprocessor etc.

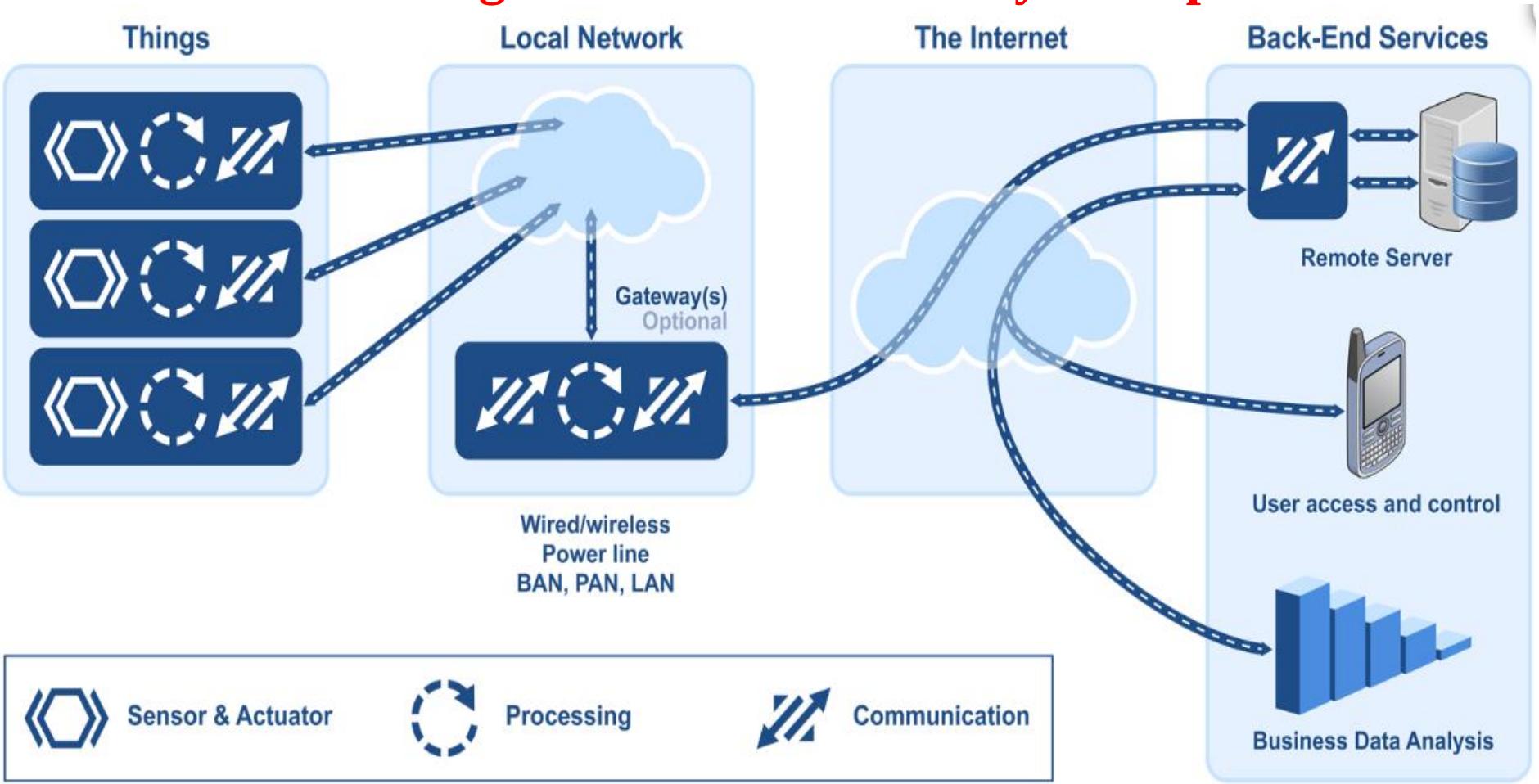
Components of IoT

* **There are four main components of an IoT system**

1. **The Thing itself** (that is, the device/Sensors)
2. **Connectivity** (cellular networks, satellite networks, Wi-Fi, Bluetooth, wide-area networks (WAN), low power wide area network and many more).
3. **Data Processing**
4. **Back-end services(User Interface)-** enterprise data systems, or PCs and mobile devices.

- Next, the information is made useful to the end-user in some way.
- This could be via an alert to the user (email, text, notification, etc).

The Internet of Things from an embedded systems point of view



Sensors/Devices

* First, sensors or devices help in collecting very minute data from the surrounding environment and send it through the Internet for processing.
* All of this collected data can have various degrees of complexities ranging from a simple temperature monitoring sensor or a complex full video feed.
* A device can have multiple sensors that can bundle together to do more than just sense things.
* For example, our phone is a device that has multiple sensors such as GPS, accelerometer, camera but our phone does not simply sense things.

Cont. ..

* There are three types of Devices in IoT:

- **The smallest devices** have embedded 8-bit System-On-Chip (SOC) controllers.
- **Small home routers and derivatives of those devices**. Commonly, these run a cut-down or embedded Linux platform, such as OpenWRT, or dedicated embedded operating systems.
  - Have very limited 32 bit Atheros and ARM chips
- The **most capable IoT platforms that are full 32-bit or 64-bit** computing platforms
  - Systems such as the Raspberry Pi or the BeagleBone, may run a full Linux OS or another suitable Operating System, such as Android.

Connectivity

* Next, that collected data is sent to a cloud infrastructure but it needs a medium for transport.
* The sensors can be connected to the cloud through various mediums of communication and transports such as cellular networks, satellite networks, Wi-Fi, Bluetooth, wide-area networks (WAN), low power wide area network and many more.
* Every option we choose has some specifications and trade-offs between power consumption, range, and bandwidth.
* Choosing the best connectivity option in the IOT system is **important**.

Data Processing

* Once the data is collected and it gets to the cloud, the software performs processing on the acquired data.
* This can range from something very simple, such as checking that the temperature reading on devices such as AC or heaters is within an acceptable range.
* It can sometimes also be very complex, such as identifying objects (such as intruders in your house) using computer vision on video. But there might be a situation when a user interaction is required, example- what if when the temperature is too high or if there is an intruder in your house?
* That’s where the user comes into the **picture**.

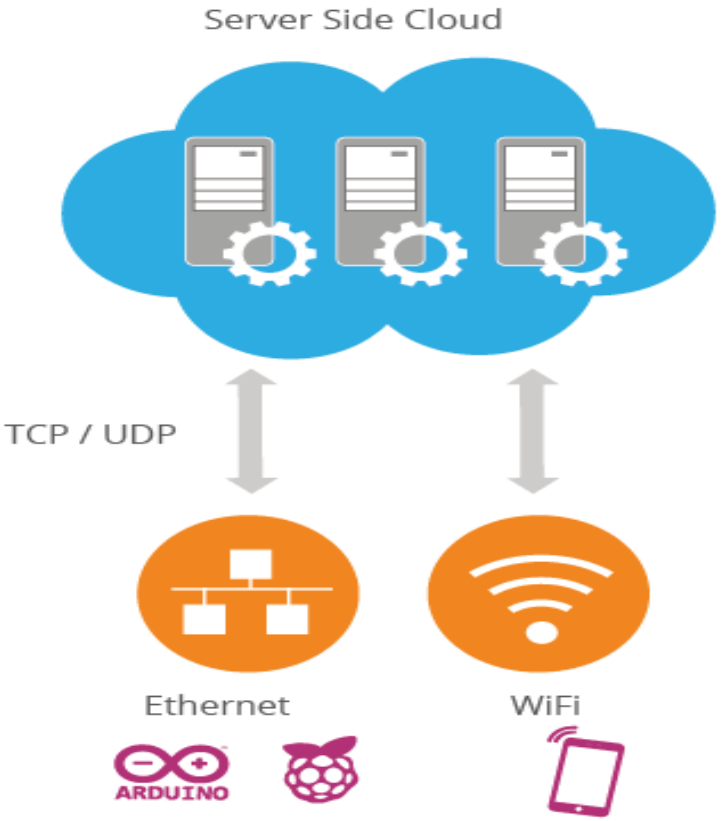
User Interface

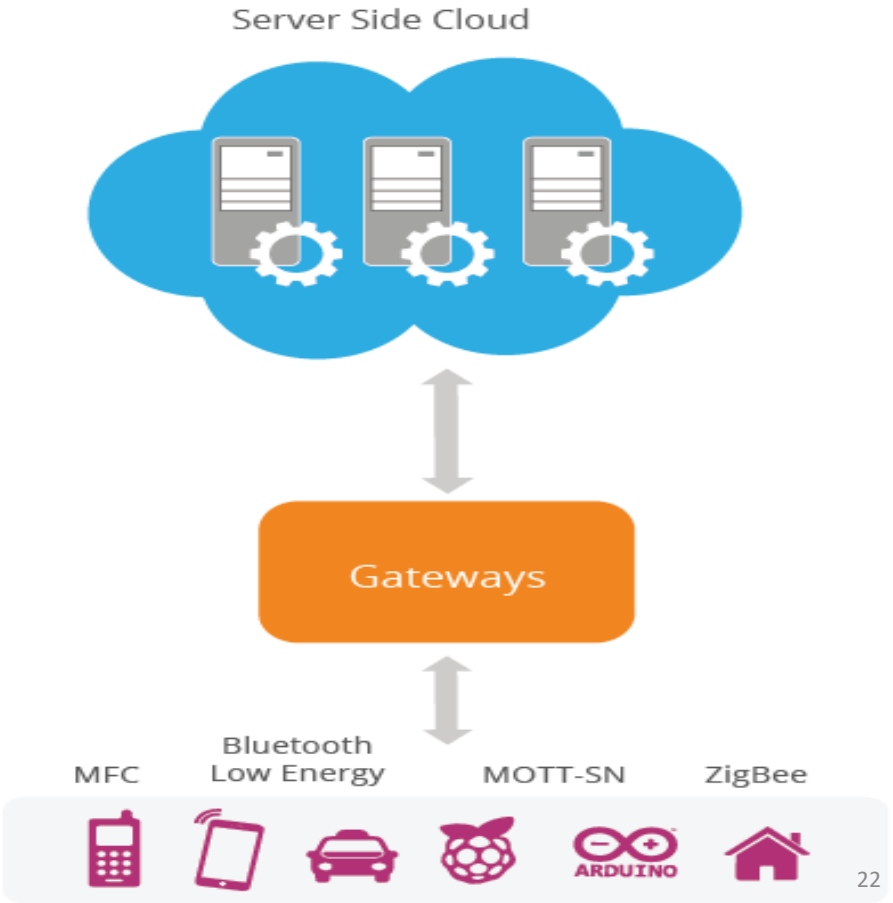
* Next, the information made available to the end-user in some way.
* This can achieve by triggering alarms on their phones or notifying through texts or emails.
* Also, a user sometimes might also have an interface through which they can actively check in on their IOT system.
* For example, a user has a camera installed in his house, he might want to check the video recordings and all the feeds through a web server.
* However, it’s not always this easy and a one-way street.
* Depending on the IoT application and complexity of the system, the user may also be able to perform an action that may backfire and affect the system.
* For example, if a user detects some changes in the refrigerator, the user can remotely adjust the temperature via their phone.

IoT Communication Mechanisms

* Communication between devices and the Internet or to a gateway includes many different models
  - Direct Ethernet or Wi-Fi connectivity using TCP or UDP
  - Bluetooth Low Energy(BLE)
  - Near Field Communication (NFC)
  - Zigbee or other mesh radio networks
  - SRF and point-to-point radio links
  - UART or serial lines

Two major modes of connectivity (communication)





IoT network requirements

* The ability to connect large numbers of heterogeneous IoT elements
* High reliability
* Real-time awareness with low latency
* Ability to secure all traffic flows
* Programmability for application customization
* Traffic monitoring and management at the device level
* Low-cost connectivity for a large number of devices/sensors

History of IoT

* **1832 – First Electromagnetic Telegraph**
  - The path to IoT began with basic forms of long distance communication.
  - In 1832, Baron Shillings in Russia invented the first electromagnetic telegraph.
* **1844 – First Public Communication Message**
  - In 1844, Samuel Morse sent the first public telegraph message. The message read “What hath God wrought!”
* **1900s —The Rise of Connectivity**
* **1955 – First Wearable Computer**

Cont ..

* **1965 – Communication between Two Electronic Devices**
  - In the MIT Lincoln Lab, two computers communicate with each other for the first time.
* **1968 – First M2M Technology**
  - The concept of machine to machine technology (M2M) was invented in 1968 by Theodore Paraskevakos.
* **1973 – First Mobile Phone**
  - Martin Cooper invented the first mobile phone while working at Motorola.
  - This invention also introduced cellular data and later, the data plans we are familiar with today.
  - The concept of cellular data is now a big part of IoT as many options exist for **IoT or M2M data plans**.

Cont..

* **1990 – First IoT Device**

- John Romkey creates the first smart toaster that could be controlled from the internet.

* **1991 – First Sim Card Created**

- Munich developed the first **sim card** for wireless networks in 1991.
- This allowed devices to connect with more than one direct source.
- This development paved the way for machine to machine (M2M) sim cards which would be essential for IoT growth.
- M2M sim cards would allow devices to communicate with one another as they connect to cellular data.

Cont ..

* **1999 – The Concept of "the Internet of Things" is Born**
  - While working at Procter & Gamble, **Kevin Ashton** coined the term "Internet of Things" during a presentation on RFID.
  - From this point on, industry leaders began to experiment more with the ability to connect devices to one another.
* **2000s – The IoT Industry Experiences Major Growth**
* **2000 – Plans for First Internet Refrigerator**
  - LG released plans for a refrigerator with wifi compatibility. This would be one of the first of many smart household objects.

Cont ..

- **2003 – The Term "IoT" is More Widely Used**
  - Major companies start using the term "IoT" in replacement of M2M.
  - This also changed sub-terminology such as M2M sim cards to IoT sim cards.
- **2010s – IoT Gains Popularity (Recognized by Tech Giants)**
- **2011 – IPV6 Public Launch**
- **2013/2014 – IoT Devices Start Using Sensors**
  - Thermostats and home lighting start using sensors to accurately sense the surrounding environment.
  - This allowed people to control home lighting, garage doors, and thermostats all from their phone.

Cont ..

- **2014 – Sigfox Builds an Ultra Narrowband Wireless Data Network**
  - **– First Smart City**
- **2017 – The Internet of Battlefield Things**
  - **– IoT Devices Widely Used**
- **2018 – Health Care Industries**

Evolution of the Internet

- **Pre-Internet**
  - In the pre-internet era, most of the human to human communication was through fixed line and mobile telephony.

- **Dawn of Internet**
  - With the origin of Internet the world changed at once. We could be continents apart and still share vital information at just the click of a button.

Evolution of the Internet Cont'd…

- **Internet of People**
  - After the invention of blogging, social media began to explode in popularity.
  - Sites like MySpace, Facebook, and LinkedIn gained prominence in the early 2000s.
  - YouTube came out in 2005, creating an entirely new way for people to communicate and share with each other across great distances.

Evolution of the Internet Cont'd…

- **Internet of Things**
  - Nearly all of the data available on the Internet today was first captured and created by **human beings.**
  - The problem is, people have limited time, attention, and accuracy, which means they are not very good at capturing data about things in the real world.
  - So, if we had computers that knew everything there was to know about things, using data they gathered without any help from us, we would be able to track and count everything and greatly reduce waste, loss and cost
  - This is what gave birth to "**Internet of Things**".

Cont..

* IoT has evolved from the convergence of
  - wireless technologies, microelectromechanical systems (MEMS), microservices and the Internet.
* The convergence has helped tear down the silos between operational technology (OT) and information technology (IT)
* **IoT evolved from machine-to-machine (M2M) communication**

Factors for Rapid Expansion of IoT

* **Here are several crucial factors spurring this rapid IoT expansion:**
  - Falling sensor costs
  - Falling costs of data collection and storage due to cloud solutions
  - Widely expanding internet connectivity
  - Increasing computing power
  - Increasing smartphone and tablet penetration

How does IoT Works

* **Stage 1 (Sensors/Actuators)** :
- A thing in the context of “Internet of Things”, should be equipped with sensors and actuators thus giving the ability to emit, accept and process signals
* **Stage 2 (Data Acquisition Systems)**:
- The data from the sensors starts in analogue form which needs to be aggregated and converted into digital streams for further processing.
- This stage performs these data aggregation and conversion functions.

Cont..

* **Stage 3 (Edge Analytics):**

- Once IoT data has been digitized and aggregated, it may require further processing before it enters the data center, this is where Edge Analytics comes in

* **Stage 4 (Cloud Analytics):**

- Data that needs more in-depth processing gets forwarded to physical data centers or cloud-based systems.

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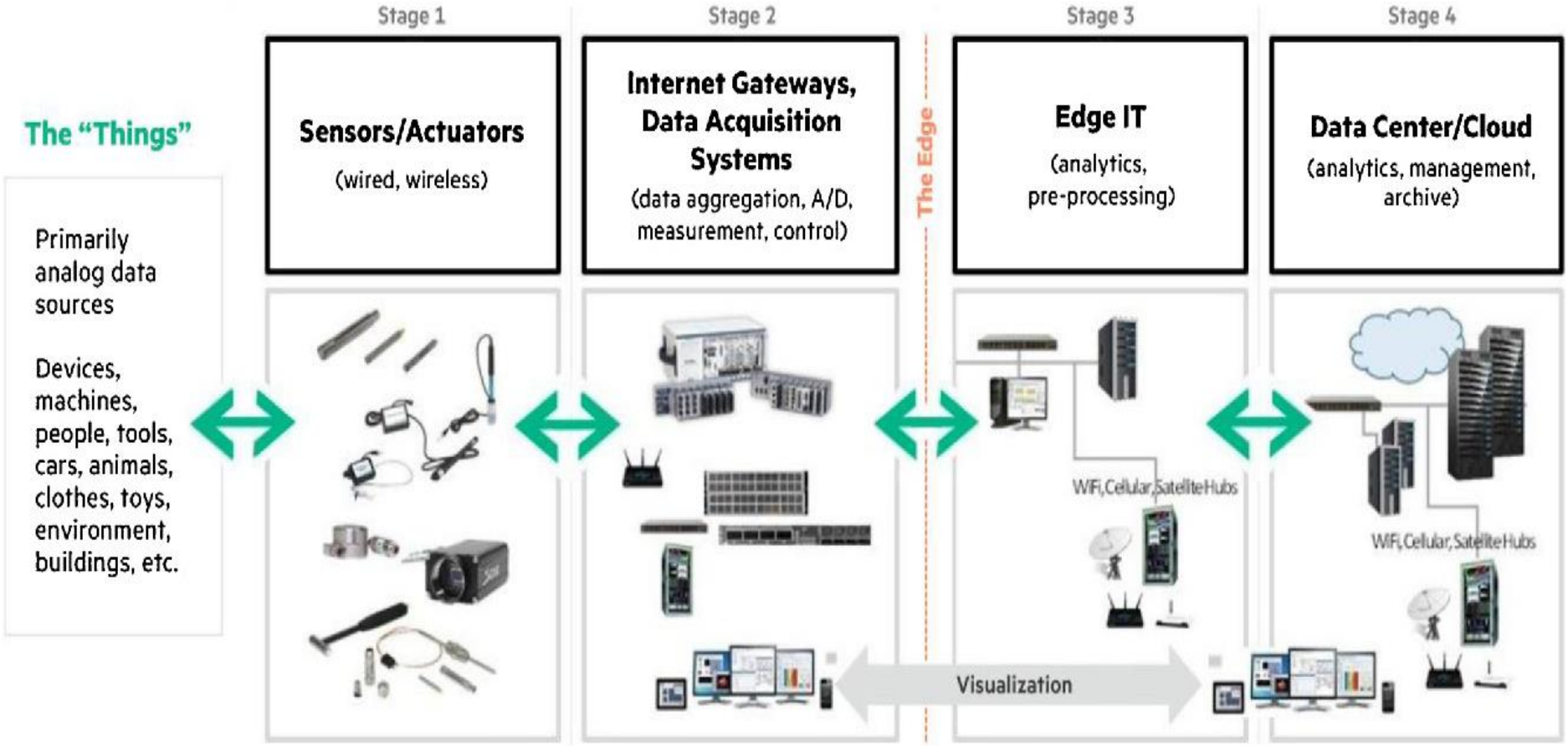
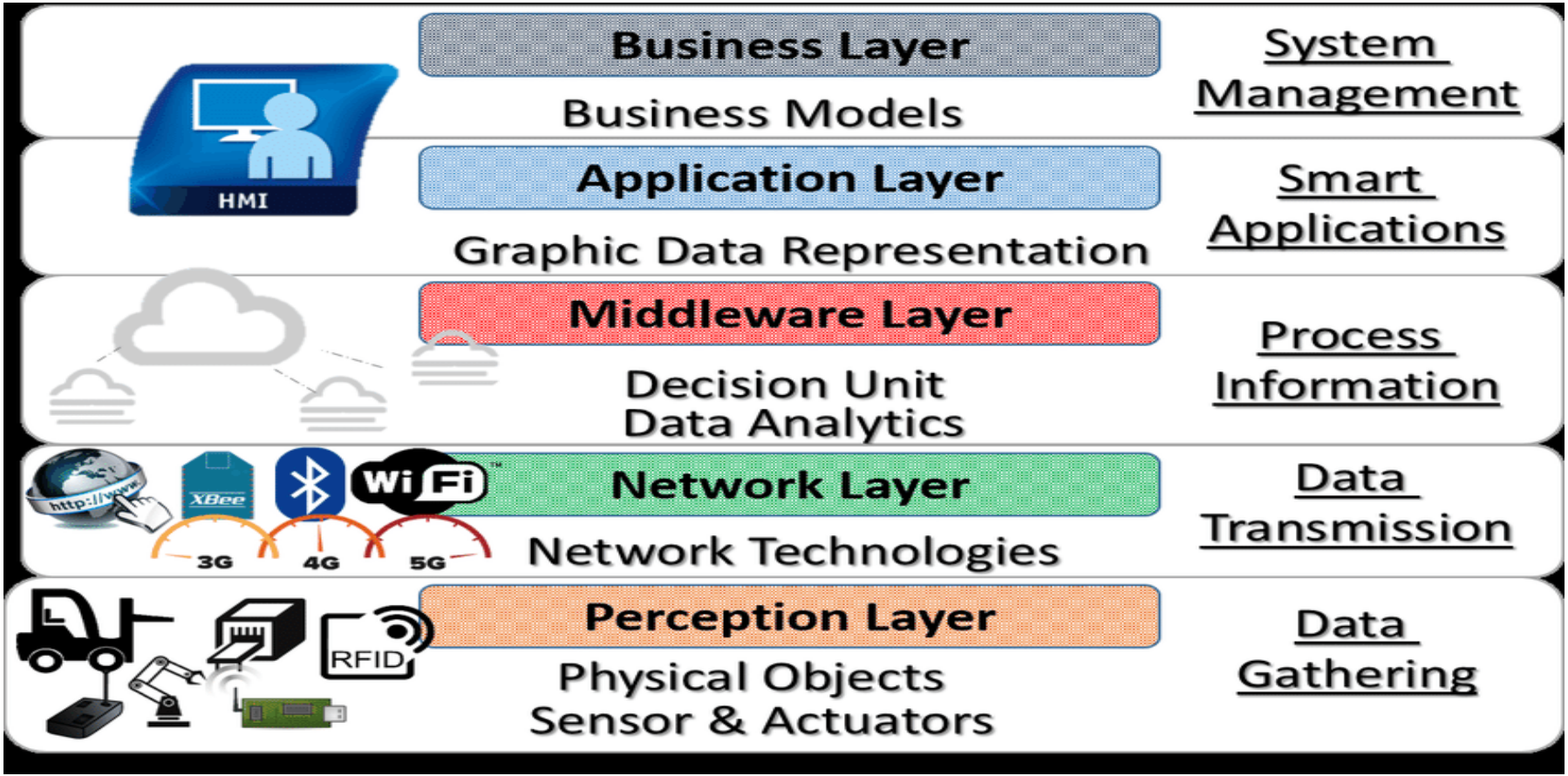

Stage 1
Stage 2
Stage 3
Stage 4
The "Things"
Primarily analog data sources
Devices, machines, people, tools, cars, animals, clothes, toys, environment, buildings, etc.
Sensors/Actuators
(wired, wireless)
Internet Gateways, Data Acquisition Systems
(data aggregation, A/D, measurement, control)
The Edge
Edge IT
(analytics, pre-processing)
Data Center/Cloud
(analytics, management, archive)
WiFi, Cellular, Satellite Hubs
WiFi, Cellular, Satellite Hubs
Visualization

How does IoT Works(Layered Architecture)



Why is IoT important?

* Touches every industry, including healthcare, finance, retail, and manufacturing
* **Helps people live and work smarter – better quality of life**
  - Smart homes, smart, cities, smart kitchen…
  - Smart cities help citizens reduce waste and energy consumption
* **More data means better decisions**
  - With added sensors, these devices are able to collect a large amount of data on many different areas.
* **Increases efficiency by saving money and resources**
  - As well as saving time for the device owner, it can also result in cost savings.
  - For example, if lights automatically turn themselves off the moment you leave the room, you could save a lot of money on you electricity bills.

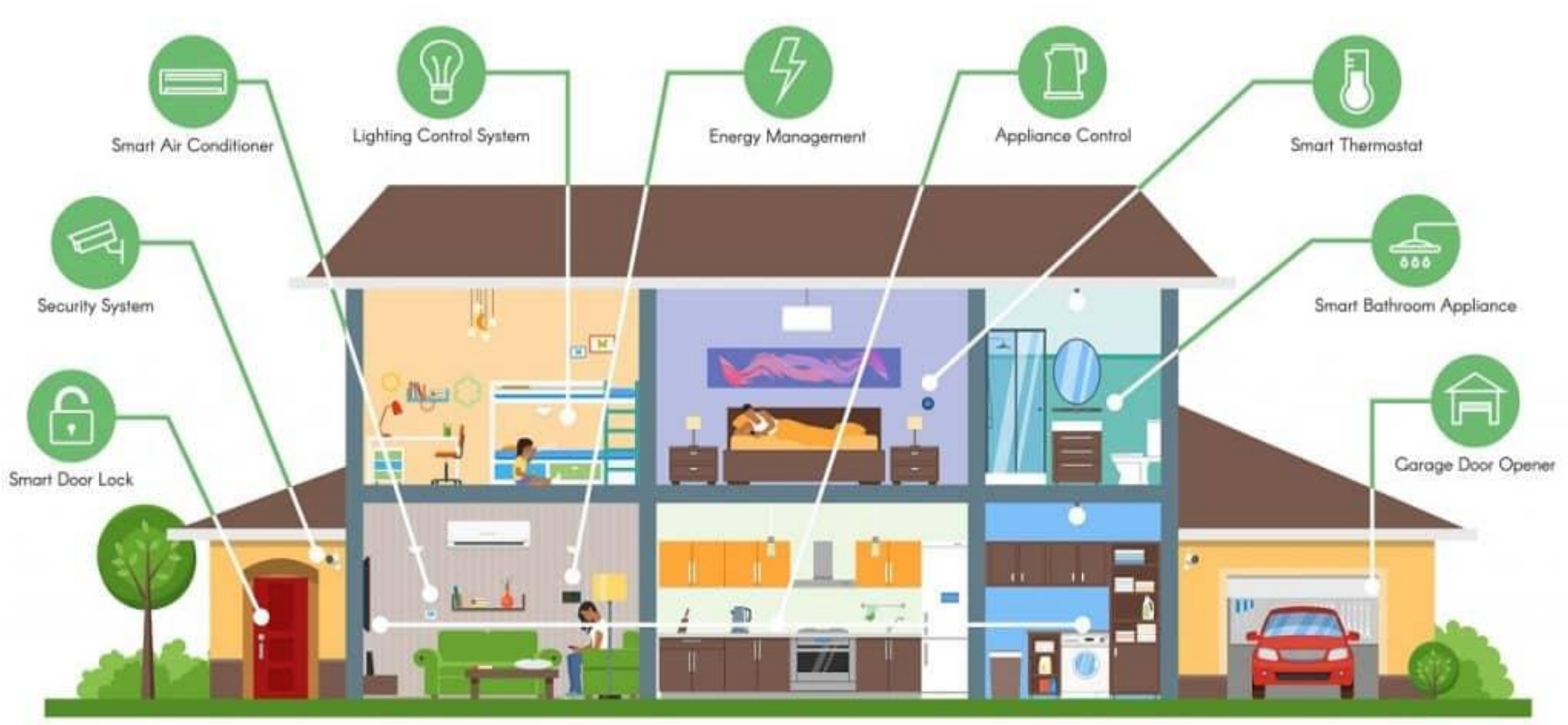
Cont..

* **Provides businesses with a real-time look into how their companies' systems really work**
  - Delivering insights into everything from the performance of machines to supply chain and logistics operations
  - Connected sensors are even used in farming to help monitor crop and cattle yields and predict growth patterns
* **Ability to track and monitor things**
  - As well as tracking data for a company to use, it also greatly benefits the user.
* **Lighten the workload with automation**
  - Having a device doing most the work for you means that you can save more time and cost.

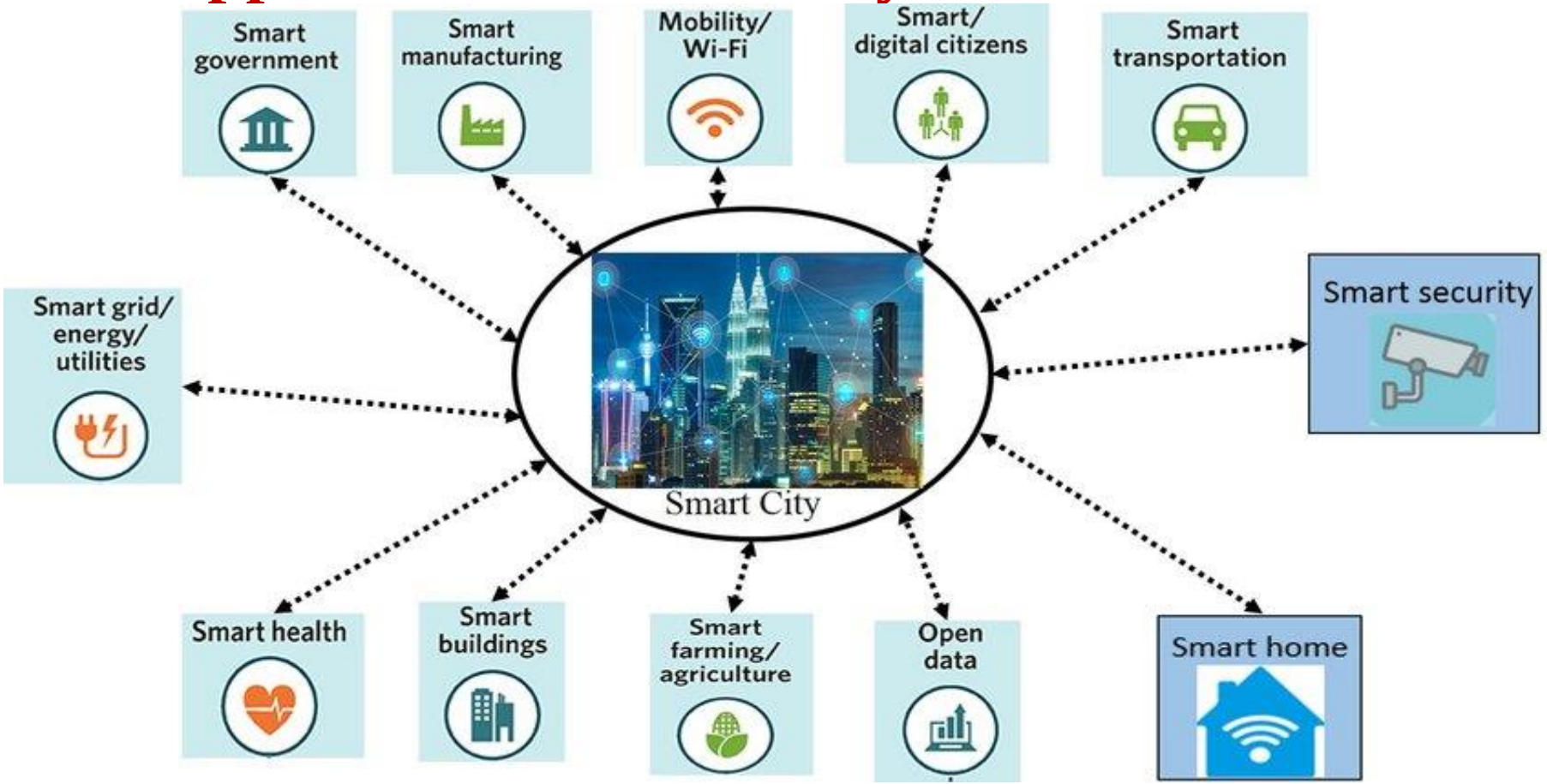
IoT Across Application Domains

* There are numerous real-world applications of the internet of things
  - Consumer IoT and Enterprise IoT
  - Manufacturing and Industrial IoT

IoT Applications - Smart Homes

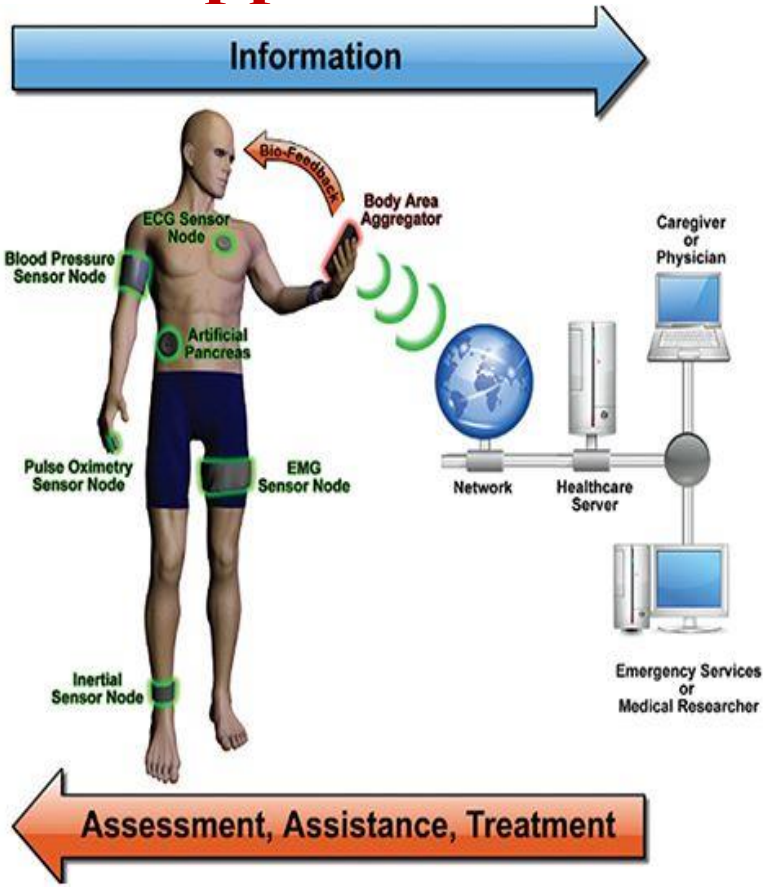


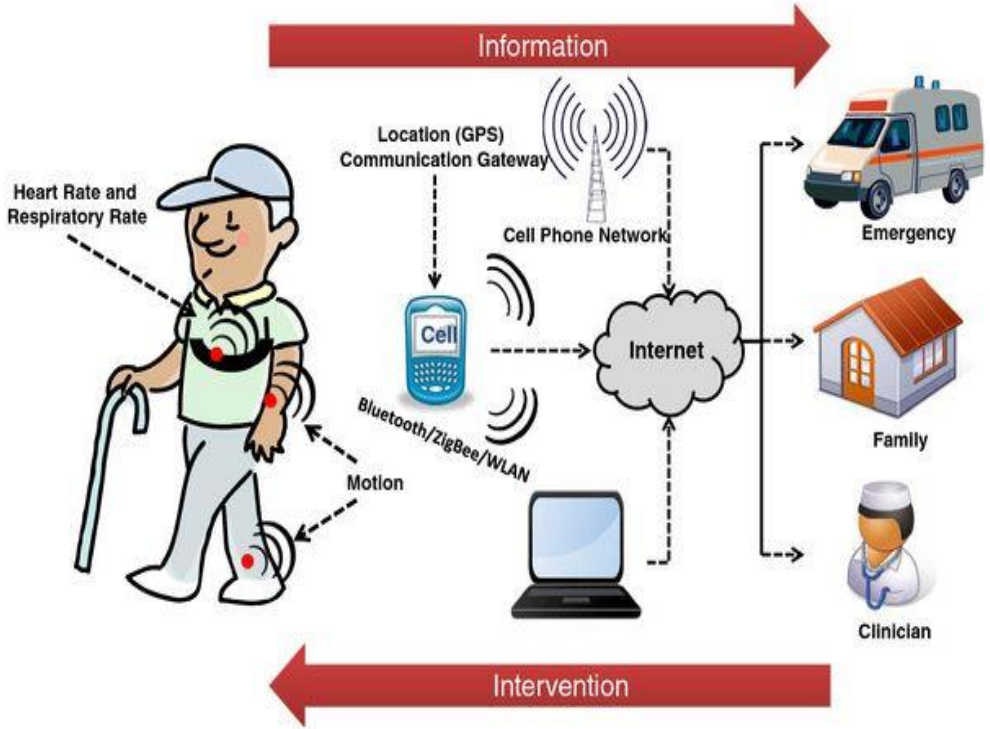
IoT Applications - Smart City



IoT Applications - Smart Farming

IoT Applications - Health Care





Key IoT Challenges

- **Privacy and Security** (refer to the security issues at different Layers of IOT)
  - Trust and quality of-information in shared information models
  - Secure exchange of data between IoT devices and consumers of their information
  - Protection mechanisms for vulnerable devices
- **Cost versus Usability**: reduction in cost of devices and mechanism to use devices is expected

Pros and Cons of IoT

* **Advantage**
  - ✓ Improved(active) Customer Engagement
  - ✓ Technology Optimization
  - ✓ Reduced Waste (Improved resource utilization)
  - ✓ Enhanced Data Collection(sensors do that)

Cont..

* **Interoperability** : With numerous sources of data and heterogeneous devices, the use of standard interfaces between these diverse entities becomes important
* **Data Management:** the volume of the generated data and the processes involved in the handling of those data become critical
* **Device Energy Consumption Level :** How to interconnect “things” in an interoperable way while taking into account the energy constraints
  - Communication between devices takes the most energy

Cont..

* **Disadvantages**
  - ✓ Increased Security Concern(more devices and more info created and shared)
  - ✓ Big Data Management issue(handling huge numbers)
  - ✓ The higher chance of system corruption (if there is a bug in any part of the system)
  - ✓ Device Interoperability(multiple, different device vendors with no accepted standard)
  - ✓ Complexity of the system
  - ✓ High dependency on the internet
  - ✓ Reduced mental and physical activity

IoT Tools and Application Development Platforms

- **IoT Platform**:
  - IoT platform is an essential component of a huge IoT ecosystem that supports and connects all components within the system.
  - It helps to facilitate device management, handle hardware/software communication protocols, collect/analyze data, enhance data flow and functionality of smart applications
- The overall **IoT system includes**
  - Hardware (devices and sensors)
  - Connectivity through a router, gateway, wi-fi, satellite, Ethernet, etc.
  - Software
  - User interface

Cont. ..

- Cloud hosting has become a wide-spread and generally appreciated method of developing and running various technology solutions,
- IoT, directly depending on Internet, definitely benefits from all the advantages of cloud computing
- Special cloud-based IoT platforms support the Internet-based functions of the application – running, maintenance, analytics, data storage, and security measures.

Cont. ..

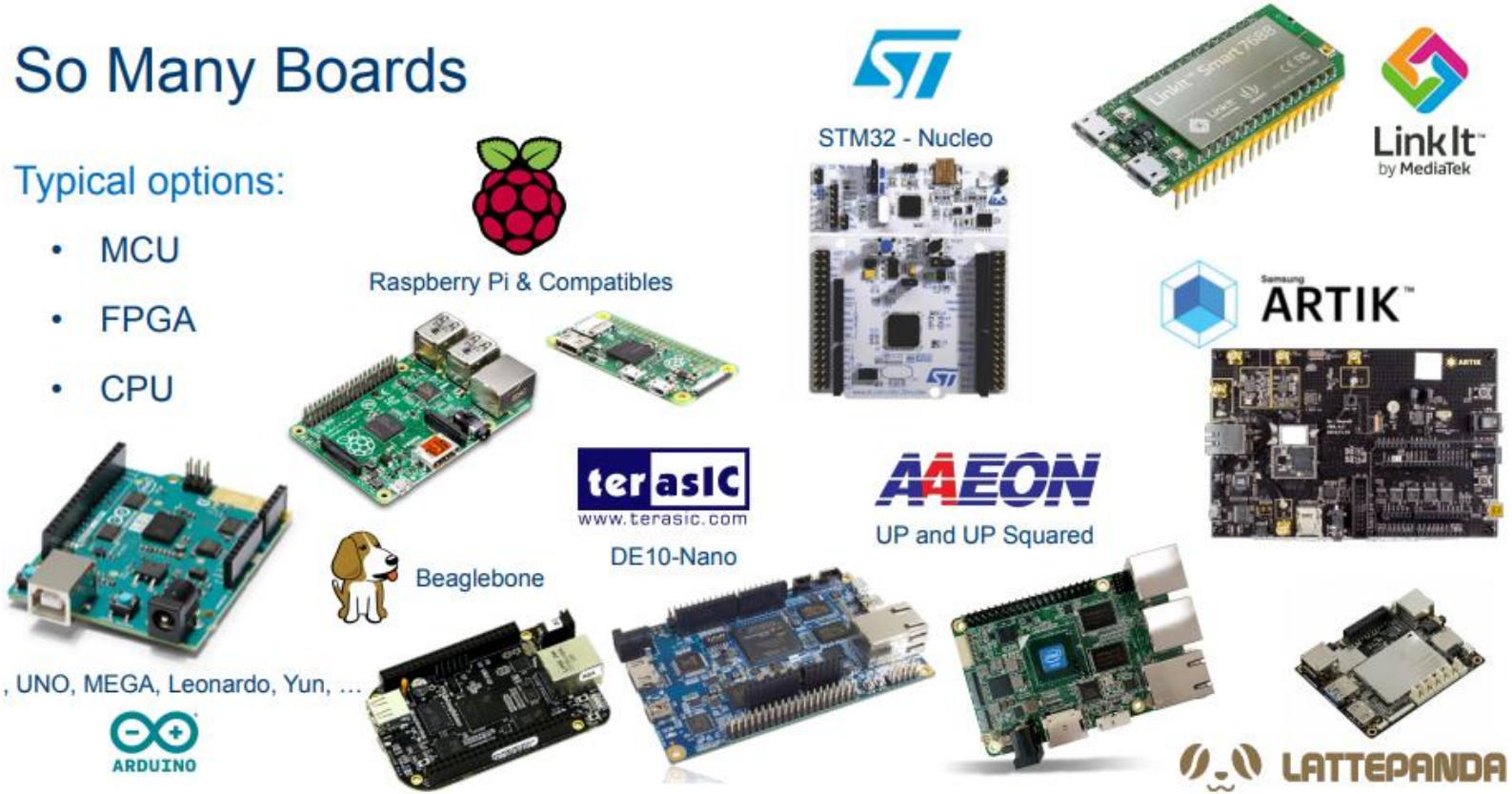
* **Cloud IoT Tools** : Google Cloud IoT, Microsoft Azure IoT Suite, SAP, Salesforce IoT, Oracle Internet of Things, Cisco IoT Cloud Connect, Bosch IoT Suite, IBM Watson Internet of Things, ThingWorx IoT Platform, Huawei Cloud Core

* **IoT Development Platforms:** Tessel 2, Eclipse IoT, Arduino, PlatformIO, Kimono Create, IBM Watson, Raspbian (Raspberry Pi), OpenSCADA, Node-RED, Device Hive

Cont. ..

- **IoT Development Platforms**
  - ✓Top-class IoT development tools that can be employed by both developers and for all those who wish to pursue IoT include
    - Tessel 2
    - Arduino
    - Kimono Create
    - Raspbian (**Raspberry Pi**)
    - Node-RED
    - Eclipse IoT
    - PlatformIO
    - IBM Watson
    - OpenSCADA
    - Device Hive

IoT hardware platforms - So many IoT Chips



Conclusion

* The IoT is a concept that will have an enormous effect on the world.
* Many people are still skeptical about this idea and whether or not it will have a negative or positive impact on society.
* Like it or not, we will eventually reach a point where almost everything we use is connected to the internet in some way.
* This will be very useful and can be used to benefit and improve the lives of individuals all across the world.
* People will be healthier because they will be able to monitor their vitals and eating habits, as well as be safer as they can secure their home from intruders.
* It will also be used to benefit businesses all around the world by making their strategies and products more effective.
* There is no doubt that the advantages of the IoT outweigh the disadvantages, and the IoT will have a positive impact on the world.
* We should be excited for this new concept and look at it as a way to improve our lives everyday.

Chapter 4 - Summary

- In this chapter we have learnt
  - What IoT is and how it emerged as a Technology
  - How IoT works
  - The architectures for IoT(Devices, Network, Communications etc.)
  - The common application areas of IoT in real-life
  - The IoT development and Deployment Platforms

Review Questions

- What are the main parts of the IoT system?
- What are the security concerns related to IoT?
- Explain IoT Protocol stack?
- What is meant by a smart city regarding the IoT?
- Give examples of the impact of IoT on our lives?
- What influence will the IoT have on monetary growth?
- Why will be the IoT successful in the coming years?
- What impact will the IoT have on the health care sector?
- What are the main social and cultural impacts of IoT?
- What the main challenges of an IoT?
- What role does the network play in the IoT of everything?
- How wireless communication might affect the development and implementations of IoT?