IoT-related technologies and applicable areas

Wei Li

CTTL-Terminals, CAICT

2017.11.2

Course Objectives:

- **IoT Architecture**
- **Technology evolution and development**
- **Industrial applications of IoT**
- **Summary**

The definition of IoT

- IoT=Internet of Things， is a network of devices that are connected to the internet via communications technologies, in order to provide a range of new and innovative services and applications.

- Five features:

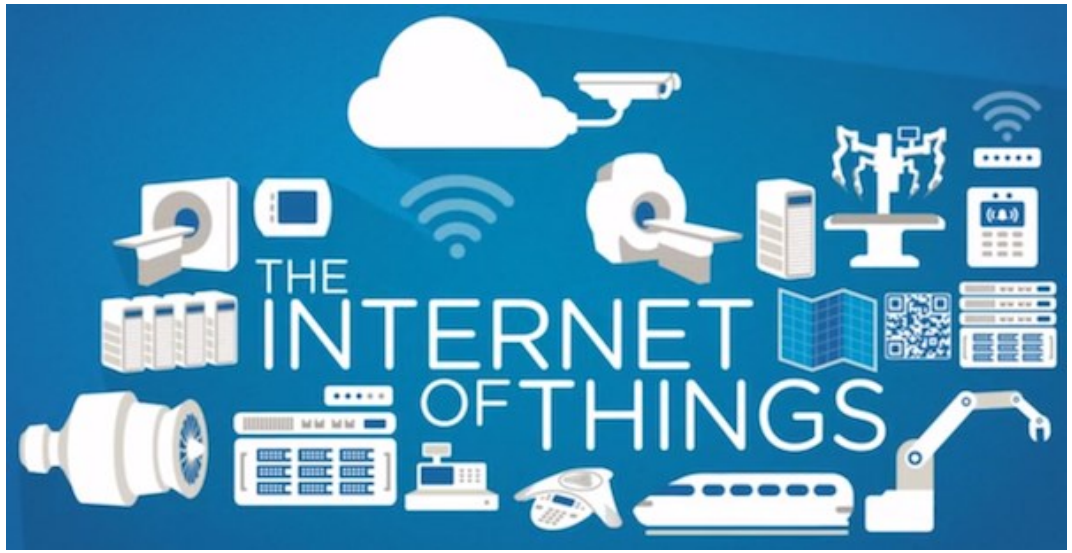
➢ be embedded in everyday objects

➢ use an embedded microprocessor

➢ connect via the Internet

➢ use interconnected networks

➢ use standardized communications



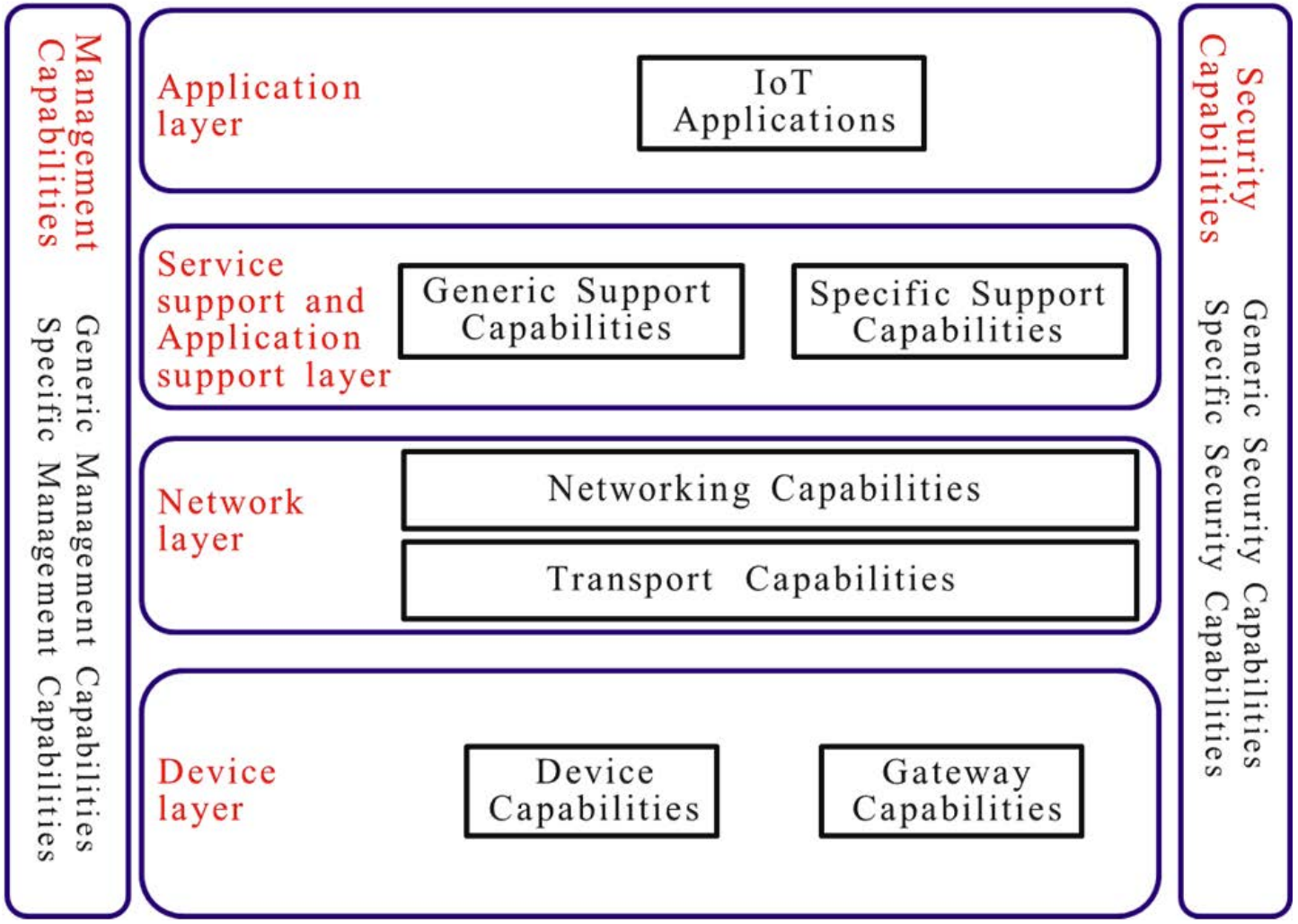
Background and development

- Versions of connected objects have existed for decades. However, recent advances in the technologies that support IoT devices have accelerated their adoption.

1990	• Carnegie Mellon's Computer Science Department uses the internet to track how many soda bottles are in a vending machine
1999	• Massachusetts Institute of Technology creates the term IoT to describe technology that uses electronic tags for tracking specific objects and transmits that information using the Internet, allowing for greater accuracy in tracking the distribution of goods
2005	• At the World Summit on the Information Society (WSIS) in Tunisia, the ITU published the 《ITU Internet Report 2005: Internet of Things》, which refers to the concept of IoT
2008	• Standardization organizations start the process of creating specifications for IoT technology used to manage machines remotely(over networks)
2009	• A turning point is reached in IoT adoption as more Internet-connected devices are in existence than people on Earth

IoT Architecture

- The chart below shows the IoT reference model. It is composed of four layers as well as management capabilities and security capabilities



Rec. ITU-T Y.2060

The four layers are as follows:

- application layer
- service support and application support layer
- network layer
- device layer.

- The chart below shows the main considerations affecting different levels of the IoT architecture.

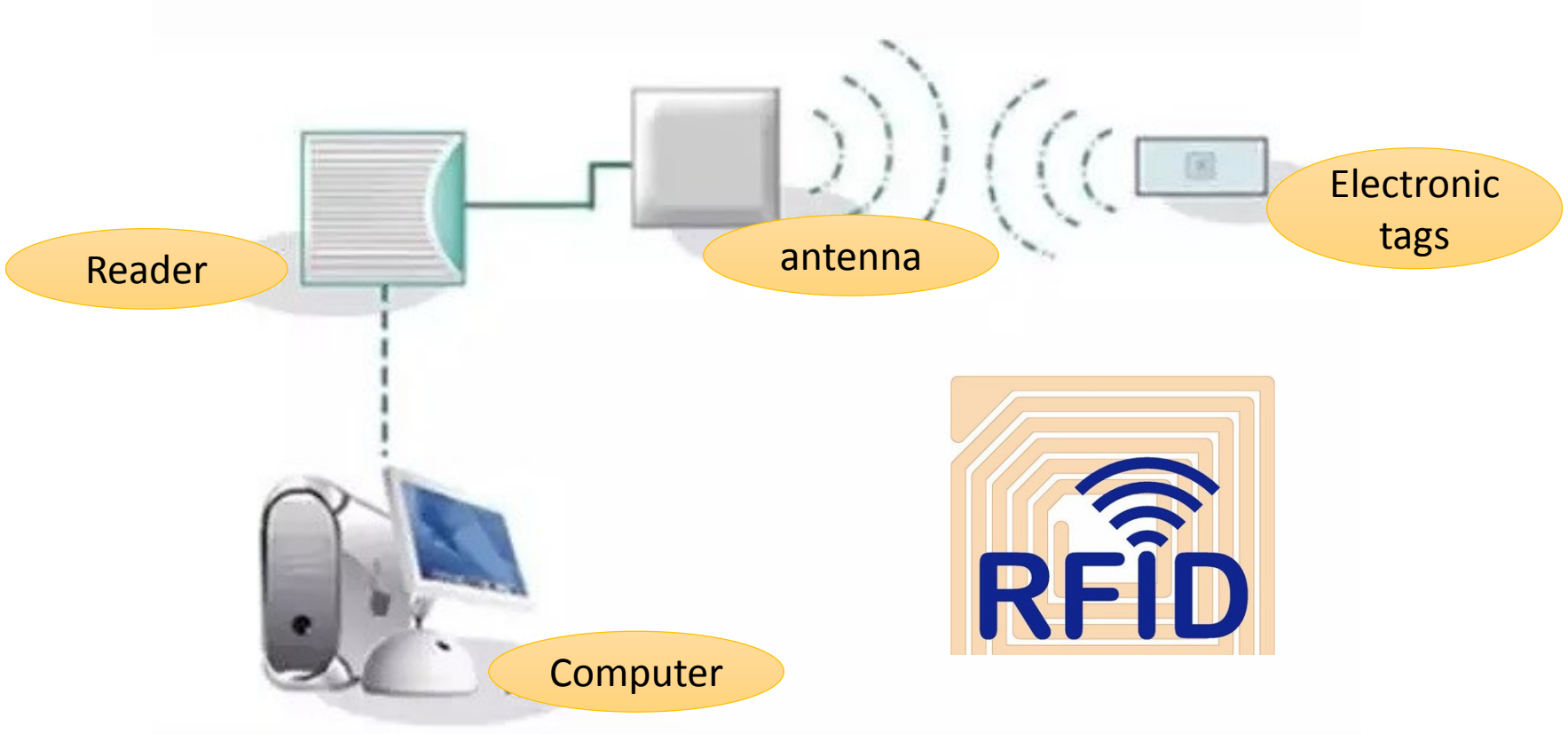
	Enablers	Key technologies	Public factors
Services & Applications	•Evolution from products to services •Availability of scalable cloud services	•Cloud services •IoT brokerage platforms	•Cost savings •Safety concern •User experience •Government policy •Network management
Connectivity	•Network coverage •Cellular standards •Standards supporting new entrants •Available spectrum	•Local area, e.g. Bluetooth, Wi-Fi, Thread •Low power wide area, e.g. LoRa, Sigfox •Cellular, e.g. 2/3/4G,eMTC,NB-IoT	
Things	•Low cost sensors •Improvements in battery technology	•Sensors specific to applications •Actuators specific to applications •Local processing, e.g. algorithms and artificial intelligence	

Course Objectives:

- IoT Architecture
- Technology evolution and development
  - Sensing Technology
    - RFID
    - Sensor
  - Connectivity Technology
- Industrial applications of IoT
- Summary

Sensing technology

- **RFID**(Radio Frequency Identification), is the technology to identify the target object and obtain the relevant data ,through the radio frequency method for non-contact two-way data communication.



RFID system consists of **three parts**:

Reader;

electronic Tag;

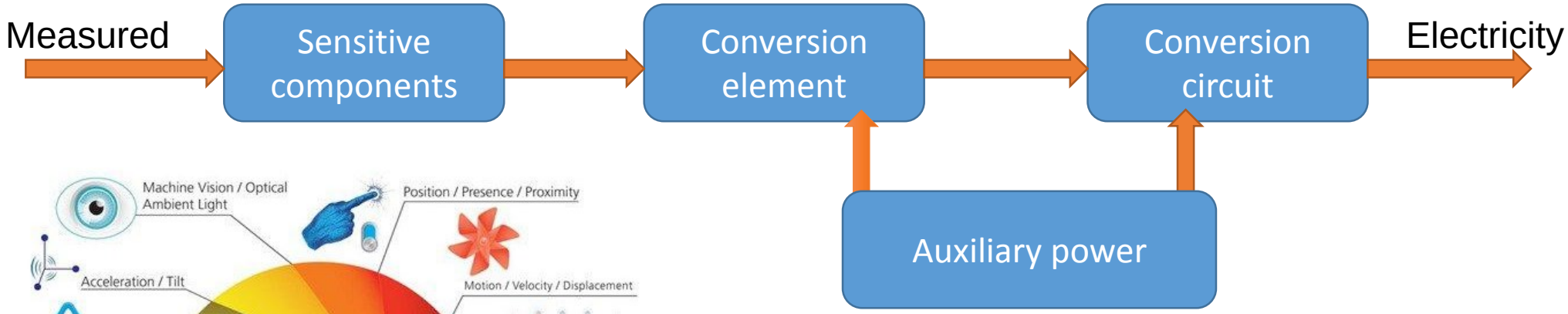
central processing system.

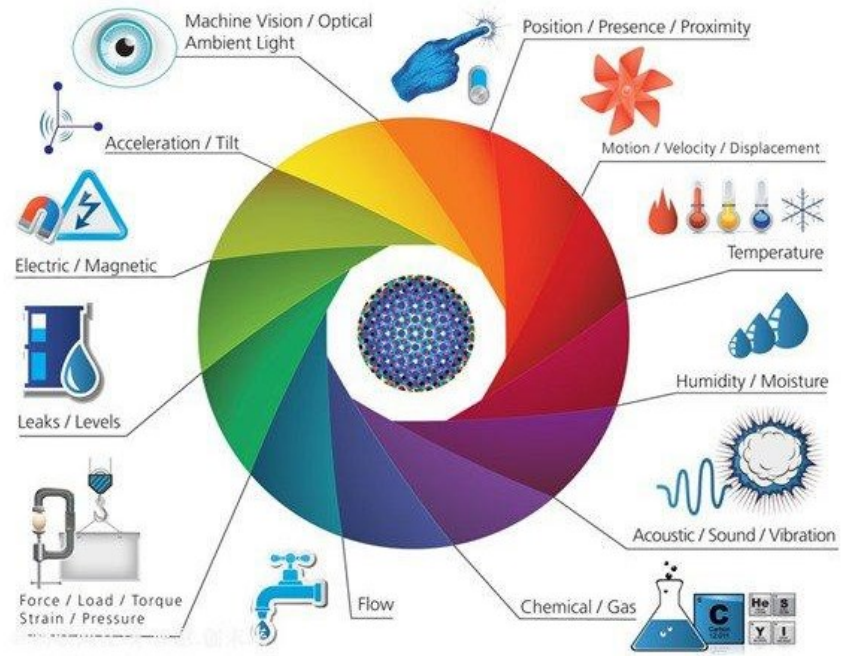
Course Objectives:

- IoT Architecture
- Technology evolution and development
  - Sensing Technology
    - RFID
    - Sensor
  - Connectivity Technology
- Industrial applications of IoT
- Summary

Sensing technology

- A **sensor** is a device that converts a form of information(Physical 、 chemical or biological) into another set of information(electric signal) by means of a sensing element.





· Main features:

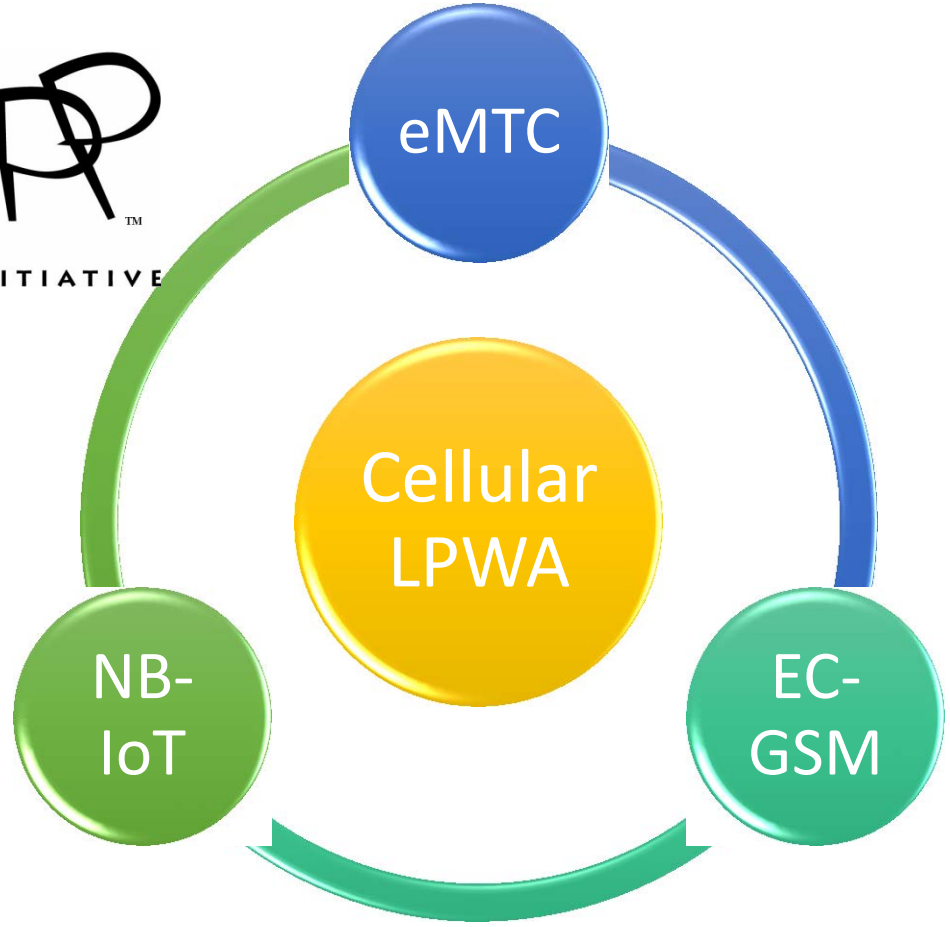
- ➢ Miniaturization
- ➢ Intelligent
- ➢ Networked
- ➢ Digitizing
- ➢ Multi-functional

Course Objectives:

- IoT Architecture
- Technology evolution and development
  - Sensing Technology
  - Connectivity Technology
    - Cellular technologies
    - LoRa
    - Bluetooth Low Energy
    - IEEE 802.15.4 ZigBee
    - 5G NR
    - Summary
  - Services Technology
- Industrial applications of IoT
- Summary

Cellular technologies for IoT

- In 2016,a major development has been the standardization of technologies designed to upgrade existing cellular infrastructure to support IoT services.



The three technologies delivered on licensed spectrum will ensure customer choice and help the IoT market to flourish.

The concepts：

- LPWA= Low-Power, Wide-Area;
  NB-IoT= Narrow Band Internet of Things;
  eMTC =enhanced Machine Type Communication;
  EC-GSM= Extend Coverage GSM.

Cellular technologies for IoT

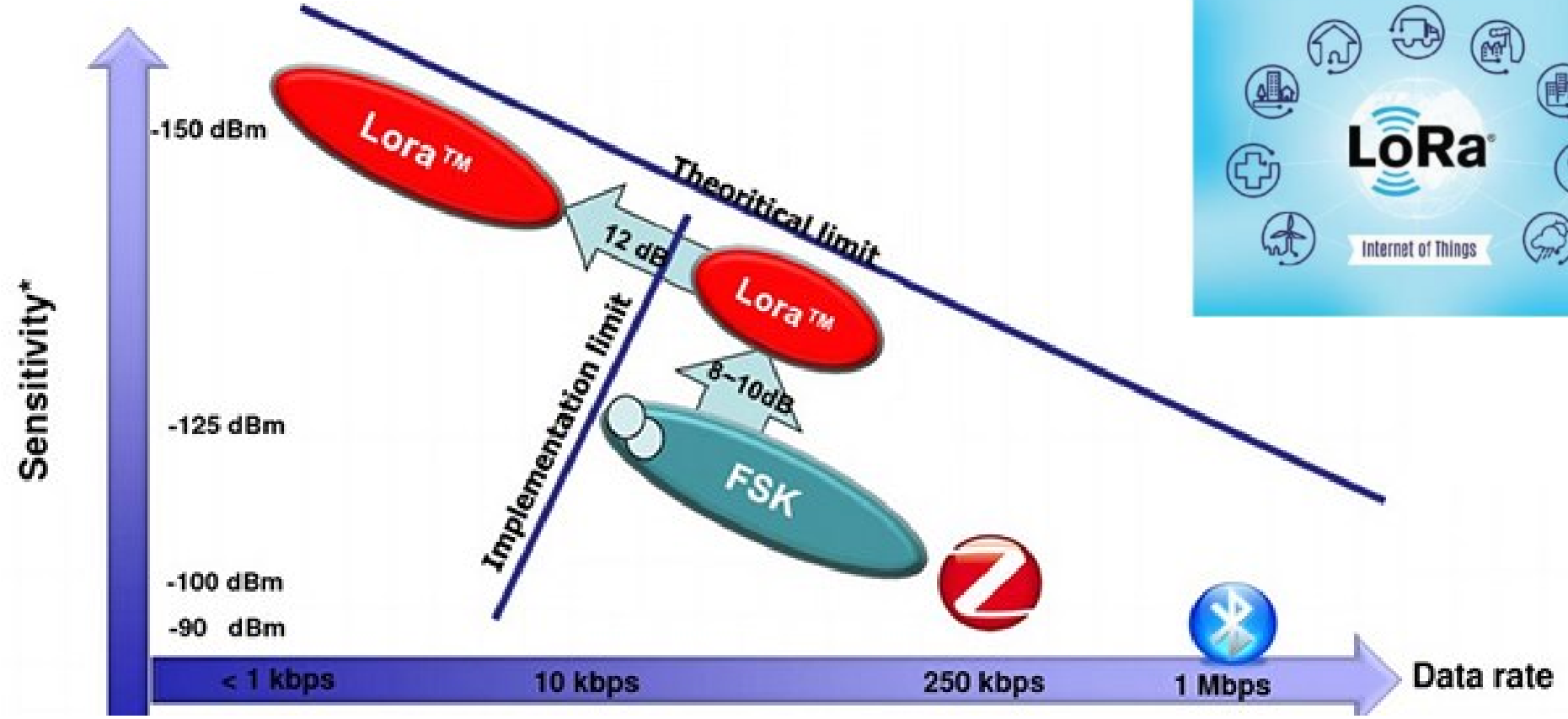
	NB-IoT	eMTC	EC-GSM
Deployment	In-band & Guard-band LTE, standalone	In-band LTE	In-band GSM
Coverage	164dB	155.7 dB	164dB,154dB
Downlink	OFDM,15 kHZ tone spacing,TBCC,1 Rx	OFDM,15 kHZ tone spacing, Turbo Code,16QAM,1Rx	TDMA/FDMA,GMSK and 8PSK(optional),1Rx
Uplink	Single tone,15kHZ and 3.75 kHZ spacing SC-FDMA,15 kHZ tone spacing, Turbo Code	SC-FDMA,15 kHZ tone spacing, Turbo Code,1 Rx	TDMA/FDMA,GMSK and 8PSK(optional),
Bandwidth	180kHZ	1.08MHZ	200kHZ per channel
Peak rate	DL:250kbps UL:250kbps 20kbps	1Mbps	70kbps 200kbps
Duplexing	HD(type B) FDD	FD&HD(type B)FDD&TDD	HD FDD
Power saving	PSM ext. I-DRX,C-DRX	PSM ext. I-DRX,C-DRX	PSM ext. I-DRX
Power class	23dBm	23dBm 20dBm	33dBm 23dBm

Course Objectives:

- IoT Architecture
- Technology evolution and development
  - Sensing Technology
  - Connectivity Technology
    - Cellular technologies
    - LoRa
    - Bluetooth Low Energy
    - IEEE 802.15.4 ZigBee
    - 5G NR
    - Summary
- Industrial applications of IoT
- Summary

IoT key technologies: LoRa

- LoRa has been developed by a single vendor, Semtech. This is being led by the LoRa Alliance, a non-profit organization responsible for the on-going standardization and certification of devices and infrastructure.



IoT key technologies: LoRa

- The main features of LoRa

LoRa is designed to support more than 10,000 devices per access point, with data rates from around 250 bps to 50 kbps typically. It is also able to offer location based services using differential time of arrival techniques in order to work out the distance from a number of hubs to the terminal, and hence triangulate its location.

Main features	Advantages
157dB link budget	**Long distance**
Distance>15km	
Minimum infrastructure cost	**Easy to build and deploy**
Extend capacity with gateways and concentrators	
Battery Life>10 years	**Extend battery life**
Receive current 100mA, sleep current<200nA	
Licence-exempt	**Low cost**
Low infrastructure costs	
Low cost of nodes and terminals	

Course Objectives:

- IoT Architecture
- Technology evolution and development
  - Sensing Technology
  - Connectivity Technology
    - Cellular technologies
    - LoRa
    - Bluetooth Low Energy
    - IEEE 802.15.4 ZigBee
    - 5G NR
    - Summary
- Industrial applications of IoT
- Summary

IoT key technologies: Bluetooth Low Energy

- Bluetooth Low Energy (BLE) has been the mainstay of connectivity for consumer IoT products released into the market to date. It forms a connection to a user's Smartphone, is highly power efficient and is marketed as 'Bluetooth Smart'.

BLE wireless technology, the hallmark features:

- ➢Ultra-low peak, average and idle mode power consumption
- ➢Ability to run for years on standard coin-cell batteries
- ➢Low cost
- ➢Multi-vendor interoperability
- ➢Enhanced range

IoT key technologies: Bluetooth Low Energy

	Bluetooth BR/EDR	Bluetooth low energy
Frequency	2400-2483.5 MHz	2400-2483.5 MHz
Deep Sleep	~80 µA	<5 µA
Idle	~8 mA	~1 mA
Peak Current	22-40 mA	10-30 mA
Range	500m (Class 1) / 50m (Class 2)	100m
Min. Output Power	0 dBm (Class 1) / -6 dBm (Class 2)	-20 dBm
Max. Output Power	+20 dBm (Class 1) / +4 dBm (Class 2)	+10 dBm
Receiver Sensitivity	≥ -70 dBm	≥ -70 dBm
Encryption	64 bit / 128 bit	AES-128 bit
Connection Time	100 ms	3 ms
Frequency Hopping	Yes	Yes
Advertising Channel	32	3
Data Channel	79	37
Voice capable	Yes	No

Bluetooth™

VS

Bluetooth® SMART

Course Objectives:

- IoT Architecture
- Technology evolution and development
  - Sensing Technology
  - Connectivity Technology
    - Cellular technologies
    - LoRa
    - Bluetooth Low Energy
    - IEEE 802.15.4 ZigBee
    - 5G NR
    - Summary
- Industrial applications of IoT
- Summary

IoT key technologies: IEEE 802.15.4 ZigBee

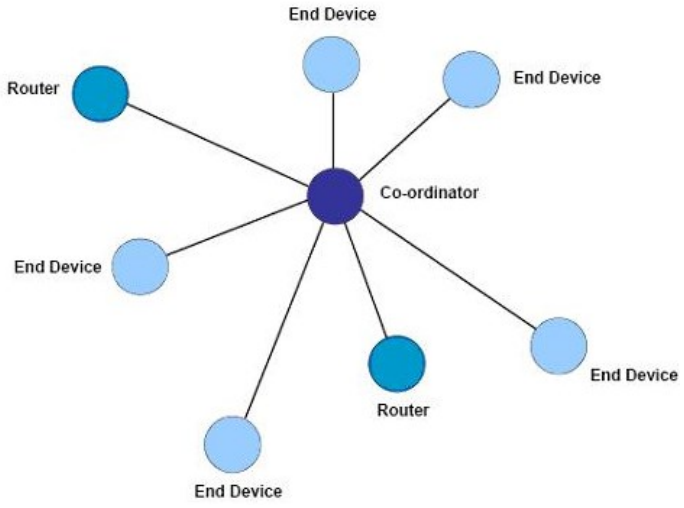
- **ZigBee** is a relatively old standard, having been standardized in 2003,

but it is still widely available in devices such as connected switches and lighting controls. It is able to form a mesh network, allowing very low power radios to improve coverage and deliver service continuity throughout a building.

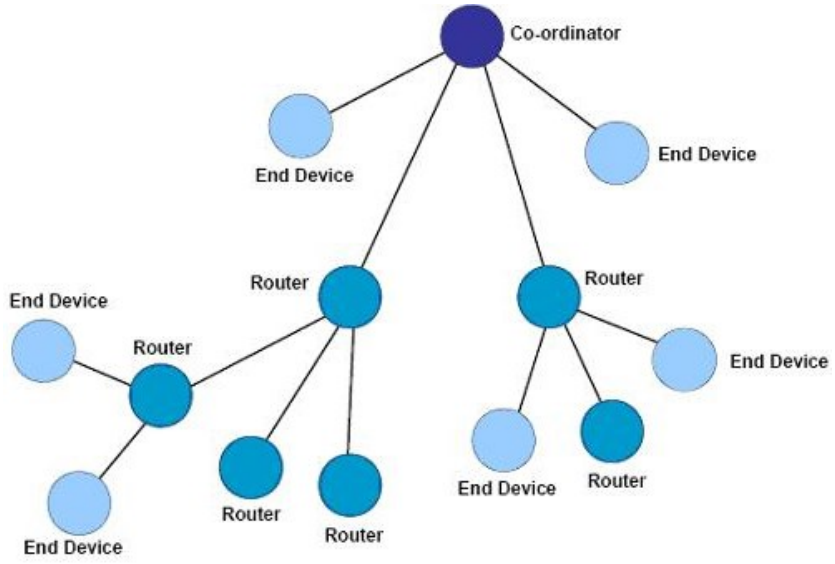
Technology	Data rate	Spectrum	Standardization approach	Comments
IEEE 802.15.4 ZigBee	Various	License-exempt	802.15.4 is standardized by the IEEE, and ZigBee apply additional protocols	Supports short-range mesh networks

IEEE 802.15.4 ZigBee

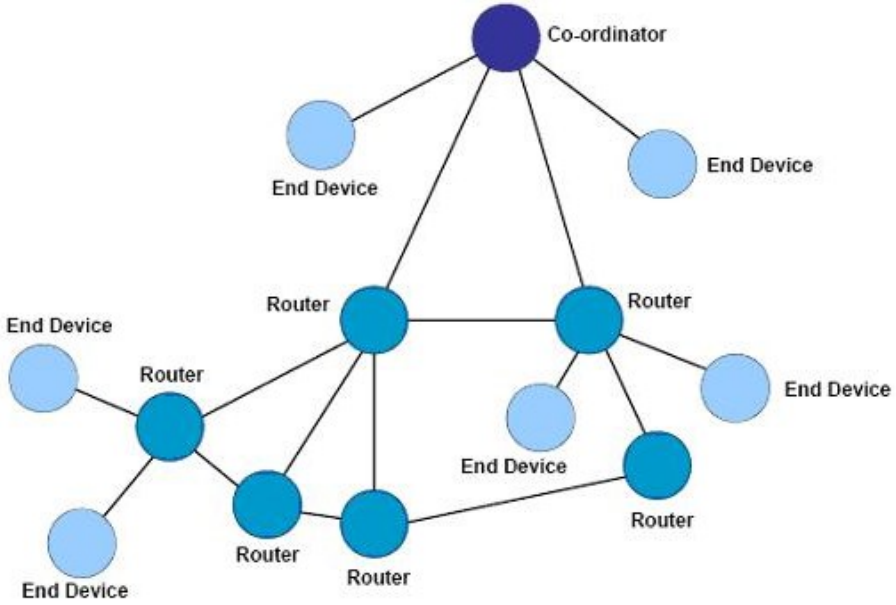
- ZigBee has **strong networking capabilities**, forming a star, tree and mesh network. According to the actual project it needs to select the appropriate network structure.



Star topology



Tree topology



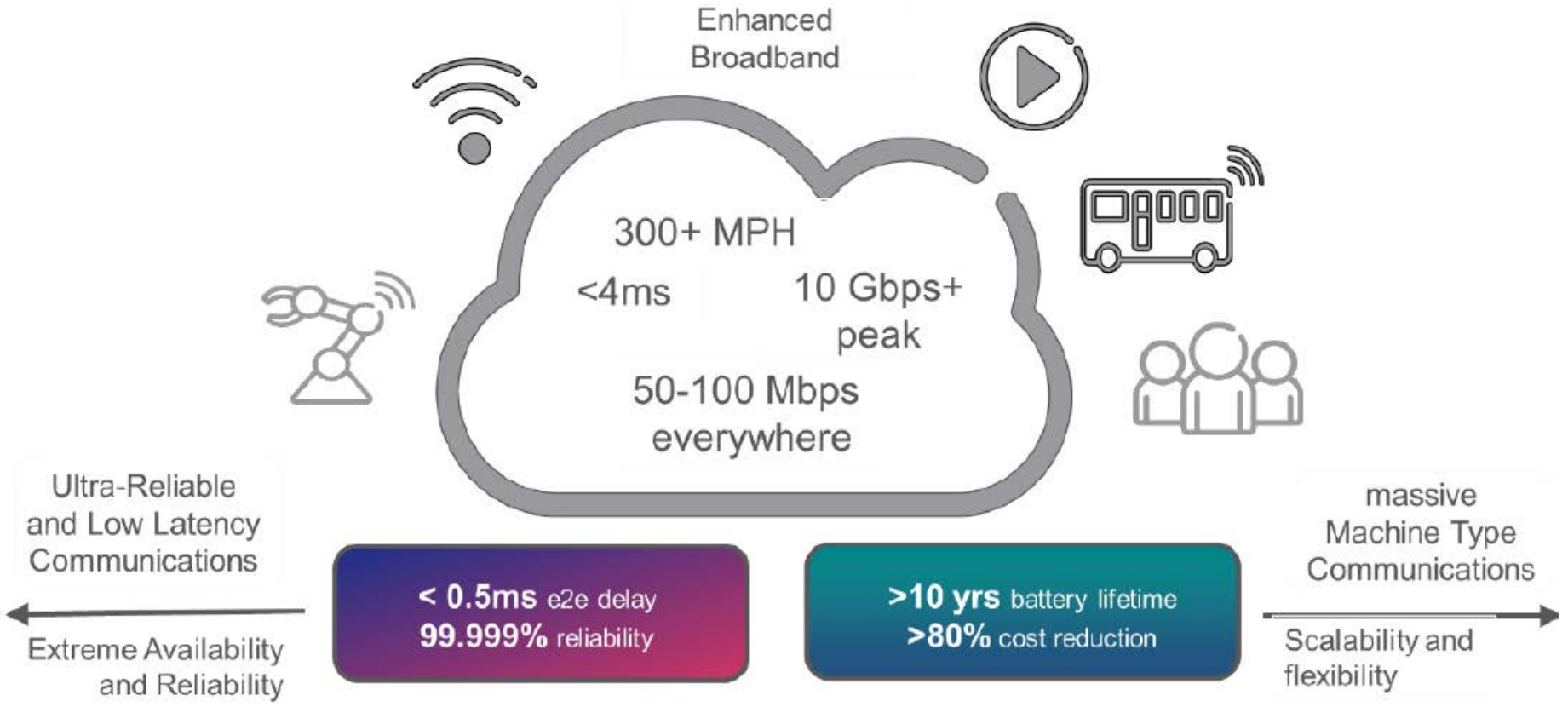
Mesh topology

Course Objectives:

- IoT Architecture
- Technology evolution and development
  - Sensing Technology
  - Connectivity Technology
    - Cellular technologies
    - LoRa
    - Bluetooth Low Energy
    - IEEE 802.15.4 ZigBee
    - 5G NR
    - Summary
- Industrial applications of IoT
- Summary

5G NR

- **5G NR** aims at refining the requirements and key performance indicators (KPIs) associated with key 5G IoT use cases, Expanding on Rel-13/14 IoT standards.



5G NR

- Looking further to the future, 5G is the first cellular standard that is being defined with support for IoT from the outset. Current standardization work focuses on **three main categories** of use case for 5G:

➢ Enhanced mobile broadband

➢ Mission critical control

➢ Massive Internet of Things

Commercial: There is much debate about when 5G services will become commercially available but what is clear is that, with the standardization activity only just beginning, it will be several years before 5G deployments and services reach significant scale.

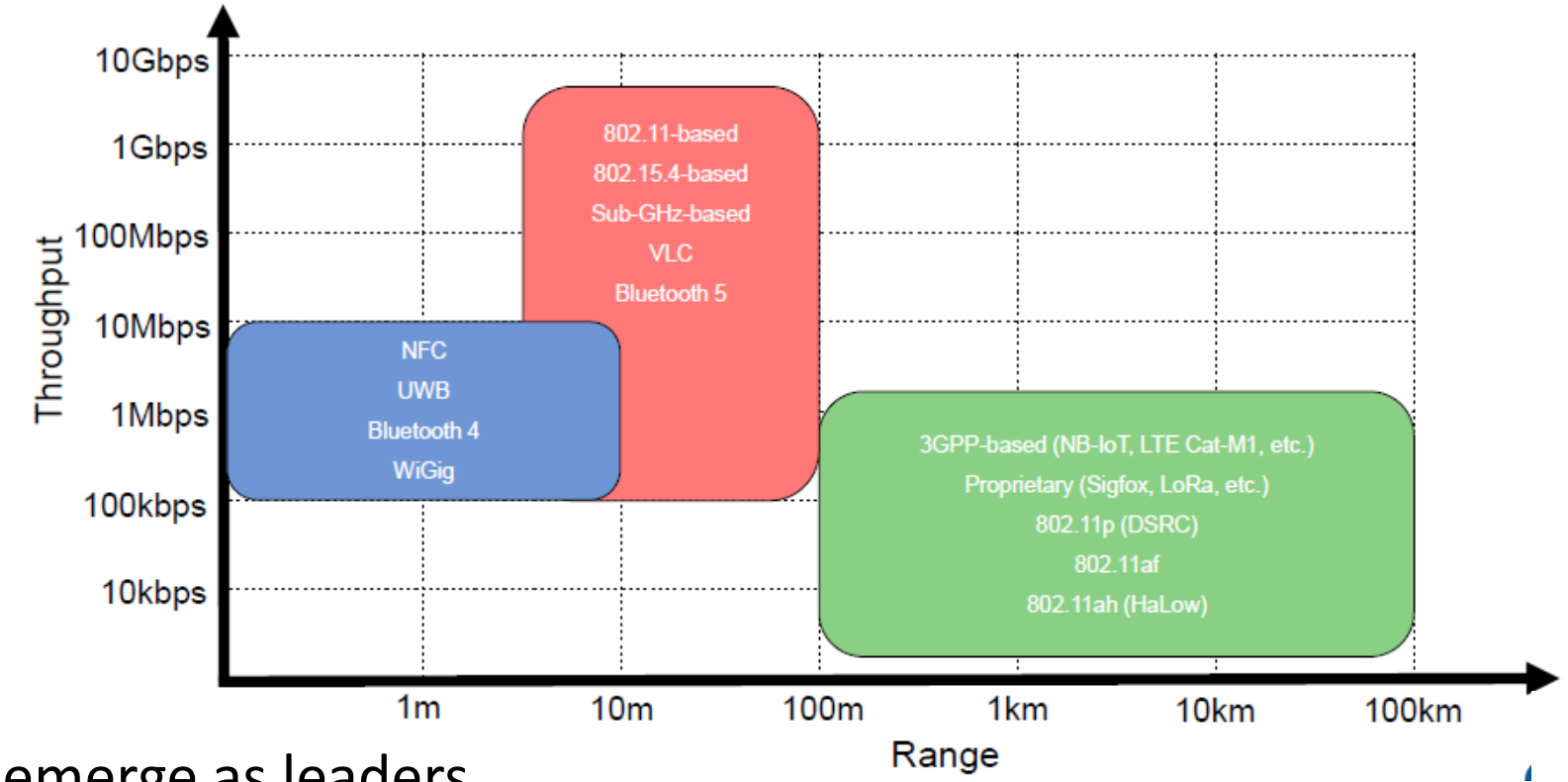
Course Objectives:

- IoT Architecture
- Technology evolution and development
  - Sensing Technology
  - Connectivity Technology
    - Cellular technologies
    - LoRa
    - Bluetooth Low Energy
    - IEEE 802.15.4 ZigBee
    - 5G NR
    - Summary
- Industrial applications of IoT
- Summary

Summary

- **Current situation：** a range of competing technologies

- **Consideration：**
  - ➢ data rate
  - ➢ device battery life
  - ➢ range
  - ➢ spectrum usage
  - ➢ the number of devices supported



- **Future：** a small number emerge as leaders

Course Objectives:

- IoT Architecture
- Technology evolution and development
- Industrial applications of IoT
  - Wearables
  - Connected & Smart Home
  - Automotive
  - Manufacturing
  - Agriculture and environment
  - Health care
  - Smart cities
- Summary

Potential market

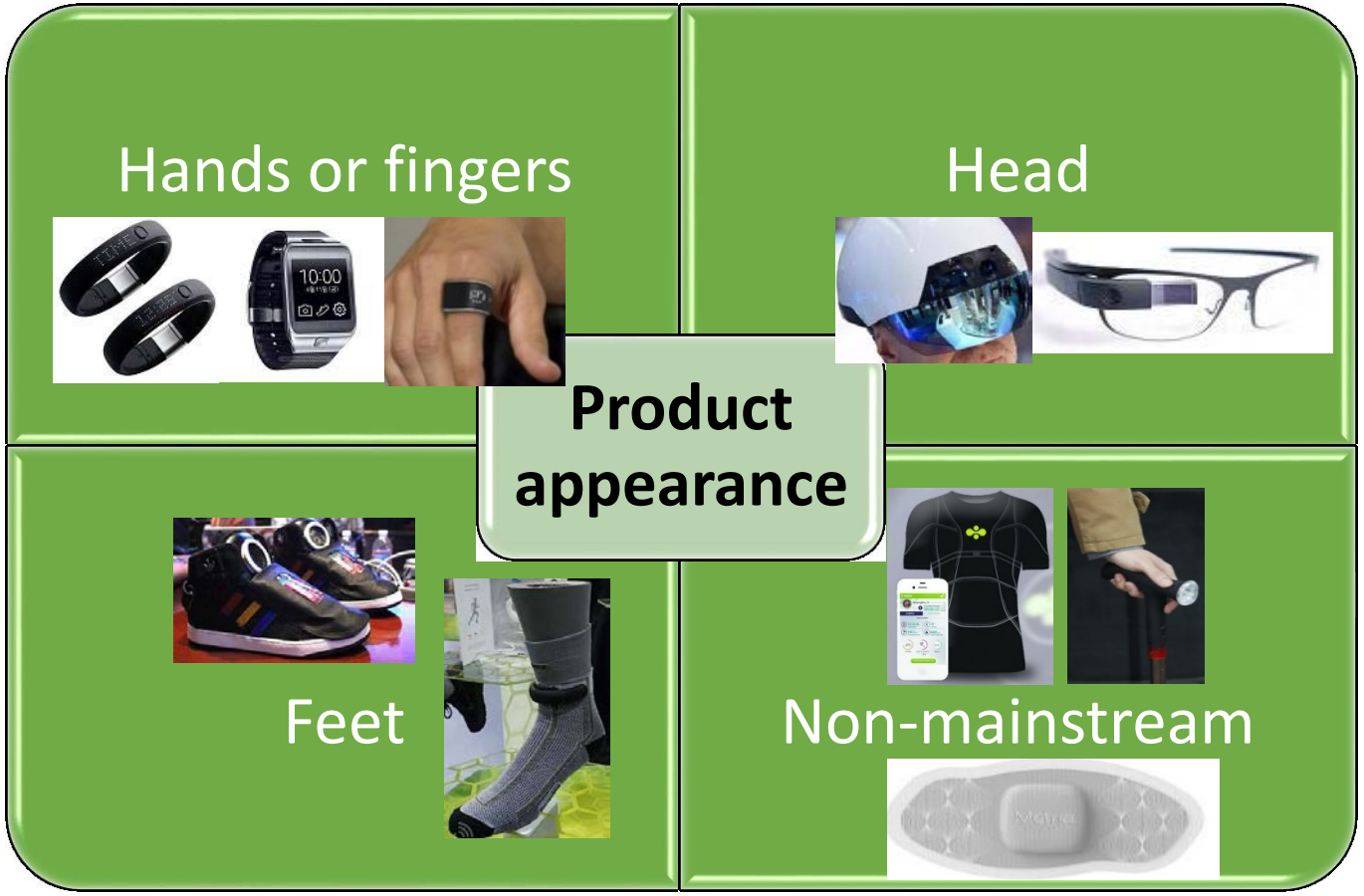
IoT devices are used across **multiple sectors** and by various **groups** and **individuals** to inform future actions and decision-making. The IoT can be used in almost any circumstance in which human activity or machine function can be enhanced by data collection or automation.

The IoT has the potential to generate about $4 trillion to $11 trillion in **economic value** by 2025.

McKinsey Global Institute analysis

Wearables

Wearable technology is a category of devices that can be worn by a consumer that track the wearer's behavior, often related to health and fitness.

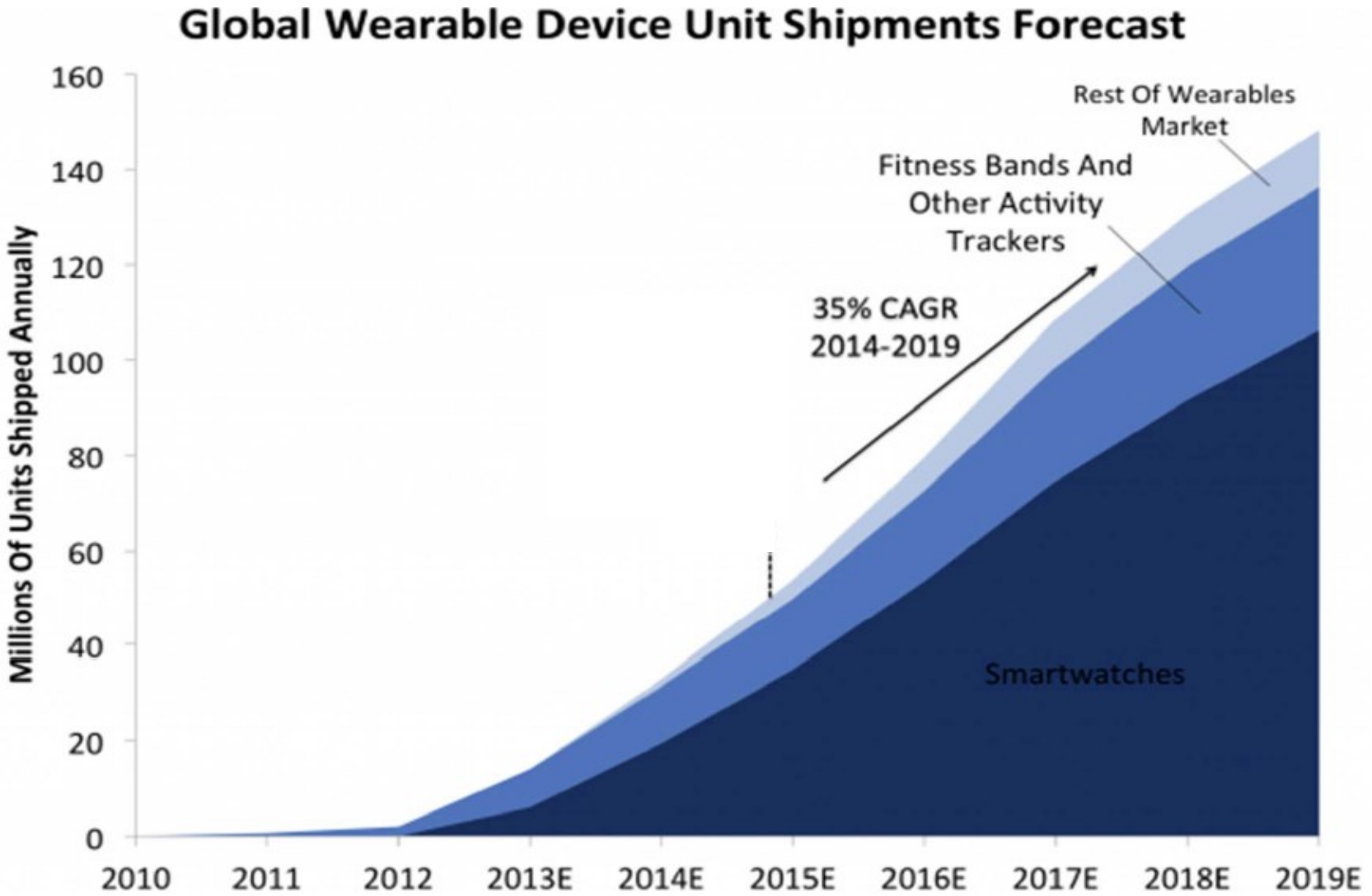


Bluetooth SMART

Wi Fi

GPS

Wearables



BI intelligence

While wearable technology has gained further momentum in the past two years, we are still in the **early stages** of the industry as many of the expectations of the market are yet to be realized.

Course Objectives:

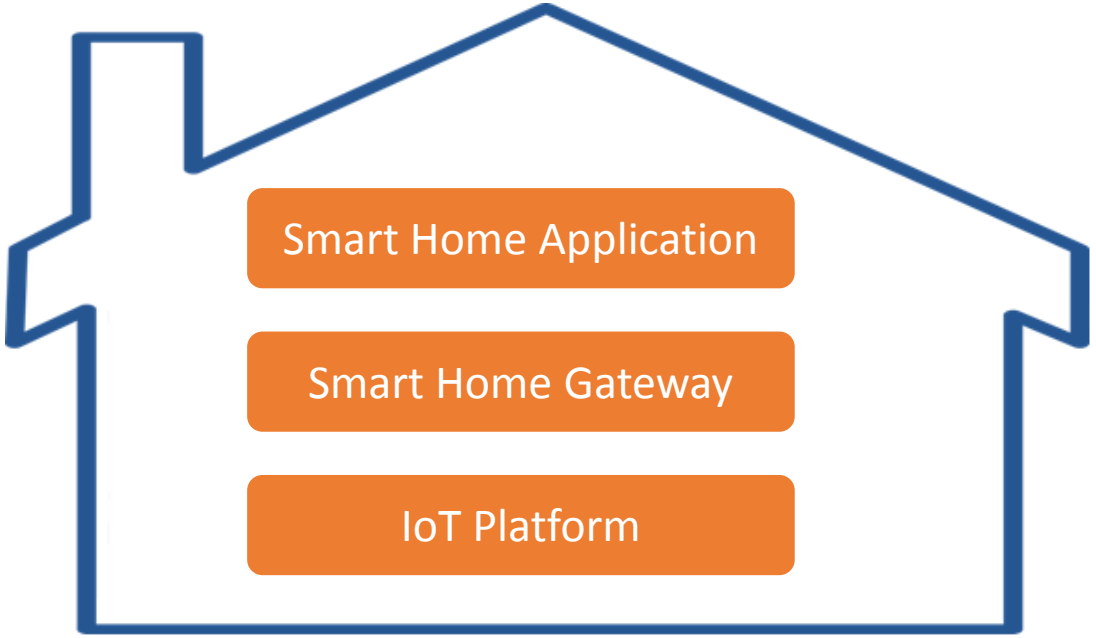
- IoT Architecture
- Technology evolution and development
- Industrial applications of IoT
  - Wearables
  - Connected & Smart Home
  - Automotive
  - Manufacturing
  - Agriculture and environment
  - Health care
  - Smart cities
- Summary

Connected & Smart Home

Home Appliances
Clothes dryer
Dishwasher
Freezer/refrigerator
Large cooking
Microwave oven
Personal care appliances
Small home appliances
Washing machine

Consumer Electronics
BD player
Connected AVR
DMA
FTA set-top box
Games console
Pay-TV set-top box
Smart TV
Soundbar
Wireless headphone

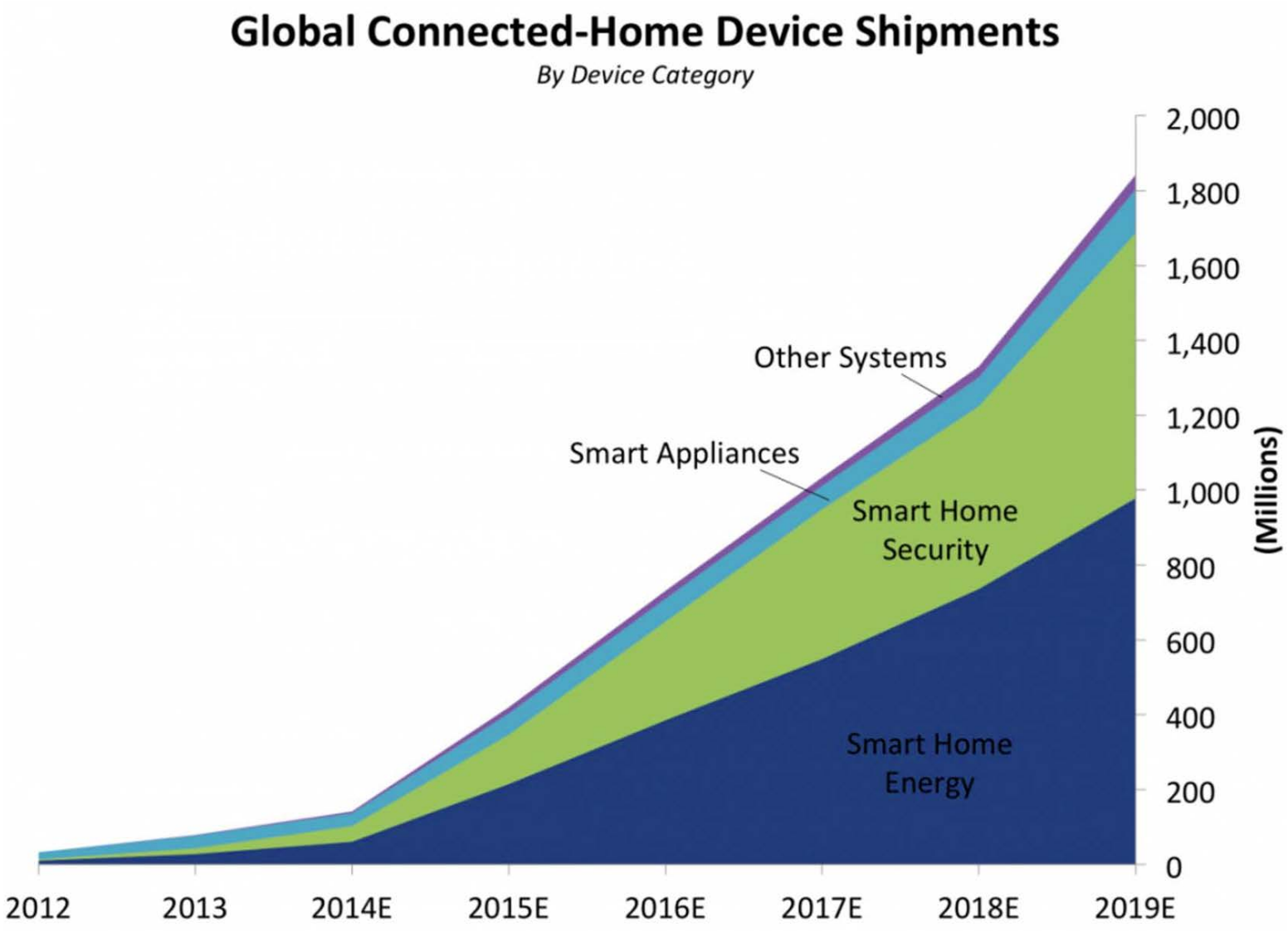
The smart home represents the intersection of home consumer technology and connectivity. It can be defined as a residential building which allows the consumer to automate or remotely manage physical security, energy management, lighting, consumer electronics, entertainment and other home automation devices.



Home Automation
Air conditioner
Fan
Irrigation
Lighting
Plug/switch
Radiator valve
Smart electricity meter
Smart water meters
Thermostat
Water/temperature
Sensor

Safety & Security
Garage door operator
Hazard detector
Electronic lock
Video camera
Video door bell
Intruder alarm

Connected & Smart Home



Source: BI intelligence

Home appliance connectivity will **grow strongly** from a low base and manufacturers will increasingly integrate connectivity into white good to remotely monitor device performance and automate the scheduling of repairs.

Course Objectives:

- IoT Architecture
- Technology evolution and development
- **Industrial applications of IoT**
  - Wearables
  - Connected & Smart Home
  - **Automotive**
  - Manufacturing
  - Agriculture and environment
  - Health care
  - Smart cities
- Summary

Automotive

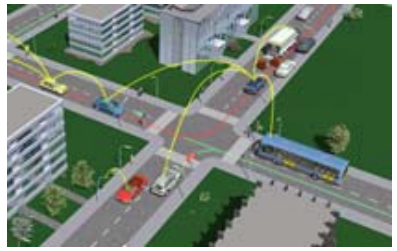
IoT in the automotive sector can bring a number of benefits: improved safety, greater efficiencies and ultimately the potential for the sector to be transformed from the traditional model with a driver, to autonomous vehicles requiring no human input.

Internet of Vehicles
- Telematics—Cellular
- Infotainment—WiFi/BT
- Positioning—GPS/GLONASS/BeiDou/GNSS

Services
- Maps, security prevention, emergency call
- Entertainment, video / music
- Emergency call, navigation

Automotive
- Radar/Induction
- V2V、V2X
  —802.11p
  —Cellular-V2V/V2X

Services
- Driving assistance, autopilot system
- Safe driving support system, vehicle operation



Inf

Wi Fi™ GPS Bluetooth® SMART

CD radio

Audio &video entertainment system

Entertainment navigation integration system

Integrated information system

Emergency Call

eCall is made automatically by the car as soon as on-board sensors register a serious accident. By pushing a dedicated button in the car, any car occupant can also make an eCall manually.

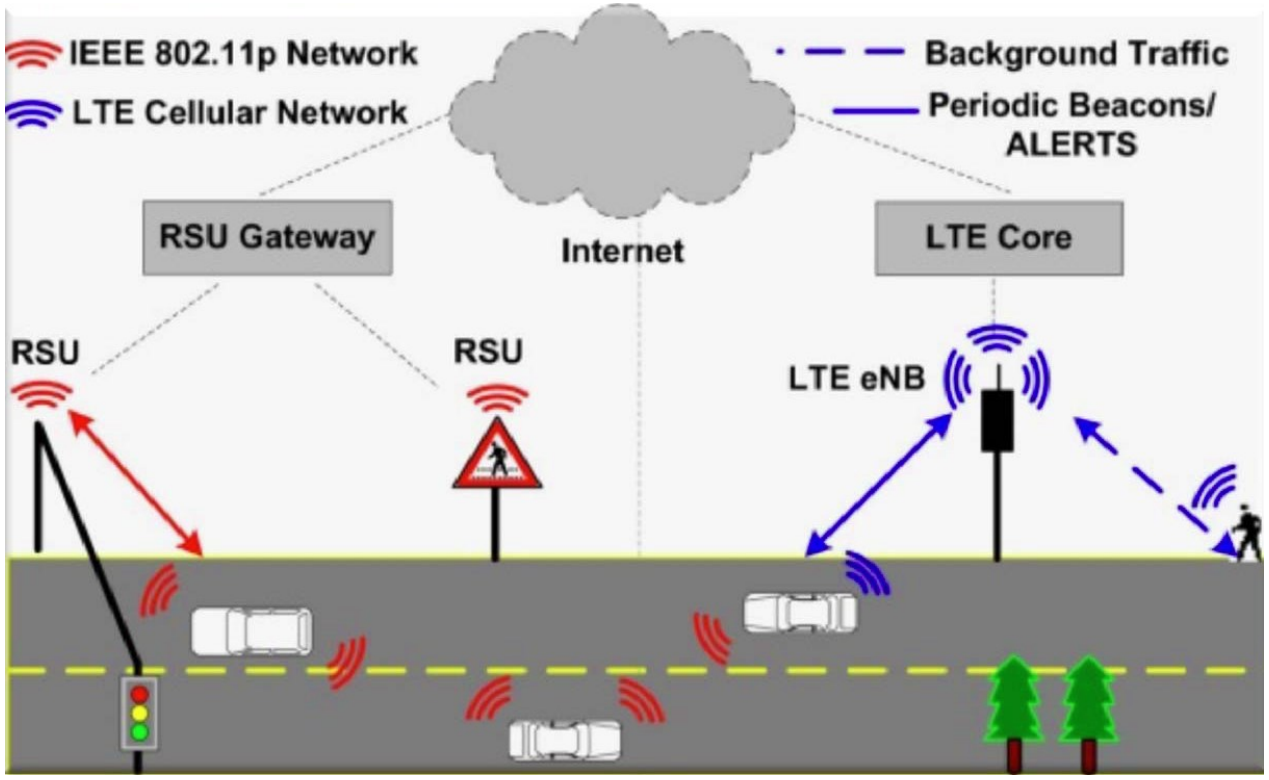
Via satellite positioning and mobile telephony caller location, the accurate position of the accident scene is fixed and then transmitted by the eCall to the nearest emergency call centre.

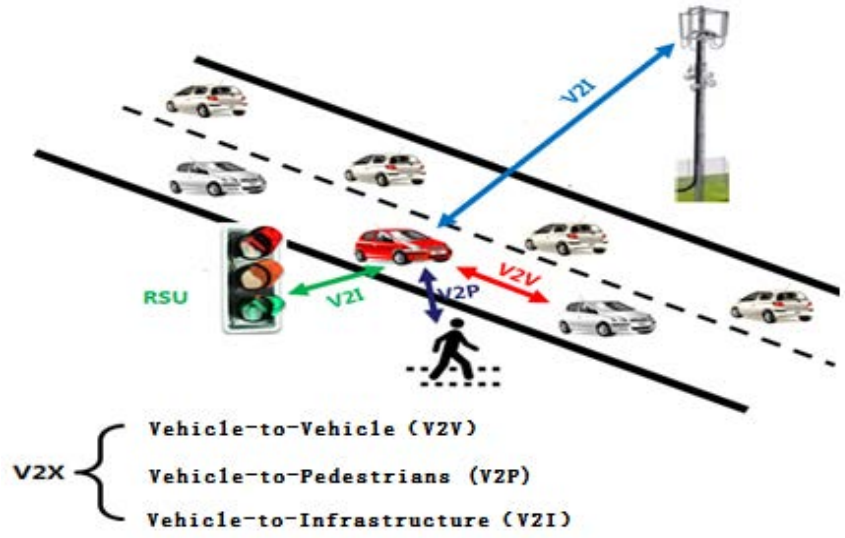
Emergency Call centre will send off services without delay, after the confirmation.

Due to the exact knowledge of the accident's location, the services arrive much quicker at the crash site. Time saved translates into lives saved.

V2X

The V2X has two main competitors: dedicated short-range communications (**DSRC**) and cellular-based (**C-V2X**) technology, which utilizes commercial cellular networks and devices managed by mobile network operators.





DSRC vs **C-V2X**

Course Objectives:

- IoT Architecture
- Technology evolution and development
- **Industrial applications of IoT**
  - Wearables
  - Connected & Smart Home
  - Automotive
  - **Manufacturing**
  - Agriculture and environment
  - Health care
  - Smart cities
- Summary

Manufacturing

IoT devices can benefit industry if they are added to machines and supplies used to produce goods—the **manufacturing process**. These machines and supplies can produce data that are analyzed to monitor process performance, which can improve efficiency and product quality.

- Five impacts:

➢ Predictive maintenance

➢ Visual supply chain

➢ Equipment efficiency analysis

➢ Automation

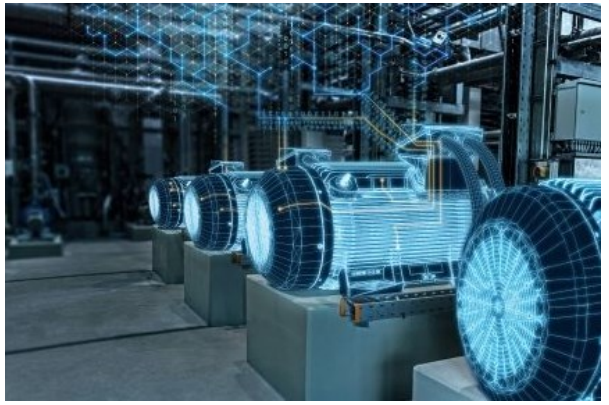
➢ Security control

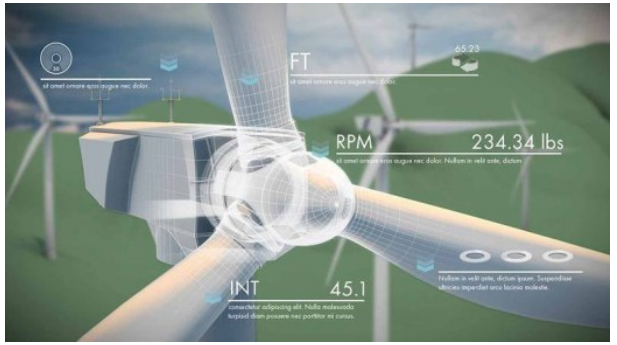
Manufacturing

Manufacturing Industries' Expectations Related to Introduction of IoT Technologies

Planning, Design and R&D	•Improving quality of demand analysis; •Developing new customers and business; •R&D, Product planning
Production	•Improving quality of products; •Improving operational efficiency •Optimization of efficiency •Reducing cost
Sales and After-sales	•Reinforce sales activity; •Improving after-the-sale services; •Understanding the usage condition of customers

IoT Technology for Vertical Integration





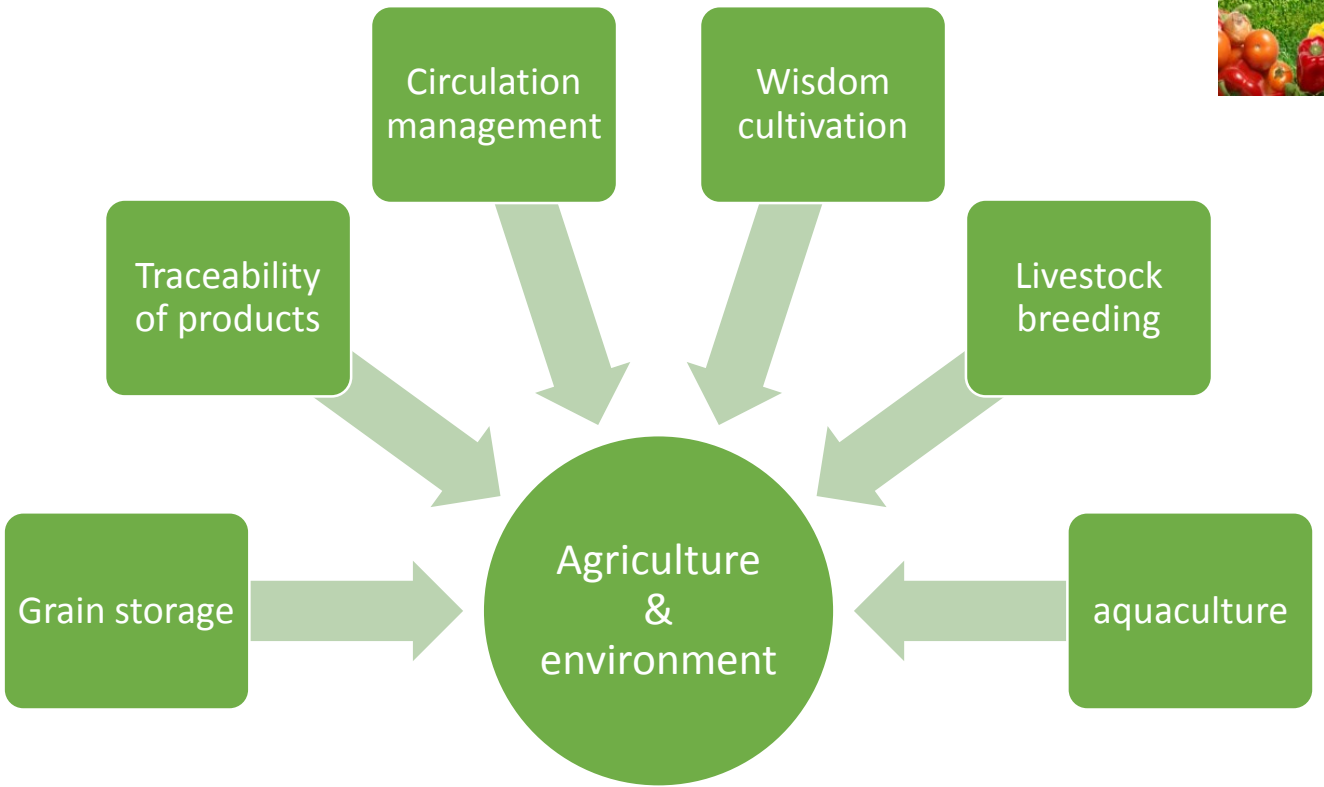
Course Objectives:

- IoT Architecture
- Technology evolution and development
- Industrial applications of IoT
  - Wearables
  - Connected & Smart Home
  - Automotive
  - Manufacturing
  - Agriculture and environment
  - Health care
  - Smart cities
- Summary

Agriculture and environment

There are a number of **external pressures** on agriculture that necessitate a smarter approach than has been taken in the past:

- Reductions in energy and water usage
- Reduction in emissions and increases in fuel efficiency
- The need for increased food production
- Scarcity of suitable land



Agriculture and environment

In the field, sensors take measurements of chemical levels, soil moisture, and air quality. These data are analyzed to determine which fields need more water or fertilizer, which improves the quality of the crops.

Track similar data in **greenhouses**, such as temperature and humidity, and transmit that data to farmers via wireless networks. Based on data, the farmers can adjust the temperature and humidity in the greenhouses as needed.

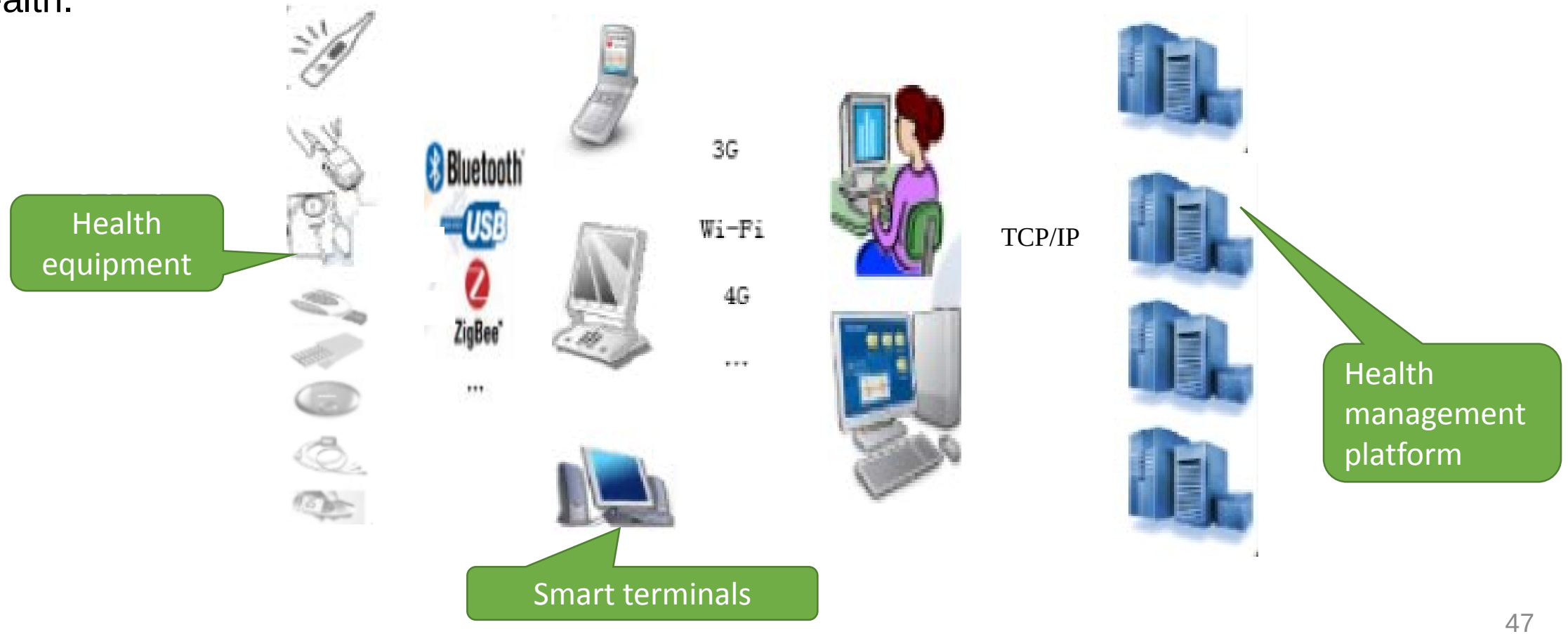
Support the care of **livestock** and other animals. Electronic identification readers implanted in livestock track movements and eating patterns, providing the farmer with insight into the location of livestock and any deviation from an animal's normal eating habits.

Course Objectives:

- IoT Architecture
- Technology evolution and development
- Industrial applications of IoT
  - Wearables
  - Connected & Smart Home
  - Automotive
  - Manufacturing
  - Agriculture and environment
  - Health care
  - Smart cities
- Summary

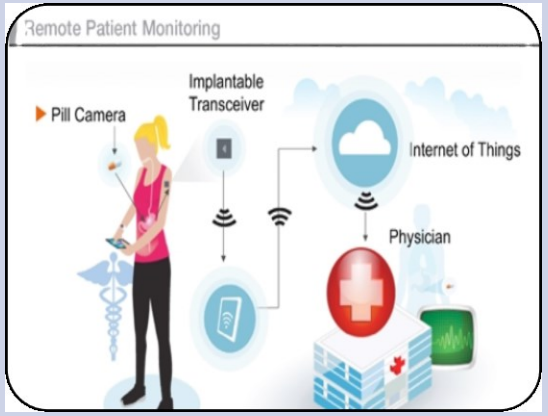
Health care

IoT devices are used in **health care**, both for home health monitoring and in hospitals, with benefits to consumers and industry. Health care IoT devices collect data to improve patient quality of life and safety by enabling patients to self-manage and monitor their health.



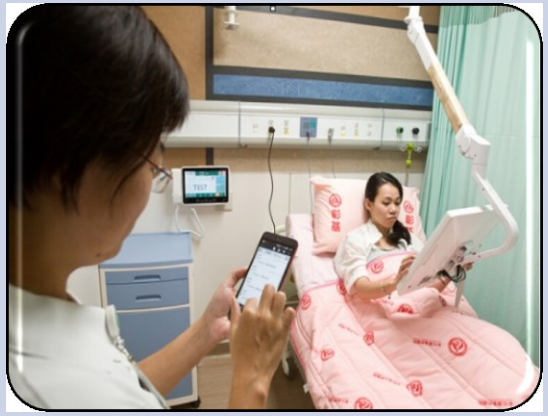
Health care

Hospital equipment, from wheelchairs to vital carts, can be tagged with Wi-Fi devices to provide real-time location and availability information.



Patients with an implanted heart device can transmit data from their heart device to specialized equipment in their home. The equipment then transmits these

data to the patient's health care provider .



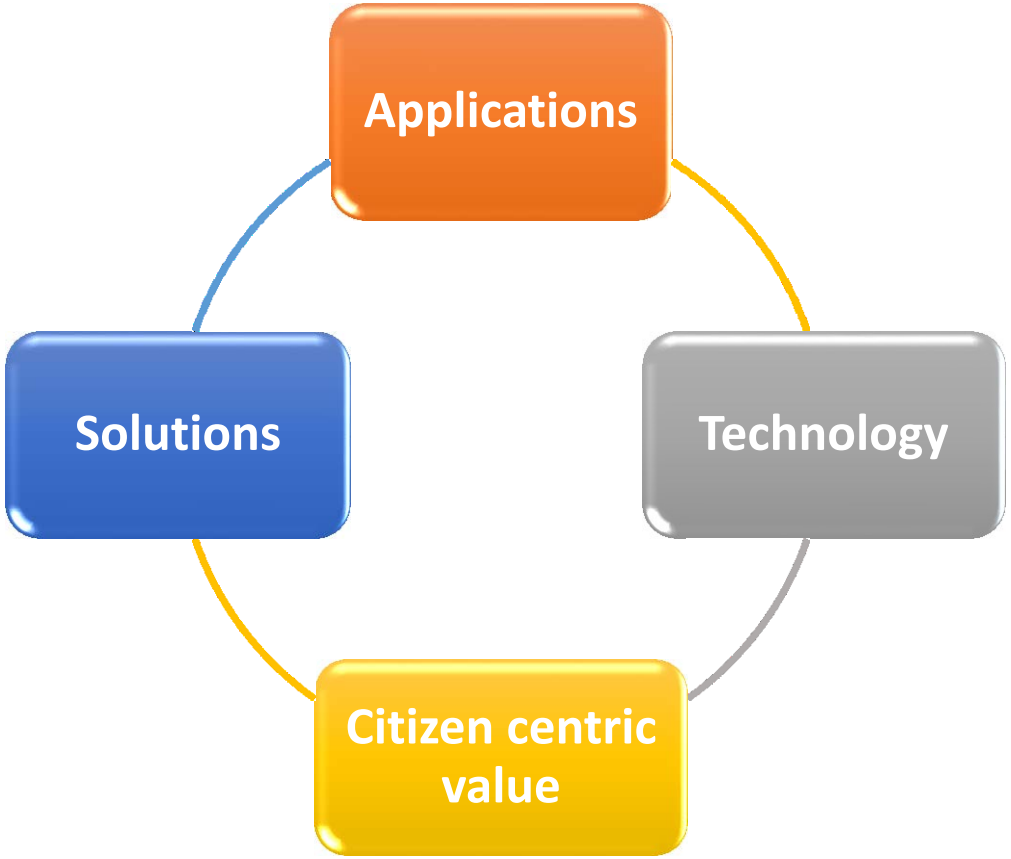
A sensor mat under a **hospital bed** can track patient movement as well as heart and respiration rates. These data are analyzed to monitor movement in and out of bed, to adjust the patient's position while in bed to reduce pressure

Course Objectives:

- IoT Architecture
- Technology evolution and development
- **Industrial applications of IoT**
  - Wearables
  - Connected & Smart Home
  - Automotive
  - Manufacturing
  - Agriculture and environment
  - Health care
  - **Smart cities**
- Summary

Smart cities

Smart cities have emerged as an important area where IoT could offer considerable value.



Smart Cities Ecosystem

- General benefits:

➢ Reduction in costs

➢ Improved efficiency or capacity of existing infrastructure

➢ Improved quality of life for citizens

➢ Increased economic growth

Smart cities

ITU-T Y.4900/L.1600 defines the series of KPI for SSC(Smart Sustainable City) Recommendations and Supplements.

- The dimensions of KPIs can be categorized as shown below:

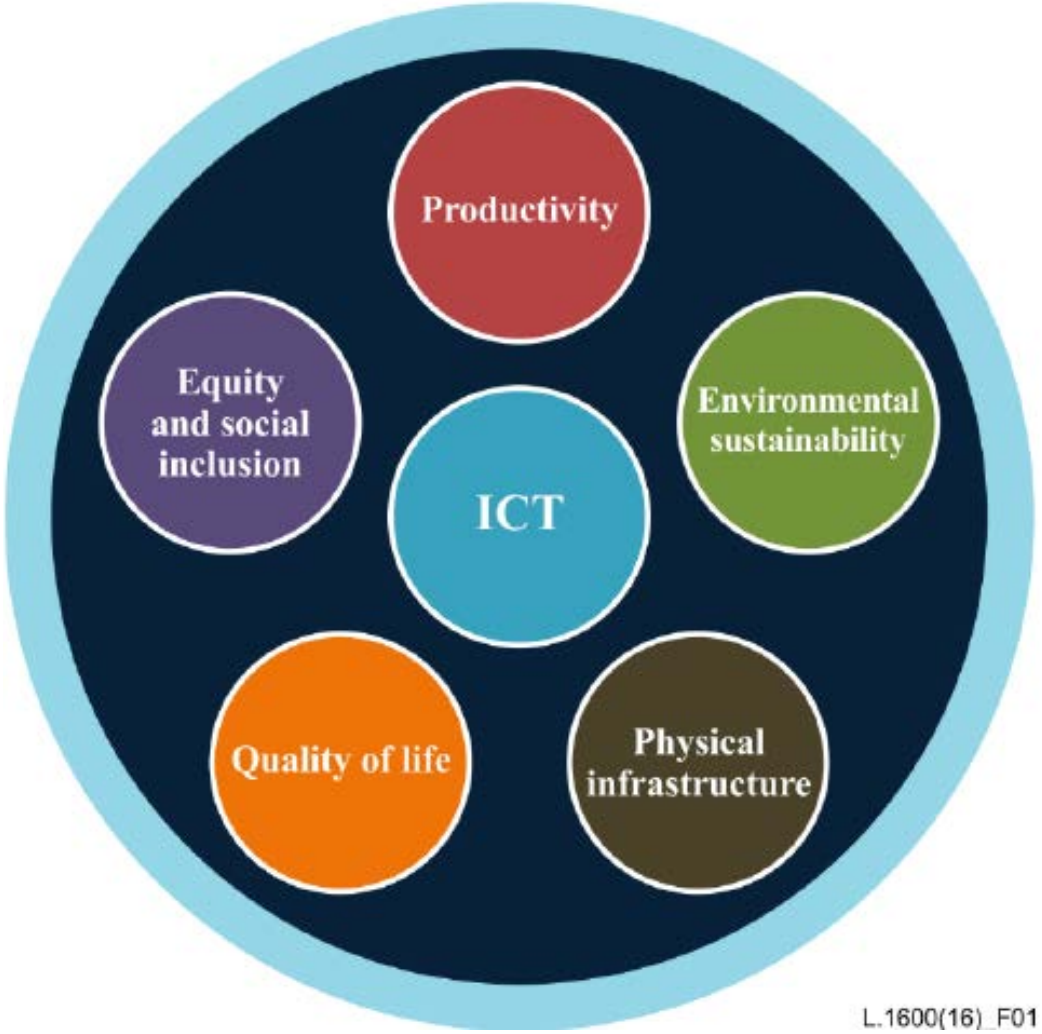
➢ Information and communication technology

➢ Productivity

➢ Quality of life

➢ Equity and social inclusion

➢ Physical infrastructure



Dimensions of KPIs for SSCs

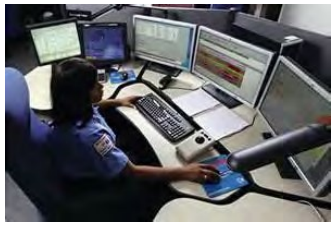
Smart cities

The **applications** of smart cities have been categorized into eight groups.

Category	Example applications	Key benefits delivered
Services and infrastructure	•Rubbish bins request to be emptied when full •Street lights which automatically report faults •Tracking of city assets and employees to improve effectiveness	Reduction in costs
Environment and energy	•Air quality monitoring • Energy usage and generation reporting • Localized weather monitoring and warning of adverse events such as floods	Reducing energy consumption and improving the environment
Public health and social care	•Monitoring of vulnerable people, such as elderly in their own homes •Monitoring the health of patients discharged from hospital	Reduction in costs and improvement of health
Public connectivity services	Public wireless connectivity services for citizens and visitors	Improved public services and economic growth

Smart cities

Category	Example applications	Key benefits delivered
Transport management	•Traffic flow monitoring and reporting • Traffic light co-ordination with live congestion data •Parking sensors to advertise spaces and enforce parking charges	Improved city efficiency with constrained road infrastructure
Civil emergencies	•Automatic road traffic accident detection •Communication of critical instructions to citizens •Information provision to emergency services	Saving lives and improving quality of life for citizens
Public information and policy	•Digital information boards	Improved public services and economic growth
Citizen monitoring	•CCTV systems with facial recognition for criminal suspects or missing persons •Crime detection through audio monitoring •More efficient litter collection by measuring footfall by street	Safety and protection of citizens and improved efficiency of services



Course Objectives:

- IoT Architecture
- Technology evolution and development
- Industrial applications of IoT
- Summary

Summary

There is continued and significant interest in IoT and activity across many segments. However, the **current market is fragmented** and yet to deliver on the promise of a massively connected world, with remote sensing and actuation delivering material impact on everyday life.

· Key conclusions：

➢ Technical and market developments point to the future success of IoT

➢ There is no single Internet of Things

➢ Progress has been slow

➢ New technologies will enable faster growth

➢ Policymakers have a key role in helping foster innovation and growth, and protecting consumers

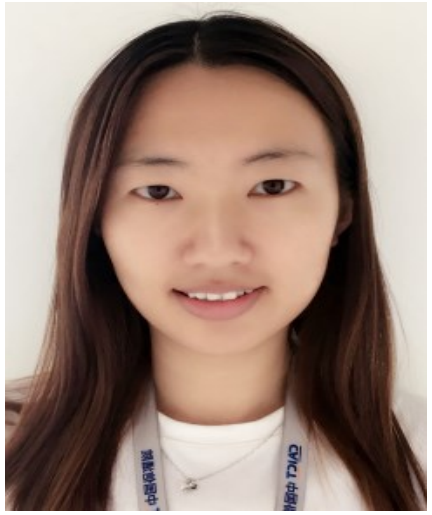
Trainer: Wei Li

E-mail:liwei4@caict.ac.cn

Department: CTTL

Address:3G building, No. 52 North Garden Road, Haidian District, Beijing, China

Photo：



- THANKs.

中国信息通信研究院 http://www.caict.ac.cn