Overview of Common IoT Communications Technologies

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Foreword

- Communications technologies are the foundation of not only the Internet of Things (IoT), but also a fully connected world. If the IoT is a logistics system of information, then communications technologies are the various means of transportation. However, regardless of the technology adopted, the ultimate goal is to connect devices to the cloud-based applications.
- Common communications technologies can be classified into two types: wired and wireless communications technologies. In terms of their applications and technical features, the specifications of wired and wireless technologies vary considerably.

Objectives

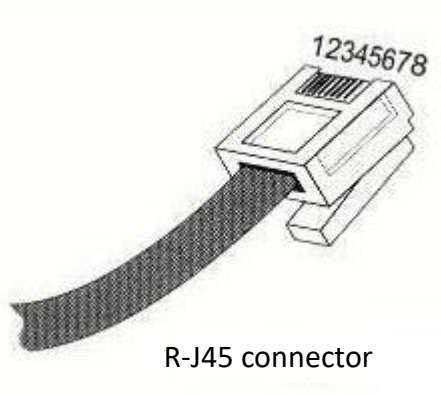
At the end of this course, you will have knowledge of:

- Common IoT wired communication technologies.
- The technical standards, features, and differences between various short-range wireless communications technologies.
- The characteristics and developing trends of cellular mobile communication technologies.
- The characteristics of Low Power Wide Area (LPWA) communications technologies and distinguish between their different types.

Contents

Ethernet

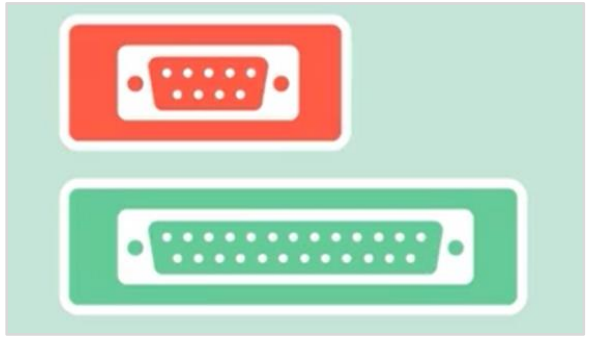
- Ethernet is the main LAN technology of TCP/IP and is named after the medium Ether, which transmits electromagnetic waves.
- A base station can use one ETH port, two FE/GE ports, or two SFP ports. ETH indicates it is a standard Ethernet, which transmits data at the rate of 10 Mbit/s. FE is short for fast Ethernet, which provides a tenfold increased transmission rate of 100 Mbit/s, and GE is short for Gigabit Ethernet, which provides a transmission rate of 1000 Mbit/s. SFP ports are gigabit optical ports, which transmit data over optical fibers. FE/GE enable autonegotiation of transmission rate with the peer switch.
- Carrier sense multiple access with collision detection (CSMA/CD) is the core Ethernet technology. "carrier sense" indicates the detection before transmission, "multi-access" indicates that data sent from one sender is received by multiple receivers, and " collision detection" indicates the detection during transmission.

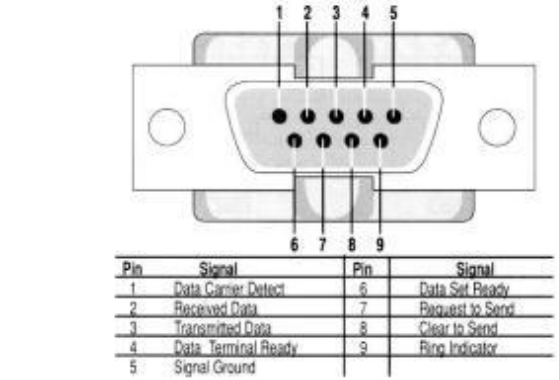


R-J45 connector

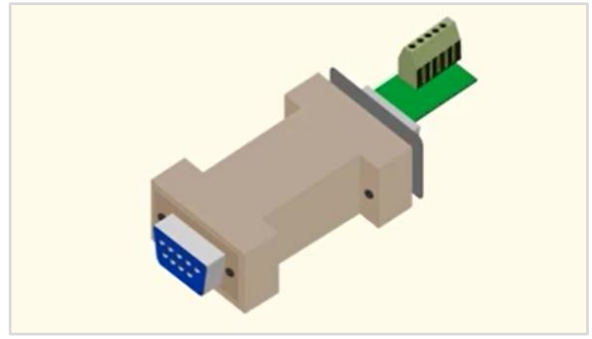
Introduction and Comparison Between RS-232 and RS-485

Item	RS-232	RS-485
Communication distance	Less than 20 m	1200 m theoretically; 300–500 m in reality
Transmission mode	Unbalanced transmission mode; single-end communications	Balanced transmission; differential transmission
Number of transceivers	One-to-one communications	A maximum of 128 transceivers on the bus
Transmission rate	38.4 Kbit/s	10 Mbit/s



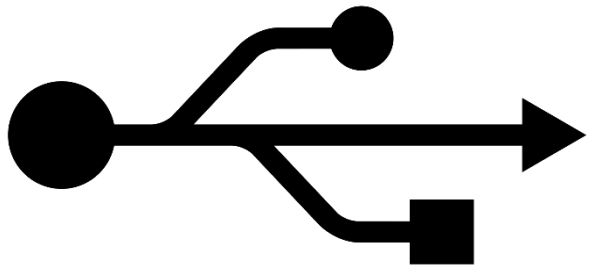


Pin	Signal	Pin	Signal
1	Data Carrier Detect	6	Data Set Ready
2	Received Data	7	Request to Send
3	Transmitted Data	8	Clear to Send
4	Data Terminal Ready	9	Ring Indicator
5	Signal Ground		



USB

- USB, short for Universal Serial Bus, is a serial bus standard for connecting computer systems and devices. It is also a technical specification for input and output interfaces. It is widely used with information communications products such as personal computers and mobile devices, and its use has been extended to related fields such as photography equipment, digital TVs (set-top boxes), and game consoles.
- Before USB was developed, the scalability of computer interfaces was inadequate with limited rates due to devices (such as the keyboard, mouse, modem, printer, and scanner) needing to be connected to different interfaces (such as serial/parallel interfaces), making it impossible for a computer to provide sufficient interfaces for connections. USB is designed for high speed, scalability, and ease-of-use.
- The latest-generation USB is USB 4, with a transmission rate of 40 Gbit/s.



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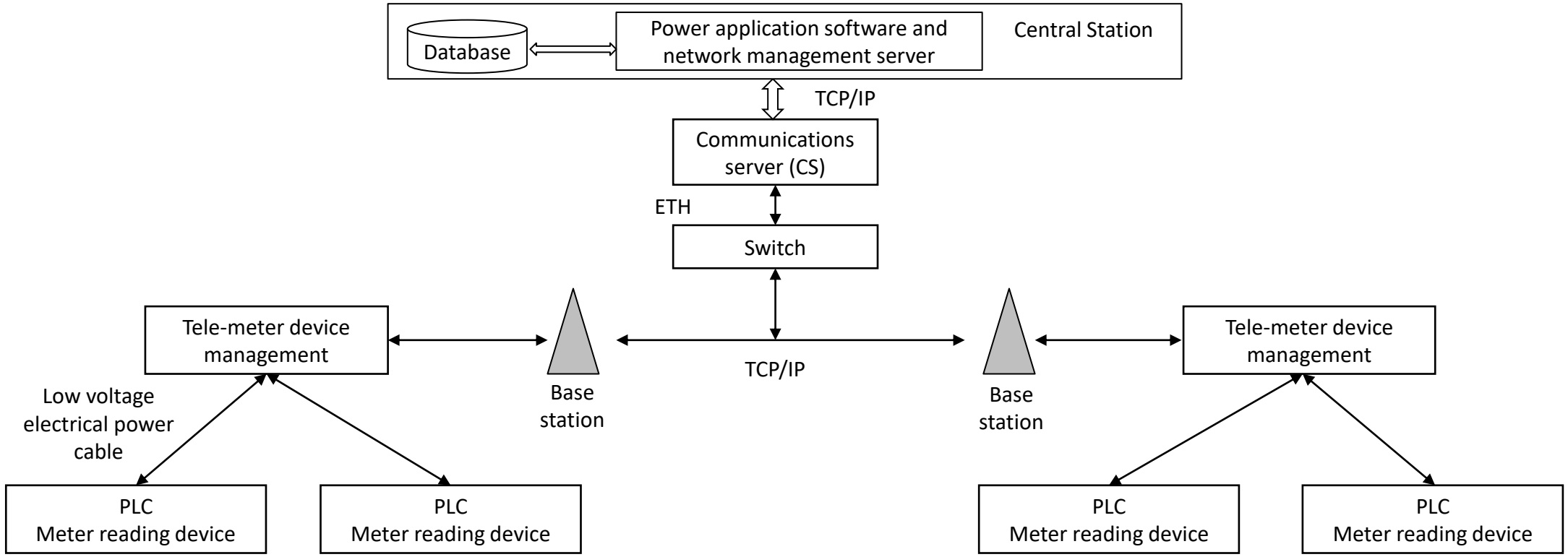
M-Bus

- M-Bus, short for Meter Bus, is a data bus designed for information transmission of consumption measuring instruments and counters. M-Bus has been widely applied in business and collection of data on industrial energy consumption.
- The maximum transmission distance of the M-Bus is 1000 m. As the M-Bus can supply power to onsite devices, no power cable needs to be connected. The power supply capability of the bus is 5 A, and the current of each node needs to be less than 0.65 mA.
- The M-Bus not only fulfills the need for the networking and remote reading of utility meters but also meets the specific requirements of the remote or battery power supply system. The bus topology of the M-Bus serial communications meets the requirements of the utility meters for reliable and cost-effective networking. Hundreds of backup devices can also be connected within a distance of several kilometers.

Power Line Communication



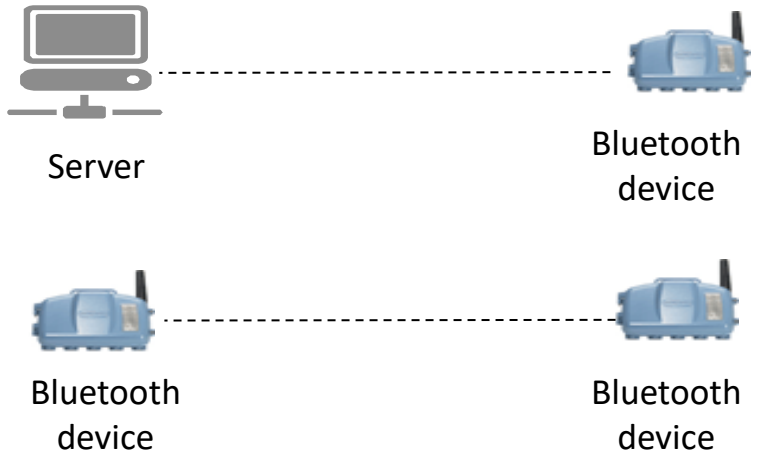
- Power line communication (PLC) refers to a mode of communication in which data and media signals are transmitted on an electrical power cable. With PLC, high frequency signals containing information are loaded onto the current, and the adapter receives the information over the cable, separates the high-frequency signals from current, and then sends the signals to a computer or telephone.

Comparison of Wired Communications Technologies

Communication Mode	Characteristics	Application Scenario
ETH	Comprehensive protocol, universal, cost-effective	Intelligent terminal, video surveillance
RS-232	One-to-one communications, cost-effective, short transmission distance	A few instruments, industrial control
RS-485	Bus topology, cost-effective, strong anti-interference capability	Industrial instruments, meter reading
USB	One-to-one communications, universal, fast transmission	Smart home, office, mobile devices
M-Bus	Designed for meter reading, common twisted-pair cables, strong anti-interference capability	Industrial energy consumption data collection
PLC	For power line communication, wide coverage, easy installation	Power grid transmission, electricity meter

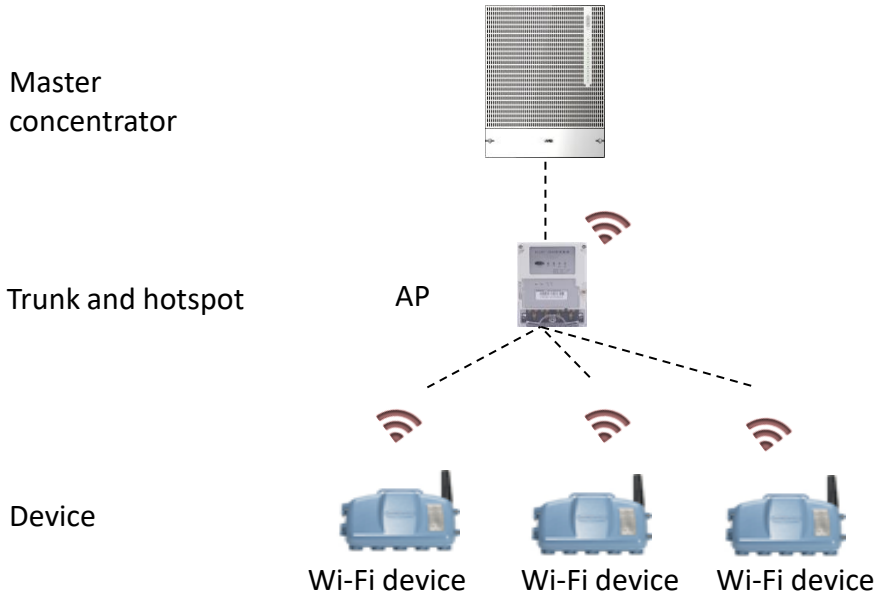
Contents

Short-Range Wireless Communications Technology: Bluetooth



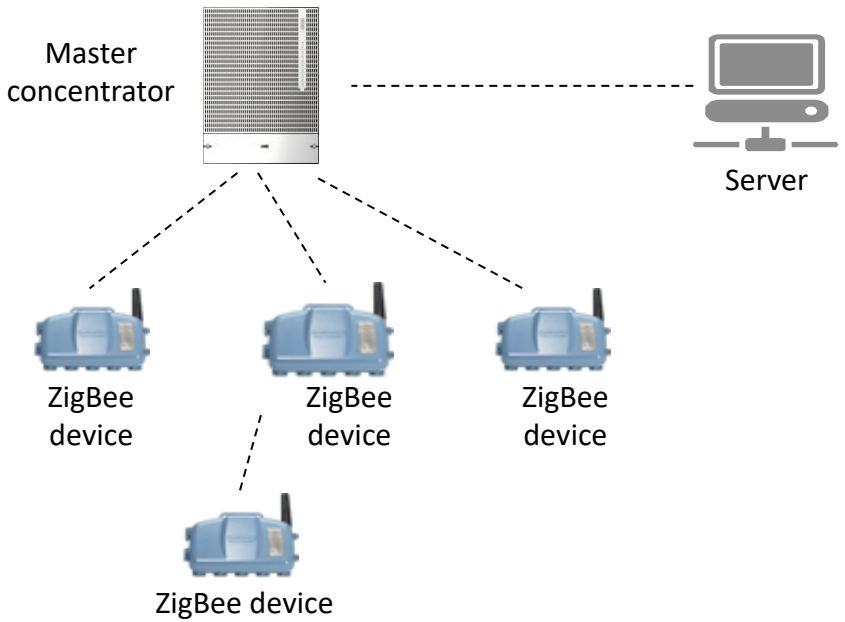
- Bluetooth is a large-capacity wireless digital communications technology standard for exchanging data over short distances. The latest Bluetooth 5.0 supports a maximum transmission rate of 3 Mbit/s and a transmission distance of about 300 meters. The technology has been divided into two types: Bluetooth Basic Rate/Enhanced Data Rate (BR/EDR) and Bluetooth low energy (BLE). The BR/EDR type supports only point-to-point (one-to-one) communications, whereas the BLE type supports point-to-point, broadcast (one-to-many), mesh (many-to-many), and other modes of communications. The BLE type is mainly used in the IoT field to provide services with higher performance that consume little power for smart home appliances.
- Advantages: high rates, high security, and low power consumption
- Disadvantages: The EDR type, with few network nodes, is not suitable for multi-point deployment.

Short-Range Wireless Communications Technology: Wi-Fi



- Wi-Fi enables an electronic device to connect to a wireless local area network (WLAN) using the 2.4 GHz UHF or 5 GHz SHF ISM radio frequency band. The latest Wi-Fi 6 supports a transmission rate of 9.6 Gbit/s and a latency of 20 ms.
- Advantages: wide coverage, fast data transmission rate
- Disadvantages: low transmission security, low stability, high power consumption, poor networking capability

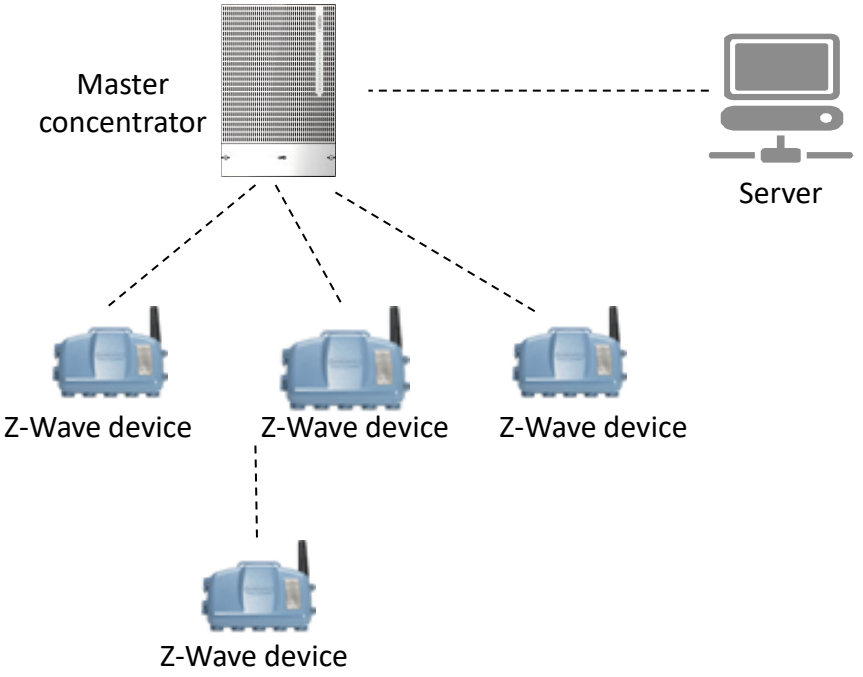
Short-Range Wireless Communications Technology - ZigBee



- ZigBee is a short-range wireless communications technology featuring low power consumption.
- Characteristics: short transmission distance, low complexity, self-organization, low power consumption, and low data rate.
  Widely used in industrial and smart home fields.

ZigBee	
Low power consumption	Two batteries can support the device for 6–24 months.
Low cost	No patent fee is required and the cost is about US$2.
Low rate	20–250 Kbit/s
Short distance	10–100 m
Low latency	15–30 ms
Large capacity	The number of nodes theoretically is 254.
High security	Three security levels
Grant free	915 MHz, 868 MHz, 2.4 GHz
Easy networking	Mesh networking, ad hoc networking
Low compatibility	The compatibility of different chips is low.
Difficult maintenance	Difficult to maintain due to high networking flexibility

Short-Range Wireless Communications Technology - Z-Wave



- Z-Wave is an emerging RF-based wireless communications technology with a short transmission distance and high reliability at low costs and little power consumption.
- Advantages: simple structure, high reliability, low rates, low power consumption, low costs
- Disadvantages: The standard is not open. The chip can only be obtained from Sigma Designs.

Comparison of Short-Range Wireless Communications Technologies

	Bluetooth	Wi-Fi	ZigBee	Z-Wave
Frequency band	2.4 GHz	2.4 GHz 5 GHz	868 MHz/915 MHz 2.4 GHz	868.42 MHz (Europe) 908.42 MHz (USA)
Transmission rate	1–3 Mbit/s (24 Mbit/s over 802.11 links)	802.11b: 11 Mbit/s 802.11g: 54 Mbit/s 802.11n: 600 Mbit/s 802.11ac: 1 Gbit/s 802.11ax: 9.6 Gbit/s	868 MHz: 20 kbit/s 915 MHz: 40 kbit/s 2.4 GHz: 250 kbit/s	9.6 kbit/s or 40 kbit/s
Typical distance	1–300 m	50–100 m	2.4 GHz band: 10–100 m	30 m (indoor) to 100 m (outdoor)
Typical application	Data exchange between nearby nodes such as a mouse, wireless headset, mobile device, and computer	WLAN, high-speed Internet access at home and other indoor areas	Home automation, building automation, and remote control	Smart home appliance, monitoring and control

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Cellular Mobile Networks - 2G

- Global System for Mobile Communications (GSM) is the second-generation mobile communications technology. It is a standard developed by the European Committee for Standardization in 1992. It incorporates digital communications technologies and a unified network standard, which ensures the quality of communications and enables it to develop various new services. The data rate of GSM is 9.6 kbit/s.
- General Packet Radio Service (GPRS) is a mobile data service available to GSM mobile phone users. It is a data transmission technology of the second-generation mobile communications and an extension of GSM. GPRS provides data rates of 56–114 kbit/s.

Cellular Mobile Networks - 3G

- 3G is the third generation mobile communications technology. It supports high-speed data transmission and can transmit voice and data simultaneously with a rate of several-hundred kbit/s. 3G is a mobile communication system that integrates wireless communications and multimedia communications such as the Internet. Currently, 3G has three standards: CDMA2000, WCDMA, and TD-SCDMA. The latest WCDMA technology HSPA+ supports a downlink rate of up to 42 Mbit/s.

Cellular Mobile Networks - 4G

- 4G is the fourth-generation mobile communications technology. It includes two modes: LTE TDD and LTE FDD.
- Integrating 3G and WLAN, 4G can transmit data, high-quality audio, video, and images at a high speed. The download rate of 4G can exceed 100 Mbit/s, which is 25 times the speed of ADSL (4 Mbit/s), meeting almost all users' requirements on wireless services. In addition, 4G can be deployed in areas where the digital subscriber line (DSL) and cable television modem are not covered, and then expanded to the entire region. 4G has shown notable advantages.

LTE UE Categories

- The LTE UE category indicates the UE access capability level, in other words, the transmission rate level supported by a UE. For example, LTE category 4 indicates that the LTE network access capability level of the UE is 4.

Level	Downlink Rate (Mbit/s)	DL-MIMO	Uplink Rate (Mbit/s)
1	10	1	5
2	50	2	25
3	100	2	50
4	150	2	50
5	300	4	75
6	300	2 or 4	50
7	300	2 or 4	150
8	1200	8	600
9	450	2 or 4	50
10	450	2 or 4	100

LTE UE Category 1

- UE category 1 supports a downlink rate of up to 10 Mbit/s, enabling IoT devices with lower power consumption and costs to connect to LTE networks. LTE operators around the world deploy LTE networks based on 3GPP Release 8 or later. As such, operators can simply reconfigure parameters to permit the access of UE category 1 without needing to upgrade the networks.
- Although higher rates are supported for UE category 4 or later, the costs are relatively high for the IoT industry. Therefore, using UE category 1 is most cost-effective.

Cellular Mobile Networks - 5G

- The fifth-generation mobile communications network, 5G's theoretical maximum transmission rate can reach 10 Gbit/s, which is 100-fold improvement over 4G. With 5G, a 1 GB movie can be downloaded in eight seconds.
- ITU Radiocommunication Sector (ITU-R) defined three major 5G application scenarios in June 2015: enhanced Mobile Broadband (eMBB), Massive Machine-Type Communications (mMTC), and ultra-reliable low-latency communication (URLLC), as well as eight capability specifications, including the throughput, latency, connection density, and spectral efficiency.
- On June 6, 2019, the Ministry of Industry and Information Technology (MIIT) officially issued 5G commercial licenses to China Telecom, China Mobile, China Unicom, and China Broadcast & Television, and announced the start of 5G commercialization on October 31, 2019.

Comparison of Cellular Mobile Network Technologies

	2G	3G	4G	5G
Frequency band	Authorized frequency band (mainly 900 MHz)	Authorized frequency band (mainly 900 MHz and 1800 MHz)	Authorized frequency band (1800–2600 MHz)	Authorized frequency band: C-band, mmWave
Transmission rate	GSM: 9.6 kbit/s GPRS: 56–114 kbit/s	TD-SCDMA: 2.8 Mbit/s CDMA2000: 3.1 Mbit/s WCDMA: 14.4 Mbit/s	Downlink Category 6/7: 300 Mbit/s Category 9/10: 450 Mbit/s	10 Gbit/s (Balong 5000 chips support a downlink rate of 4.6 Gbit/s and an uplink rate of 2.5 Gbit/s)
Typical application	POS and smart wearable devices	Vending machines, smart home appliances	Mobile terminals, video surveillance	AR, VR, assisted driving, automated driving, and telemedicine

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LPWA - SigFox

- The SigFox network uses Ultra Narrow Band (UNB) technology. Its transmission power consumption is low and the data connection is stable. Its radio link uses the unlicensed ISM radio frequency band. Frequency usage varies according to national laws and regulations. The 868 MHz frequency band is widely used in Europe, and the 915 MHz frequency band is used in the United States.
- The network adopts ultra narrow-band modulation technology. A single base station can transmit network messages over a distance of over 1000 km. Each base station supports a maximum of one million IoT devices.
- SigFox is preferred for IoT connections as it uses free frequency bands, devices that consume little power, and a simplified network architecture.

LPWA - LoRa

- The Long Range (LoRa) is a physical-layer-based technology that implements data communications over networks. It is maintained and managed by the LoRa Alliance. The technology supports bidirectional data transmission and complies with a series of open source standards. The specific solution for network implementation is called LoRaWAN, which is developed by Semtech and supported by IBM. The application of LoRa includes automatic meter reading, smart home appliance, building automation, wireless warning and security systems, industrial monitoring and control, and remote irrigation systems.
- LoRa uses unlicensed spectrum.

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LPWA - NB-IoT

- NB-IoT is a cellular based narrowband IoT. It is built on a cellular network and requires a bandwidth of only 180 kHz. It can be directly deployed on legacy GSM, UMTS, and LTE networks to reduce deployment costs and implement smooth upgrades.
- NB-IoT is an emerging technology widely used for LPWA IoT markets. It features enhanced coverage and wide connections with low rates, costs, power consumption, and the optimal architecture.
- According to 3GPP Release 14, NB-IoT supports base station positioning and mobility scenarios with a speed less than 80 km/h.

LPWA - eMTC

- eMTC is a wireless IoT solution proposed by Ericsson. The solution designs the soft features of the wireless IoT network based on LTE access technology. It is mainly used in IoT scenarios that require low rates, deep coverage, low power consumption, and a considerable number of connections.
- eMTC features a higher rate (up to 1 Mbit/s) and power consumption and smaller coverage and capacity than NB-IoT. eMTC also supports voice communications.

Comparison of LPWA Technologies

	SigFox	LoRa	NB-IoT	eMTC
Frequency band	Sub-GHz unlicensed frequency band	Sub-GHz unlicensed frequency band	Mainly sub-GHz licensed frequency band	Sub-GHz licensed frequency band
Transmission rate	100 bit/s	0.3–5 kbit/s	< 250 kbit/s	< 1 Mbit/s
Typical distance	1–50 km	1–20 km	1–20 km	2 km
Typical application	Smart home appliances, smart electricity meter, mobile healthcare, remote monitoring, and retail	Smart agriculture, intelligent building, and logistics tracking	Water meter, parking, pet tracking, garbage disposal, smoke alarm, and retail devices	Shared bicycle, pet collar, POS, and smart elevator

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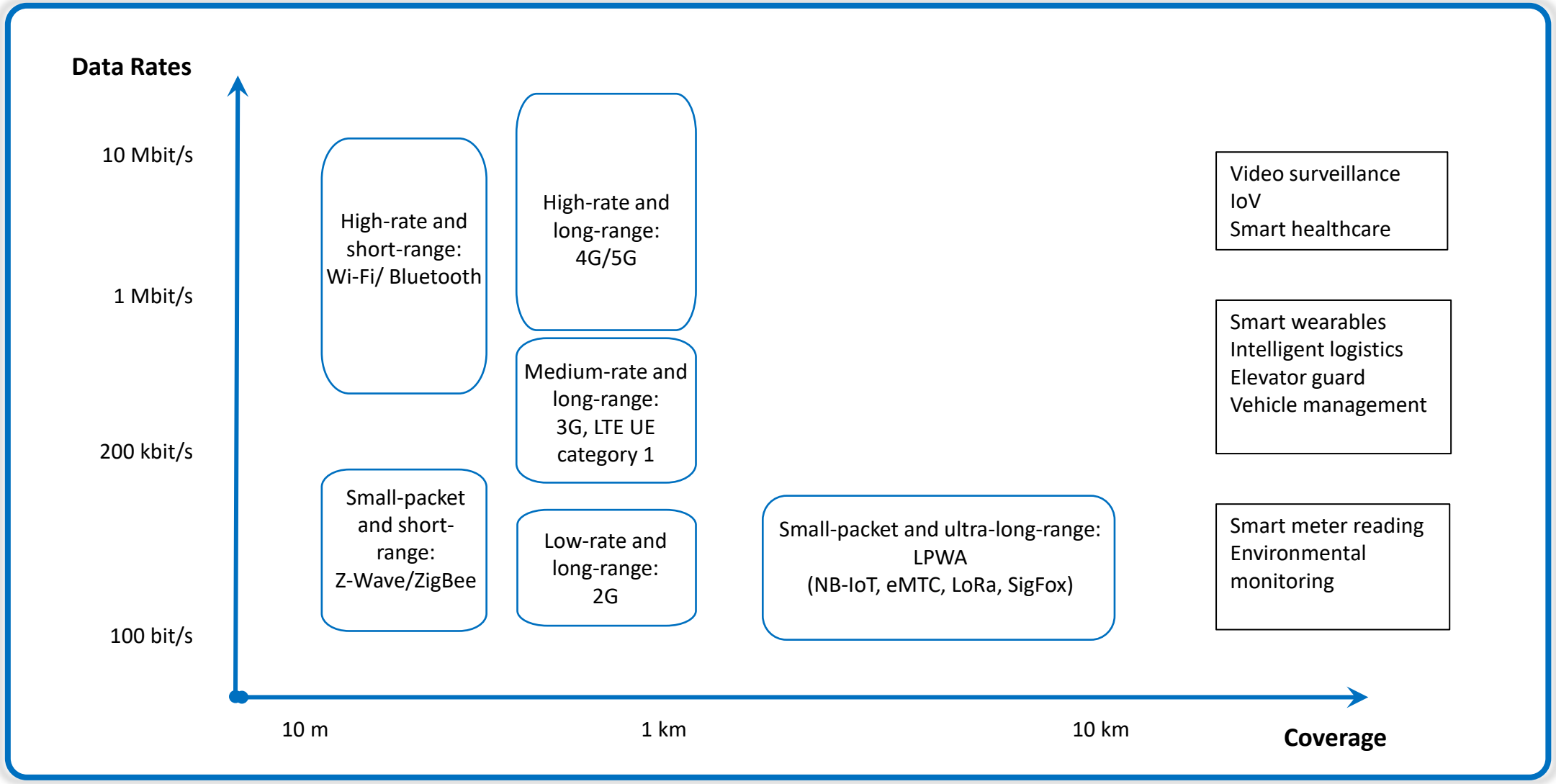
Comparison of Wireless Communications Technologies



Quiz

1. (Single-Choice) Which of the following communications technologies is a wired communications technology?

   A. 5G

   B. NB-IoT

   C. PLC

   D. ZigBee

2. (True or False) All NB-IoT networks are deployed on sub-GHz licensed bands.

Summary

- This document described common IoT communications technologies, which are divided into wired and wireless ones. Wireless communications technologies are further classified into three types: short-range wireless, cellular mobile, and LPWA communications technologies. This document also provided the characteristics and application scenarios of these communications technologies in various aspects.

Thank you.

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