CT106-3-M-BIA - Building IoT Applications

CT127-3-M-ODL - BIA - Building IoT Applications

Topic 7 - IoT Network Access and Physical Layer

TOPIC LEARNING OUTCOMES

At the end of this topic, you should be able to:

- Understand the concept of network access in IoT, including different communication technologies used to connect IoT.
- Identify and describe various physical layer protocols commonly used in IoT, such as Wi-Fi, Bluetooth, Zigbee, LoRaWAN, and cellular technologies.
- Explain the considerations involved in selecting appropriate network access and physical layer protocols for specific IoT applications, considering factors such as range, power consumption, data rate, scalability and security.
- Examine emerging trends and advancements in IoT network access and physical layer protocols, such as 5G, NB-IoT, and LPWAN technologies, and their potential implications for IoT deployments.

Contents & Structure

- Wired Network Access:
  - Ethernet
  - Powerline communication (PLC)
- Wireless Network Access:
  - Wi-Fi (IEEE 802.11)
  - RFID (Radio Frequency Identification)
  - Bluetooth and Bluetooth Low Energy (BLE)
  - LR-WPAN (Zigbee and other mesh networking protocols)
  - Cellular (LTE-M, NB-IoT)
  - LPWAN (LoRaWan, Sigfox, NB-IoT)
- Considerations for Network Access and Physical Layer Protocols:
  - Factors to consider when selecting network access protocols
  - Range, data rate, power consumption, scalability and security considerations

Wired network access

- Wired network access refers to the use of physical cables to establish connectivity between IoT devices and networks.
- Unlike wireless communication, which relies on radio waves, wired networks provide a reliable and secure means of data transmission.
- Ethernet, Powerline Communication (PLC), Coaxial Cable and Fiber Optic are common wired connectivity options.
- Benefits of Wired Network Access include reliability, higher bandwidth, robust connectivity and better security.

Ethernet (IEEE 802.3)

- Ethernet is a widely used networking technology that forms the backbone of local area networks (LANs).
- It provides a reliable and efficient means of transmitting data between devices in a network.
- Uses twisted pair, fibre optic, or coaxial cables for data transmission.
- Supports various data rates, such as 10 Mbps (Ethernet), 100 Mbps (Fast Ethernet), 1 Gbps (Gigabit Ethernet), and higher.
- Ethernet is widely used in IoT applications, particularly for local network connectivity.
- It provides high-speed and reliable communication for IoT devices, gateways, and servers.

Powerline communication (PLC)

- Powerline Communication (PLC) is a technology that enables the transmission of data over existing electrical power lines.
- PLC uses the existing electrical power lines as a medium for data transmission.
- Utilizes the ubiquitous power infrastructure, eliminating the need for additional wiring or wireless connectivity.
- Can support high data rates, allowing for the transmission of large amounts of data.
- Electrical power lines introduce noise which can affect the quality of communication. Moreover, other connected devices, such as electrical appliances, can introduce interference that may impact communication reliability.

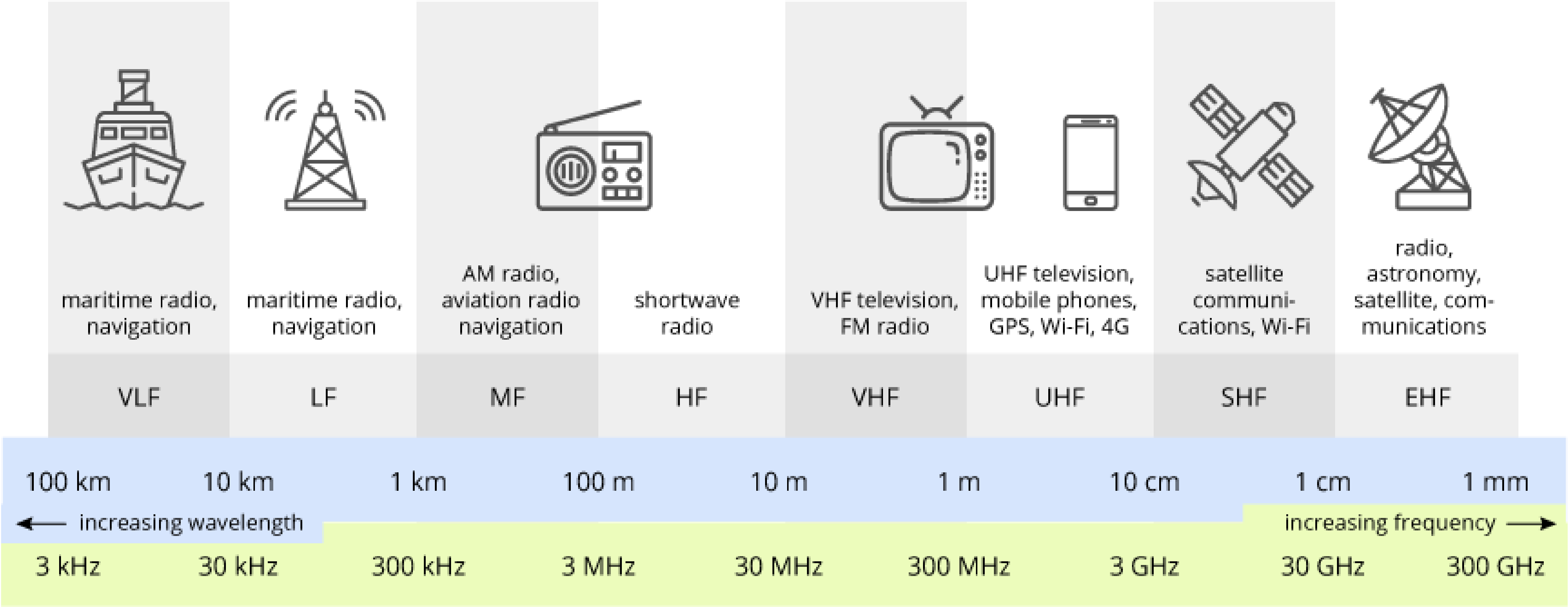
Wireless network access

- Wireless network access plays a crucial role in connecting IoT devices, enabling seamless communication and data exchange.
- It provides the flexibility and mobility required for various IoT applications.
- There are several wireless technologies used for IoT network access, each with its own characteristics and suitability for different use cases.
- The choice of wireless technology depends on factors such as range requirements, data rates, power consumption, and the specific needs of the IoT application.

Radio Waves and Radio Frequency (RF)

- Radio waves refer to the electromagnetic waves used for wireless communication between IoT devices.
- Radio Frequency (RF) refers to the wireless transmission of data using radio waves.
- RF bands determine the range, data rates, and interference characteristics of wireless communication.
- RF signals can travel through air, obstacles, and even walls, enabling communication across different environments.
- Short-range protocols like Bluetooth and Zigbee typically have a range of a few meters to tens of meters, suitable for personal area networks or home automation.
- Long-range protocols like LoRaWAN and cellular can achieve coverage over several kilometres, making them suitable for wide-area IoT deployments.

Radio Frequency (RF) Chart



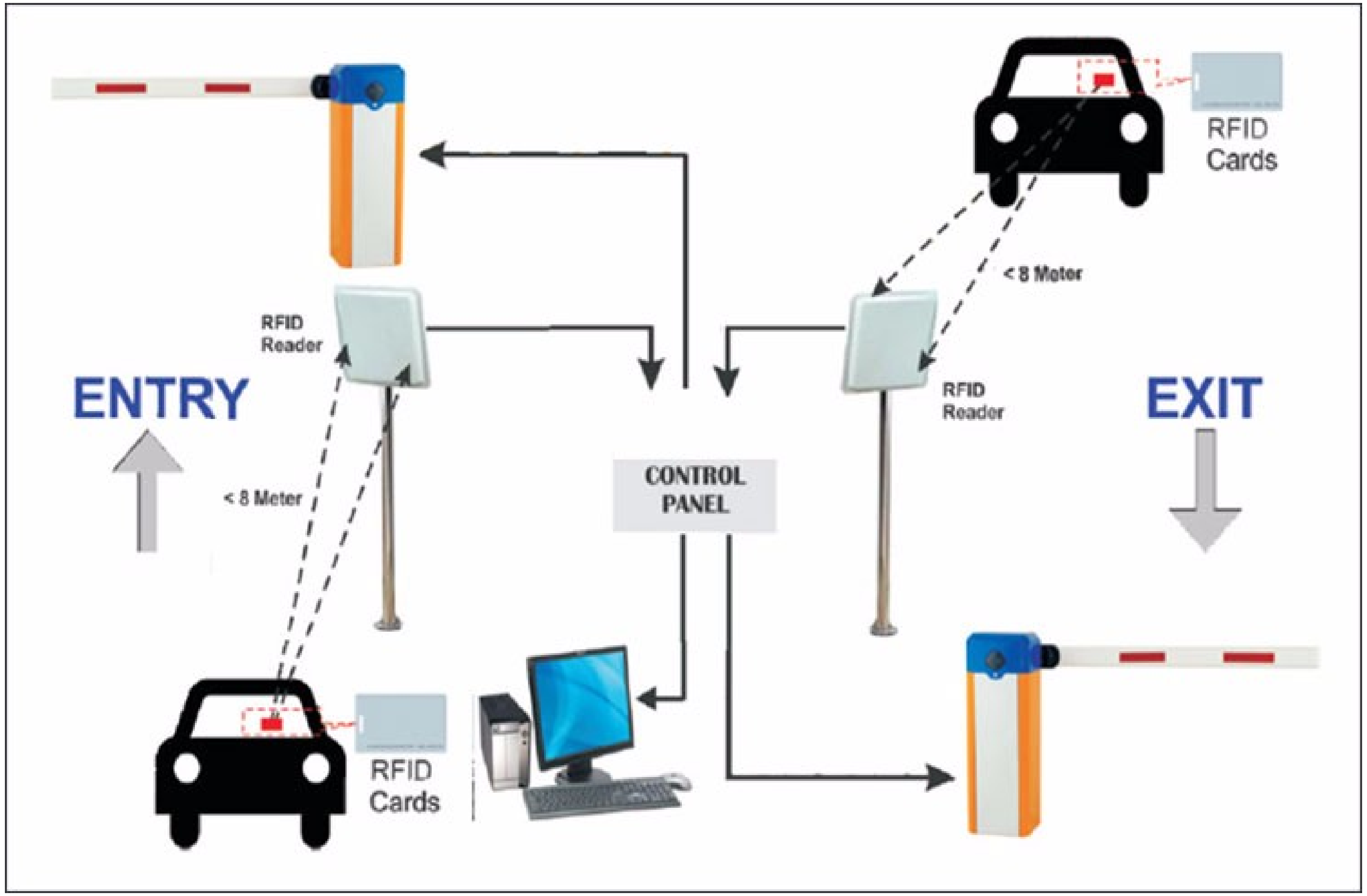
Wi-Fi (802.11 a/b/g/n)

- Wi-Fi is standard wireless networking based on **IEEE 802.11a/b/g/n** specifications. 802.11n offers the highest data throughput, but at the cost of high power consumption, so IoT devices might only use 802.11b or g for power conservation reasons.
- Although Wi-Fi is adopted within many prototypes and current-generation IoT devices, as longer-range and lower-power solutions, become more widely available, it is likely that Wi-Fi will be superseded by these lower-power alternatives.

RFID (Radio Frequency Identification)

RFID uses radio waves to identify and track objects. It consists of tags that contain a unique ID and readers that communicate with the tags wirelessly to retrieve information stored on them.

- RFID tags can be active, passive, or assisted passive. Passive tags are ideal for devices without batteries, as the ID is passively read by the reader. Active tags periodically broadcast their ID, while assisted passive tags become active when an RFID reader is present.



NFC

- The near-field communication (NFC) protocol is used for very small-range communication (up to 4 cm), such as holding an NFC card or tag next to a reader.
- NFC use cases include Smart Access Control (unlock doors or gates with their NFC-enabled devices), Mobile Payments (contactless payment using their smartphones or wearable devices), Device Pairing (Bluetooth headsets or speakers) and IoT Device Configuration (by transferring settings and credentials for smart home appliances or industrial sensors).

Comparison of RFID Technologies

Technology	Frequency Range	Read Range	Power Source	Applications
NFC	13.56 MHz	Short range (cm)	Active device	Mobile payments, access control, device pairing
Active RFID	Various	Extended range (m)	Battery	Real-time location tracking, asset tracking
Passive RFID	Various	Varies based on range	No battery	Supply chain management, inventory tracking

Bluetooth

Bluetooth is a wireless communication protocol designed for short-range connectivity. It operates in the 2.4 GHz frequency band and supports low-power communication.

- Bluetooth devices can be easily paired and connected without the need for complex setup processes.
- Bluetooth is supported by a vast range of devices, making it a widely adopted standard for IoT connectivity.
- Common Bluetooth IoT Applications include Smart Home Automation (lights, thermostats, and security systems), Wearable Devices (health monitors) and Asset Tracking (Bluetooth beacons).

Bluetooth Low Energy (BLE)

BLE is a power-efficient version of Bluetooth designed for IoT applications with low-energy requirements. It operates in the 2.4 GHz frequency band, utilizing shorter data packets and optimized connection intervals.

- BLE is ideal for IoT devices that require long battery life, such as wearables, fitness trackers, and medical devices. BLE allows IoT devices to operate on small coin-cell batteries for extended periods.
- BLE is best suited to devices that transmit low volumes of data in bursts, as the devices are designed to sleep to save power when they are not transmitting.
- Personal IoT devices like wearable health and fitness trackers often use BLE.

Classic Bluetooth Vs BLE

	Bluetooth	BLE (Bluetooth Low Energy)
Power Consumption	Relatively higher	Low
Data Transfer Rates	Higher (several Mbps)	Lower (few hundred kbps)
Range	Longer range (up to 100 meters)	Shorter range (up to 10-30 meters)
Connection Speed	Higher connection setup time	Faster connection establishment
Application Focus	Higher data rates, complex interactions	Low-power, intermittent data exchange

LR-WPAN (IEEE 802.15.4)
low-rate wireless personal area network

IEEE 802.15.4 is a standard that was developed to provide a framework for low-cost, low-power wireless connectivity networks.

It is the standard which is the basis for many low-power wireless connectivity solutions including Zigbee, 6LoWPAN, Thread, etc.

The two IEEE 802.15.4 network topologies are:

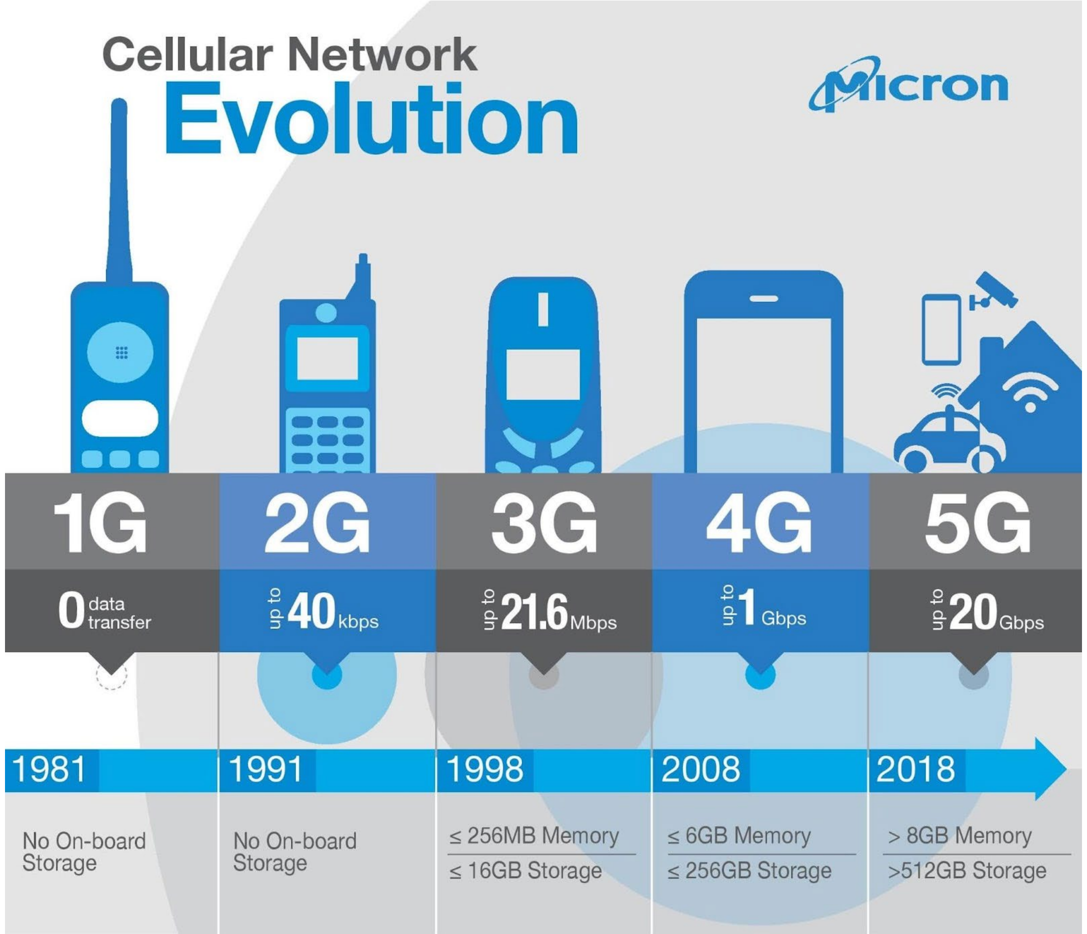
- Star topology: As the name implies the start format for an IEEE 802.15.4 network topology has one central node called the PAN coordinator with which all other nodes communicate.
- Peer to Peer network topology: In this form of network topology, there still exists a PAN coordinator, but communications may also take place between different nodes and not necessarily via the coordinator.

LR-WPAN (IEEE 802.15.4) - ZigBee

- ZigBee also operates on 2.4GHz wireless communication spectrum, but it has a longer range than BLE of up to 100 meters. It also has a slightly lower data rate (250 kbps maximum compared to 270 kbps for BLE) than BLE.
- ZigBee is a mesh network protocol, and unlike BLE, not all devices can sleep between bursts, depending on their position in the mesh and whether they need to act as routers or controllers within the mesh.
- ZigBee was designed for building and home automation applications, like controlling lights. Another closely related technology to ZigBee is Z-Wave.

Cellular

- Cellular technologies provide wide-area network connectivity for IoT devices using cellular networks.
- These technologies leverage existing infrastructure and offer extensive coverage, making them suitable for mobile and remote IoT applications.
- Cellular technologies offer higher data transfer rates, facilitating applications that require real-time data or video streaming.



Comparison of Cellular Technologies

Cellular Technology	2G (GSM/GPRS)	3G (UMTS/HSPA)	4G LTE	5G
Network Generation	Second Generation	Third Generation	Fourth Generation	Fifth Generation
Data Transfer Speed	Low (tens of kbps)	Medium (Mbps)	High (Mbps to Gbps)	Very High (Gbps)
Latency	Relatively High	Medium	Low	Ultra-Low
Power Efficiency	Moderate	Moderate	Moderate to Low	Improved Efficiency
Key Features	Voice and Text	Voice and Data	High-Speed Data	High-Speed, Low-Latency Data
IoT Use Cases	Legacy IoT, Basic Data Monitoring	Enhanced Data Services, Video Streaming	Real-time Monitoring, High-Throughput Applications	Ultra-Reliable Low-Latency Applications, Massive IoT Deployments

Cellular - LTE-M and NB-IoT

- LTE-M (Long-Term Evolution for Machines) and NB-IoT (Narrowband Internet of Things) are cellular technologies specifically designed for IoT applications.
- LTE-M and NB-IoT provide wide coverage, allowing IoT devices to connect even in remote or difficult-to-reach locations.
- These technologies offer low power consumption, ensuring extended device battery life for IoT deployments.
- Use Cases for LTE-M and NB-IoT include Smart Metering (remote monitoring and management of utility meters), Asset Tracking (shipping containers, vehicles, and equipment, improving logistics and supply chain efficiency) and Environmental Monitoring (air quality monitoring and water resource management).

LPWAN

(Low Power Wide Area Network) is a category of technologies that are designed for low-power, long-range wireless communication.

- They are ideal for use within large-scale deployments of low-power IoT devices like wireless sensors.
- LPWAN technologies include LoRa (LongRange), SigFox, LTE-M, and NB-IoT(Narrow-Band IoT).

LPWAN: LoRaWAN

- LoRaWAN™ is a network standard developed and maintained by the LoRa Alliance
- LoRaWAN is the media access control (MAC) layer protocol that manages communication between LPWAN devices and gateways.
- A LoRa node can be up to *10km (6 miles!)* away from a gateway in ideal conditions with the right radio modules.
- The connection between a node and a gateway is very low bandwidth – between *0.3 and 50 kbps* – but it is bi-directional

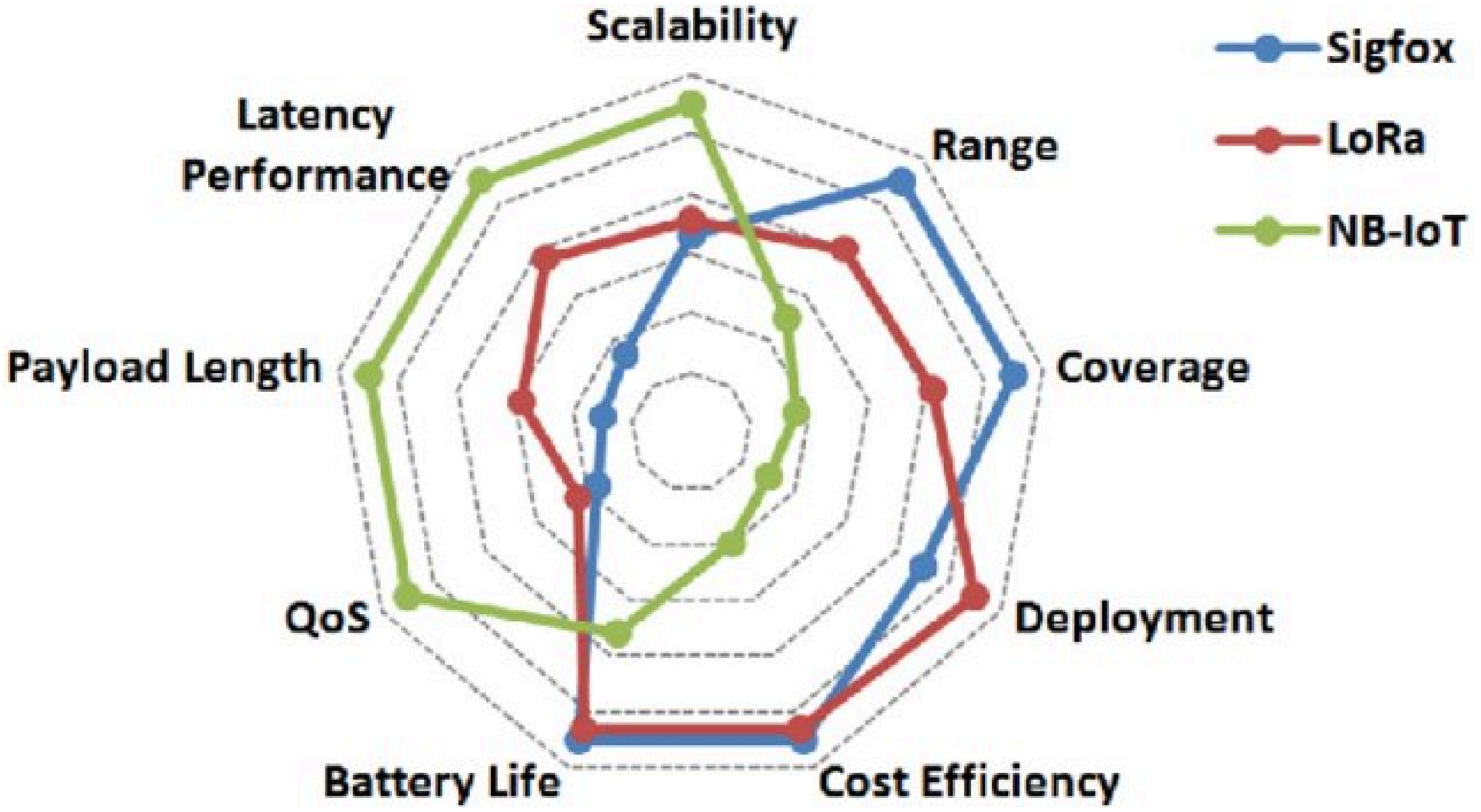
LPWAN: Sigfox

- Sigfox is a proprietary, unlicensed LPWAN running in the ultra-narrowband.
- It can deliver messages over distances of 30-50 km in rural areas, 3-10 km in urban settings and up to 1,000 km in line-of-site applications.
- Its packet size is limited to 150 messages of 12 bytes per day.
- Downlink packets are smaller, limited to four messages of 8 bytes per day.

LPWAN: NB-IoT

- NB-IoT operates on existing LTE and Global System for Mobile (GSM) infrastructure.
- It offers uplink and downlink rates of around 200 Kbps, using only 200 kHz of available bandwidth.
- NB-IoT operates on the licensed spectrum.

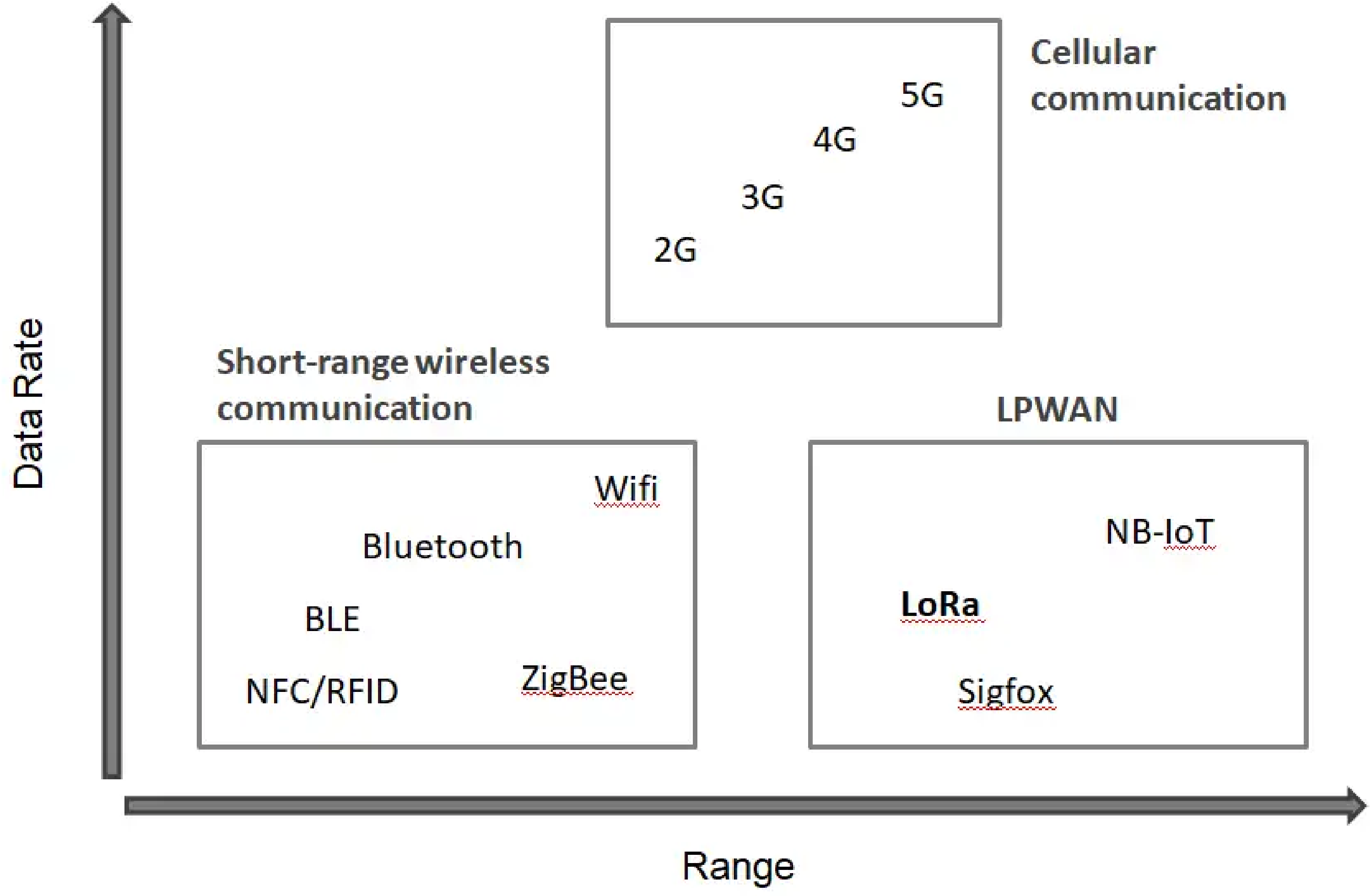
LPWAN: Respective Advantages in Terms of IoT Factors



Considerations for Network access and physical layer protocols

- **Range:** Determine the required coverage area and select protocols accordingly.
- **Power Consumption:** Optimize energy usage based on device requirements.
- **Data Rate:** Consider the amount of data to be transmitted and select protocols with suitable speeds.
- **Scalability:** Ensure the network can accommodate future growth and increased device connectivity.
- **Security:** Implement security measures to protect data and prevent unauthorized access.

Range vs. Data Rate



Conclusions

- Cellular networks often suffer from poor battery life and may have gaps in coverage. As many IoT devices are deployed for 10 years or longer, cellular coverage isn't a feasible option.
- Mesh technologies, such as Zigbee, are better suited for smart homes or smart buildings. They have high data rates but are far less battery-efficient than LPWAN.

Summary / Recap of Main Points

During this lesson, the following topics were covered:

- Wired Network Access:
  - Ethernet, Powerline communication (PLC)
- Wireless Network Access:
  - Wi-Fi, RFID, Bluetooth and BLE, LR-WPAN, Cellular and LPWAN
- Considerations for Network Access and Physical Layer Protocols:
  - Range, data rate, power consumption, scalability and security considerations

Review Questions

- Name some different wired and wireless communication technologies used to connect IoT devices.
- Explain the factors to consider when selecting network access and physical layer protocols for specific IoT applications.
- Provide three examples of IoT applications and the network access and physical layer protocols that would be appropriate for them.

What To Expect Next Week

In Class

Preparation for Class