MOBILE SYSTEM-HT25
LECTURE 13:
SHORT-RANGE WIRELESS TECHNOLOGIES
&
APPLICATIONS OF WIRELESS TECHNOLOGIES IN IOT

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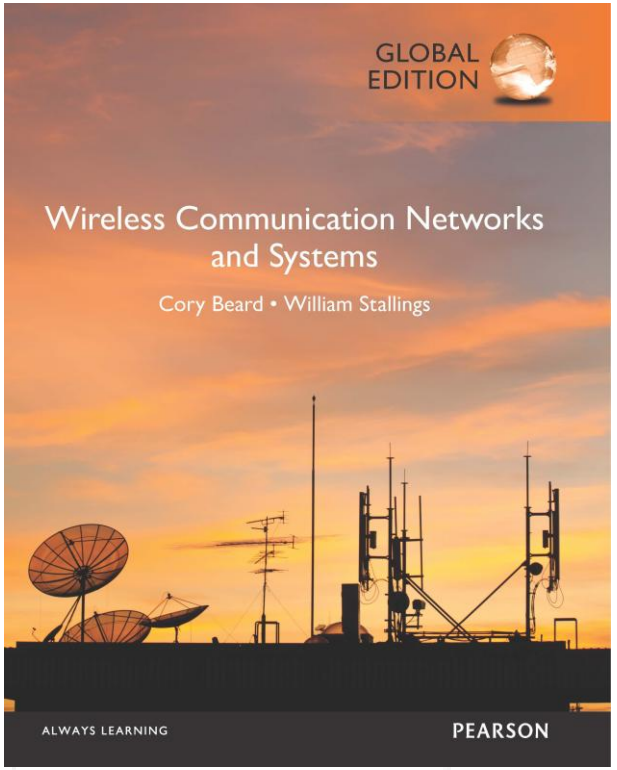
Most slides are primarily adapted from Beard & Stallings (2016), Wireless Communication Networks and Systems (Chapter 12)



Wireless Communication Networks and Systems

1st edition, Global edition

Cory Beard, William Stallings

WHERE WE ARE IN THE COURSE

- Evolution of Wireless Communication, Transmission fundamentals, Analog and Digital Modulations (Lectures 2-4)
- The Wireless Channel (Lectures 5 and 6)
- Transmission Fundamentals (CTFT, DTFT) (Lecture 7)
- Orthogonal Frequency Division Multiplexing- OFDM (Lecture 8)
- Spread Spectrum (Lecture 10)
- Coding and Error Control (Lecture 11)
- Cellular Wireless Networks (Lecture 12)
- Short-Range Wireless Technologies & Applications of Wireless Technologies in IoT (Lecture 13)
- 5G, 6G och Vidare (Lecture 14)

OUTLINE

- Short-Range Wireless Technologies:
  - BLE
  - Zigbee
  - Wi-Fi
- IoT Systems
  - Introduction and Examples
  - Challenges in Mobile IoT Systems (DT I)
  - Selection of the Appropriate Wireless Technologies
  - Discussions on the applications of the Wireless Technologies in IoT (DT II, DT III, DT VI)

SHORT-RANGE WIRELESS TECHNOLOGIES

BLUETOOTH LOW ENERGY (BLE)

- Range: ~10 meters
- Power: Very low
- **Data Rate:** up to 2 Mbps (in BLE 5)
- Advantages: Extremely energy efficient, supported in smartphones
- Limitations: Not suitable for long range or high data throughput
- Use case: Wearables, proximity detection

BLUETOOTH LOW ENERGY (BLE)

- **Modulation:** GFSK (Gaussian Frequency Shift Keying)
- **Multiple Access / Channelization: FHSS (Frequency Hopping Spread Spectrum)**
- **Bandwidth:** 2 MHz channels within the 2.4 GHz ISM band (40 channels total)

Industrial, Scientific, and Medical band

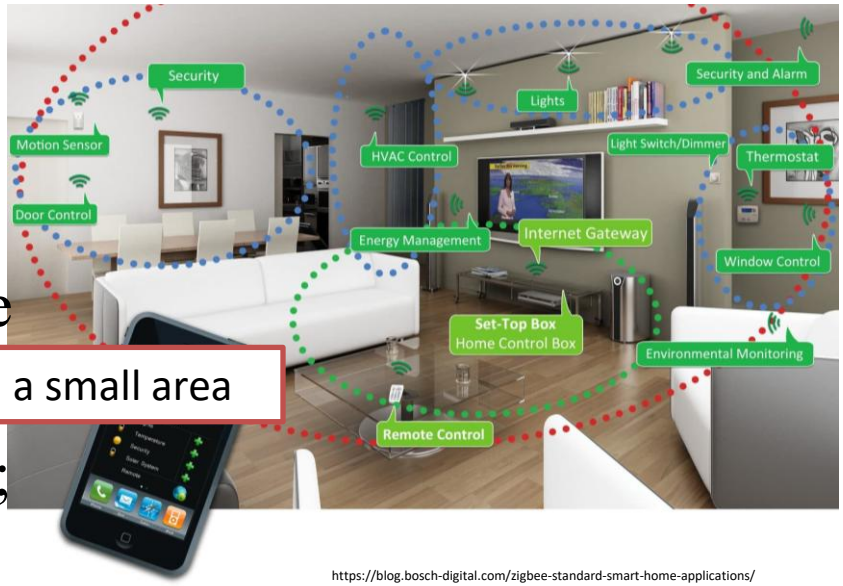
902-928 MHz, **2.4 - 2.4835 GHz** GHz and 5.7-5.8 GHz bands

ZIGBEE

In a **mesh network**, each device can connect to multiple other devices.

- Range: ~10-100 meters (mesh)
- Power: Low
- **Data Rate:** up to 250 kbps
- Advantages: Mesh support, reliable in dense deployments
- Limitations: Not great for mobility; best in fixed deployments, Not suitable for long range coverage
- Use case: Smart home, health care, low data-rate control

many devices in a small area

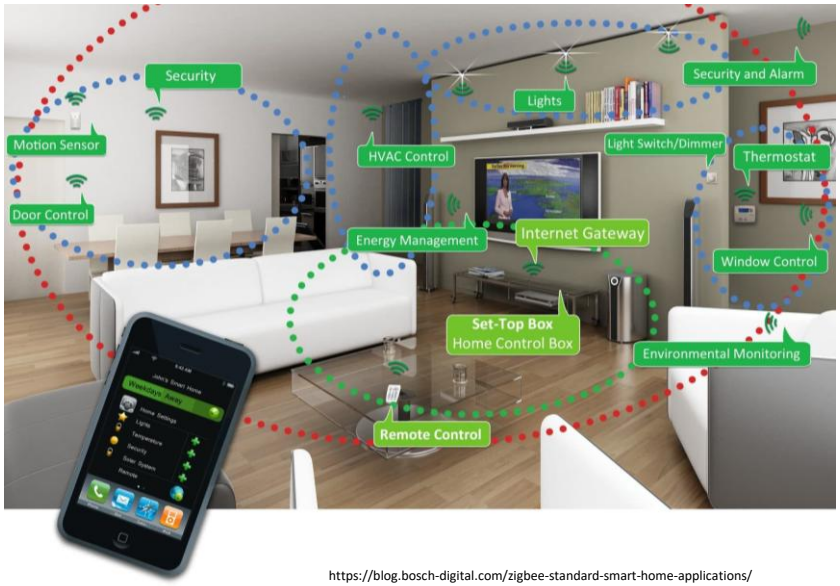


https://blog.bosch-digital.com/zigbee-standard-smart-home-applications/

like turning lights on/off, reporting temperature, or sending a health sensor reading.

ZIGBEE (IEEE 802.15.4)

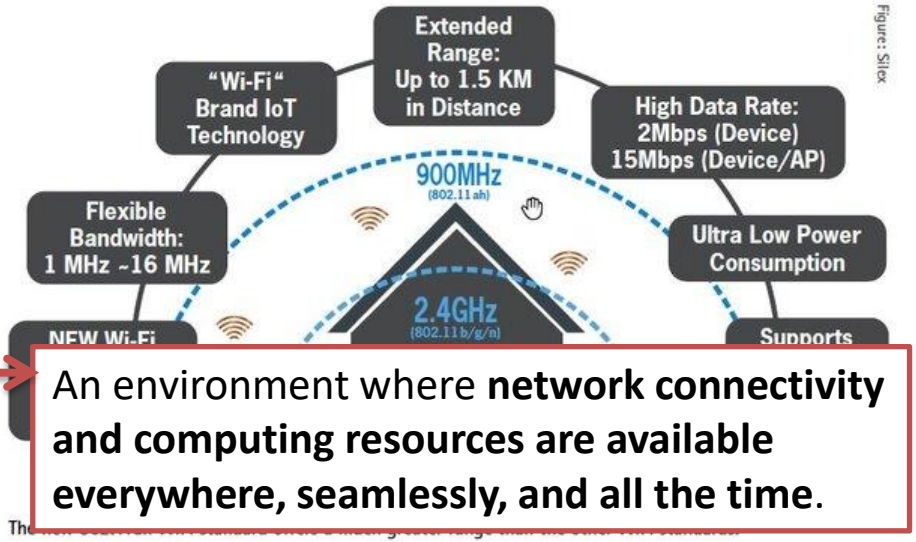
- **Modulation:** O-QPSK (Offset Quadrature Phase Shift Keying) with **DSSS (Direct Sequence Spread Spectrum)**
- **Bandwidth:** 2 MHz spacing, 16 channels in the 2.4 GHz ISM band



https://blog.bosch-digital.com/zigbee-standard-smart-home-applications/

WI-FI (802.11N/AC/AH)

- Range: ~50-100 meters
- Power: Very high
- **Data Rate:** Very high
- Advantages: High bandwidth ubiquitous infrastructure
- Limitations: High power use, limited range outdoors
- Use case: Mobile video, cameras, etc.



An environment where **network connectivity and computing resources are available everywhere, seamlessly, and all the time**.

https://www.rutronik.com/article/ieee-80211ah-alias-wifi-halow-the-best-of-wifi-and-lpwan

WI-FI (802.11N/AC/AH)

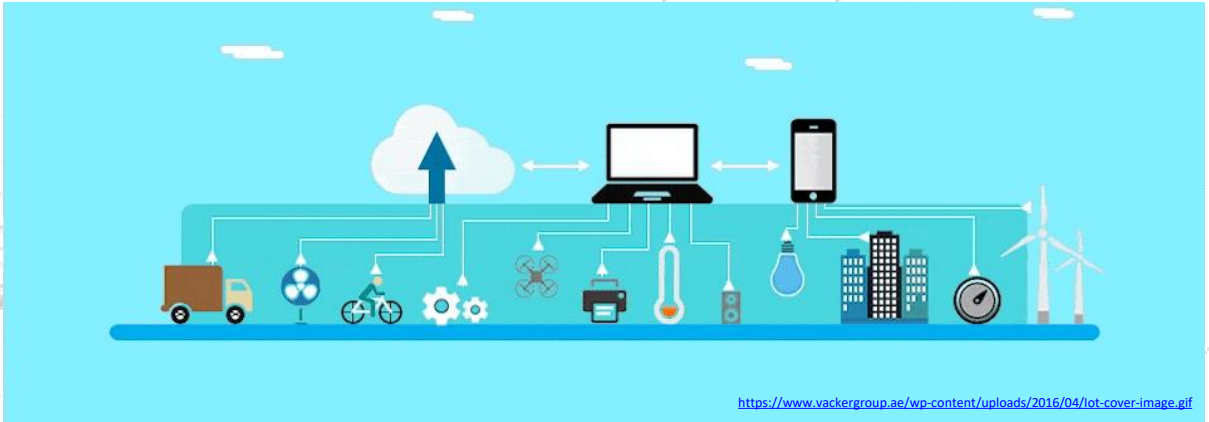
Standard	Frequency	Modulation / Spread-Spectrum Technique Used	Notes
802.11a	5 GHz	**OFDM**	Orthogonal frequency-division multiplexing — considered a form of spread spectrum.
802.11g	2.4 GHz	**OFDM** (with optional DSSS for backward compatibility)	Supports both OFDM and DSSS/CCK.
802.11n	2.4 & 5 GHz	**OFDM** (MIMO enhancements)	Uses wider channels and spatial multiplexing.
802.11ac	5 GHz	**OFDM** (with 256-QAM, MU-MIMO)	Wider channels up to 160 MHz.
802.11ax (Wi-Fi 6)	2.4 & 5 GHz	**OFDMA** (a multi-user extension of OFDM)	More efficient channel sharing.

IOT SYSTEMS

INTERNET OF THINGS (IOT)

The **Internet of Things (IoT)** refers to a network of physical objects—**"things"**—embedded with sensors, software, and connectivity ("Things" are connected to the internet):

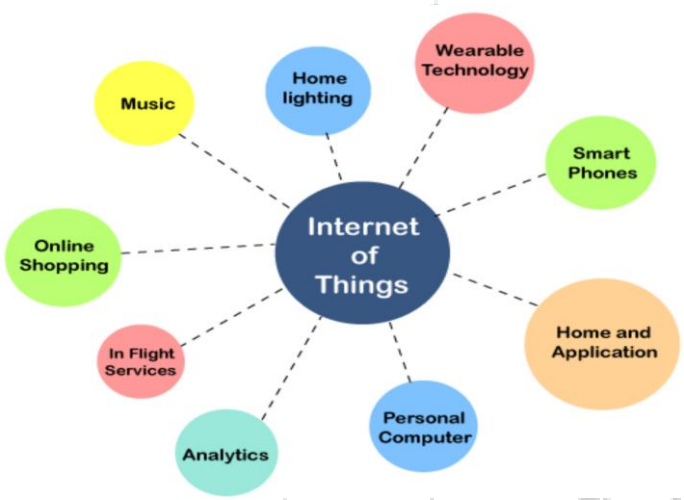
- They sense, collect, and transmit data
- Enable intelligent actions and automation



https://www.vackergroup.ae/wp-content/uploads/2016/04/Iot-cover-image.gif

INTERNET OF THINGS (IOT)

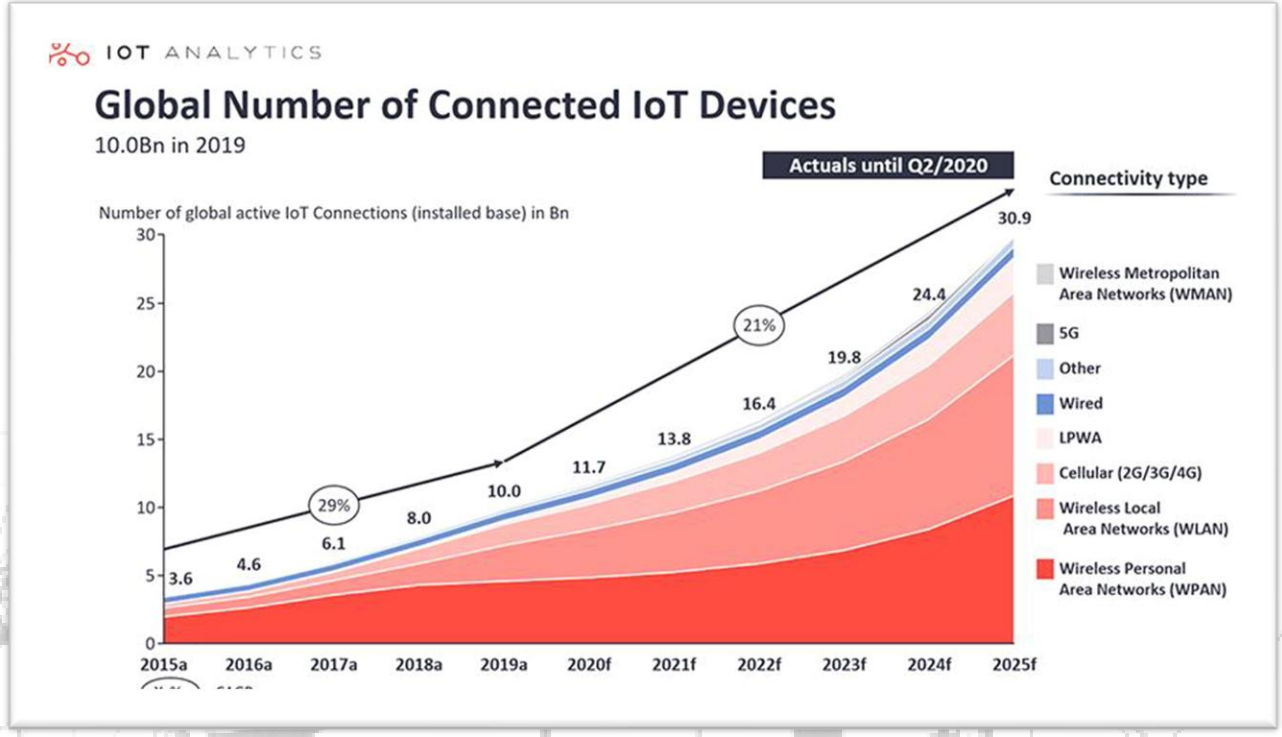
These **things** range from smart home appliances to industrial machines and connected vehicles.



IOT IS EVERYWHERE: TRACKING GLOBAL ADOPTION

MALMÖ UNIVERSITET

As IoT becomes an increasingly vital part of daily life and modern business, the **range of application areas is expanding rapidly.**



IOT EVERYWHERE

Now, we need IoT systems with **reliable and secure IoT connectivity** that can operate **anytime, anywhere — across land, sea, and air**.

Mobile IoT Systems

WHAT ARE MOBILE IOT SYSTEMS?

Mobile IoT systems refer to Internet of Things deployments where the devices or nodes are not fixed in place — they move through physical space while continuously sensing, processing, and communicating data.

- We must select the appropriate wireless connectivity technology for each application.
- **No single connectivity technology can meet the requirements of all use cases.**

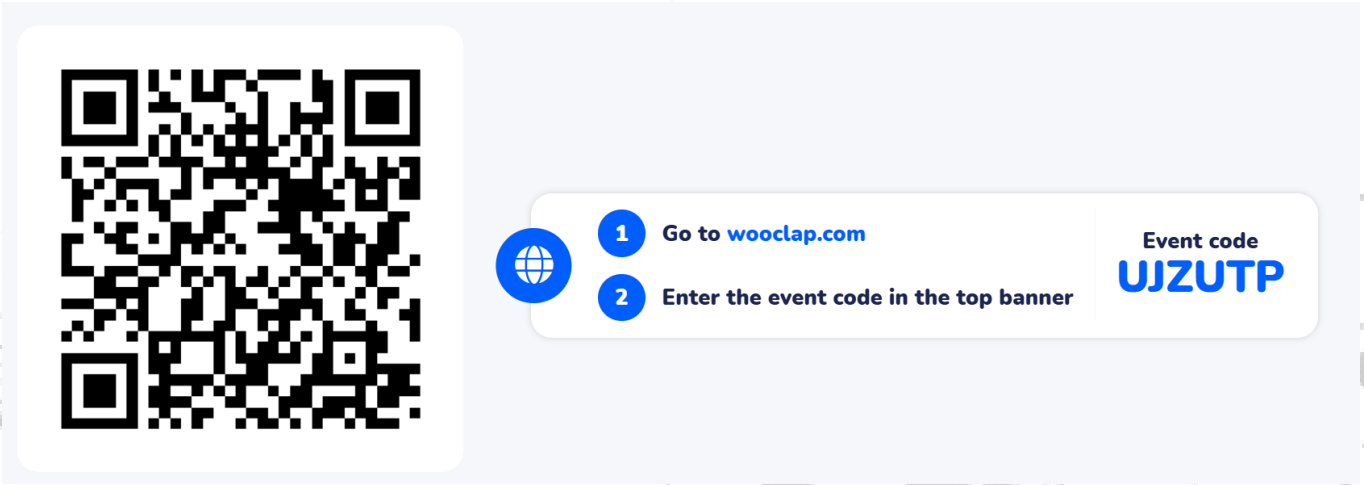
MOBILE IOT SYSTEMS

IoT systems including:

- **Wearables** like smartwatches or fitness trackers that collect health data as users move
- **Asset trackers** used in logistics to monitor cargo across long distances
- **Drones** used in agriculture or surveillance, transmitting live data in flight
- **Connected vehicles** exchanging real-time traffic or safety information
- …

GROUP DISCUSSION I: CONNECTIVITY CHALLENGES IN MOBILE IOT — WHAT DO WE NEED TO OVERCOME?

What are the **key connectivity challenges of Mobile IoT Systems?**



CHALLENGES IN MOBILE IOT — WHAT DO WE NEED TO OVERCOME?

- **Power Management**
- **Data Rate & Bandwidth Constraints**
- **Coverage Range & Network Availability**
- **Latency & Real-Time Performance**
- **Security & Privacy**
- **Mobility Support & Connectivity (Mobility Support, handoff/handover between networks, changing signal strength, …)**
- **etc.**

COMMUNICATION NEEDS IN MOBILITY

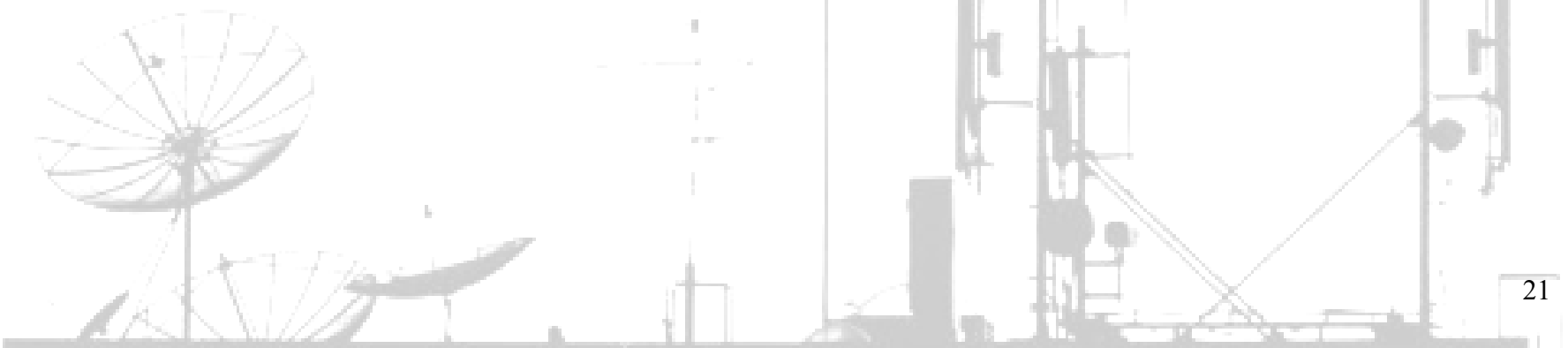
Mobile IoT systems operate across **indoor and outdoor environments, with different latency, coverage, data rate, and power constraints**.

- To ensure reliable performance, **wireless technologies** must be selected based on:
  - **Range** – Short-range vs. long-range
  - **Power Usage** – Battery constraints in mobile devices require energy-efficient options
  - **Bandwidth** – Varies from small periodic messages to high-throughput video
  - **Mobility Support** – Seamless handover and consistent connectivity while in motion
  - **Latency**
  - **Etc.**

Choosing the right technology is critical to balancing energy, performance, and connectivity in mobile environments.

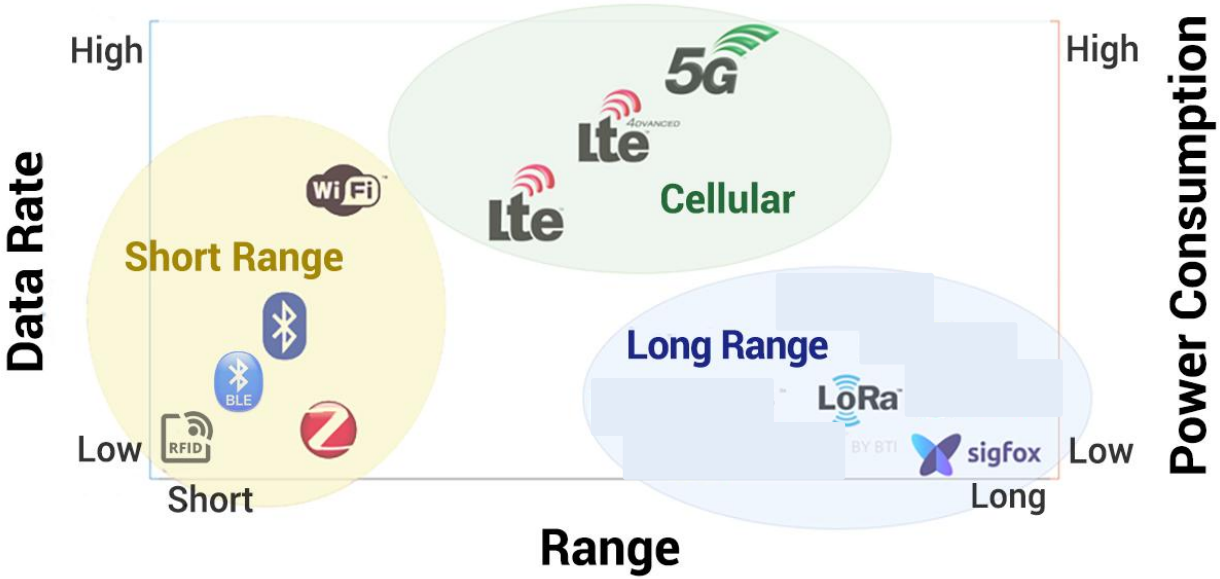
WIRELESS COMMUNICATION TECHNOLOGIES FOR IOT

Wireless technologies support both **mobile** and **static** IoT systems.



CLASSIFICATION OF WIRELESS COMMUNICATION TECHNOLOGIES

- **Short-Range**
- **Long-Range**
- **Cellular IoT**



https://extension.sdstate.edu/choosing-right-wireless-network-technologies-agricultural-internet-things-applications

DISCUSSION TIME II: MOBILE HEALTH MONITOR

- Consider a mobile health monitoring system using wearable devices (like smartwatches or fitness bands) that track your health data — such as heart rate— and send it to your smartphone or a remote server for analysis.
- Think about the devices you have seen — what kinds of health or fitness applications do they support?
- What wireless technologies do you think are best suited for mobile health monitoring, and why?

https://www.frontiersin.org/research-topics/13524/mobile-and-wearable-systems-for-health-monitoring/magazine

MOBILE HEALTH MONITOR

- Requirements: Mobility, low power, periodic data
- Possible Tech: BLE (device) ?

https://www.frontiersin.org/research-topics/13524/mobile-and-wearable-systems-for-health-monitoring/magazine

MOBILE HEALTH MONITOR

- Requirements: Mobility, low power, periodic data
- Possible Tech: BLE (device) + smartphone + **cellular connectivity**

https://www.frontiersin.org/research-topics/13524/mobile-and-wearable-systems-for-health-monitoring/magazine

BLE (Bluetooth Low Energy) connects the wearable device (e.g., smartwatch) to a nearby smartphone.

But BLE only works at short range (a few meters).
To send health data to a remote server, doctor, or cloud, you need **cellular connectivity (**works wherever mobile networks exist**)**.

GROUP DISCUSSION III: WI-FI IN WIRELESS APPLICATIONS

Wi-Fi is one of the most common wireless technologies, used in homes, offices, and public areas. IoT devices also use Wi-Fi for data transfer and connectivity to the Internet.

Discuss:

- In what types of **IoT applications** is Wi-Fi the best choice? (Discuss your experiences)
- What are the **advantages and limitations** of using Wi-Fi compared to BLE, Zigbee, and cellular technology?

WI-FI IN WIRELESS APPLICATIONS

Best use cases:

Smart Home IoT

- High-bandwidth needs (video, audio, cloud access)
- Examples: smart TVs, security cameras, voice assistants

Industrial & Office IoT

- Uses existing Wi-Fi infrastructure
- Good for building automation and asset monitoring indoors

Health & Fitness Devices

- Syncs data when near an access point
- Supports medical and activity tracking devices

Ideal for **high data rate**, **continuous connectivity**, **indoor environments**, where **power is available**.

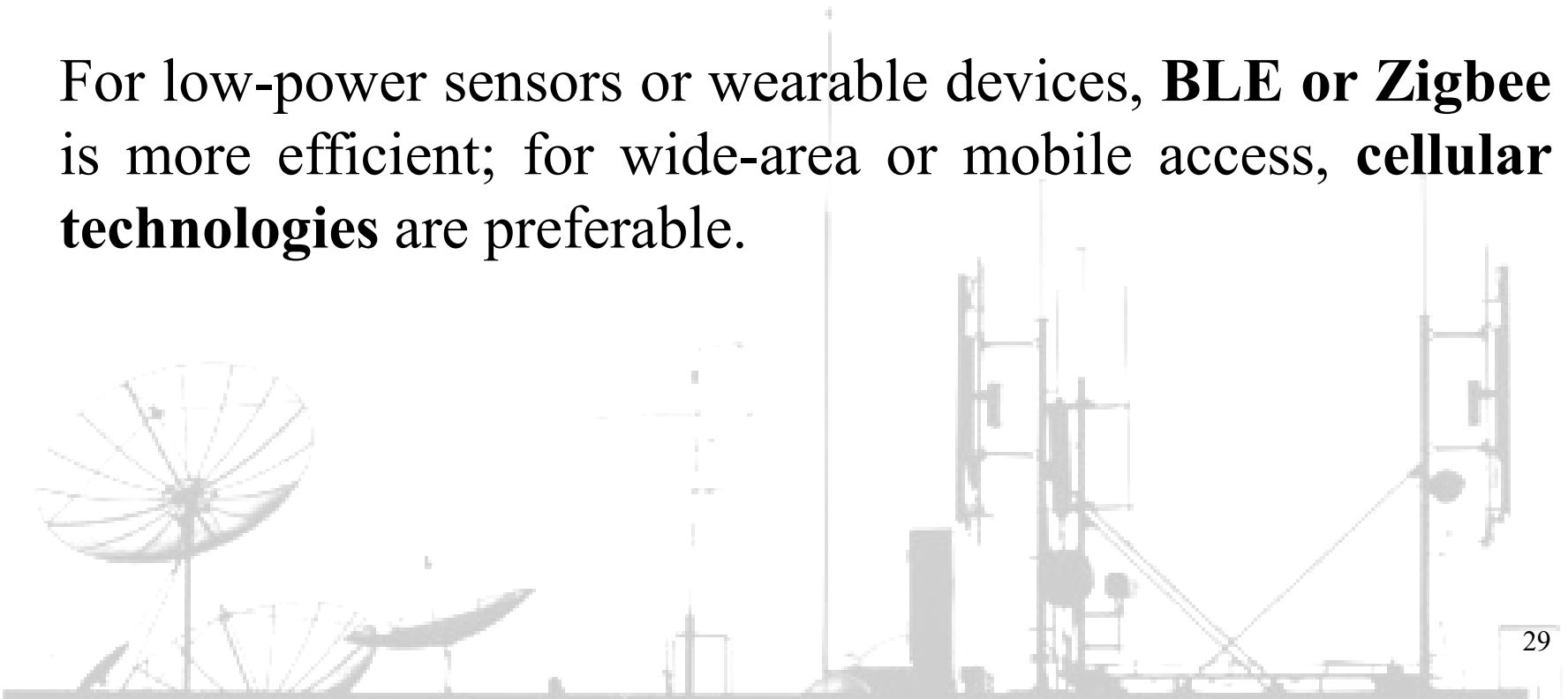
WI-FI IN WIRELESS APPLICATIONS

Technology	Range	Data Rate	Power Use	Mobility	Cost
Wi-Fi	Medium	**High**	**High**	Medium	**Low** (if infrastructure exists)
BLE	Short	Low	**Very Low**	Medium	Low
Zigbee	Short–Medium (mesh)	Low	Low	Low	Low
Cellular (3G/4G/5G /NB-IoT)	**Very Long**	Medium –Very High	Medium–High (varies)	**Excellent**	**Higher** (subscription required)

WI-FI IN WIRELESS APPLICATIONS

Wi-Fi is best for high-bandwidth, always-powered devices (e.g., cameras, appliances).

For low-power sensors or wearable devices, **BLE or Zigbee** is more efficient; for wide-area or mobile access, **cellular technologies** are preferable.



GROUP DISCUSSION IV: SMART HOME SYSTEMS

Consider:

A smart home where lights, thermostats, security cameras, wearable devices, smart locks, remotes, and sensors communicate wirelessly.

Discuss:

- Which wireless technologies (BLE, Zigbee, Wi-Fi, cellular) are most suitable for different smart home applications — and why?

SMART HOME SYSTEMS

- **Zigbee** – Best for **sensors and control devices** (lights, thermostats, motion sensors).

  Advantages: *Low power*, *mesh networking* for reliable coverage in the home.

  Disadvantages: Not ideal for mobile or high-data applications.
- **Wi-Fi** – Best for **high data rate** devices like **security cameras, smart TVs, or video doorbells**.

  Advantages: High bandwidth, widely supported.

  Disadvantages: Very high power consumption.
- **BLE (Bluetooth Low Energy)** – Useful for **personal devices** (smart locks, wearables, remotes).

  Advantages: Very low power, easy smartphone integration.

  Disadvantages: Short range, limited data rate.
- **Cellular** – Used mainly for **remote control and alerts** when the user is away from home.

  Advantages: Long-range connectivity to cloud or mobile networks.

  Disadvantages: Higher power and cost.

SMART HOME SYSTEMS

Smart homes typically combine multiple technologies:

- Zigbee for local sensors
- BLE for personal devices
- Wi-Fi for high-data devices
- cellular for remote access.

QUESTIONS?