

Lecture 43: Zigbee: Basic concept, features and applications

Wireless Technologies

DI05011011: Mobile Communication

Agenda for Today

- 1. What is Zigbee?
- 2. The IEEE 802.15.4 Standard
- 3. Zigbee Network Topologies
- 4. Zigbee Device Types
- 5. Zigbee Protocol Stack
- 6. Key Features of Zigbee
- 7. Zigbee vs. Wi-Fi vs. Bluetooth
- 8. Real-world Applications
- 9. Summary and Next Steps

What is Zigbee?

- **Zigbee** is a wireless technology developed as an open global standard to address the unique needs of low-cost, low-power wireless IoT networks.
- It operates in the **2.4 GHz ISM band** globally (alongside Wi-Fi and Bluetooth), and also 915 MHz in the Americas and 868 MHz in Europe.
- Maintained by the **Connectivity Standards Alliance (CSA)** (formerly Zigbee Alliance).
- Designed for scenarios where devices only need to transmit small amounts of data infrequently.

The IEEE 802.15.4 Standard

- Zigbee is built on top of the **IEEE 802.15.4** standard.
- **IEEE 802.15.4** defines the **Physical (PHY) Layer** and the **Medium Access Control (MAC) Layer** for Low-Rate Wireless Personal Area Networks (LR-WPANs).
- **Zigbee** defines the higher layers: the **Network Layer**, **Security Layer**, and **Application Layer**.
- Think of 802.15.4 as the road and vehicles, while Zigbee is the traffic laws and delivery system.

Zigbee Device Types

- A Zigbee network has three types of devices based on their roles:
- **1. Zigbee Coordinator (ZC):**
 - - The 'brain' of the network. Creates and manages the network.
 - - Only one Coordinator per network. Stores network information and security keys.
- **2. Zigbee Router (ZR):**
 - - Acts as an intermediate node, passing data from other devices.
 - - Must be constantly powered (plugged in) as it keeps the network mesh alive.
- **3. Zigbee End Device (ZED):**
 - - Battery-powered sensors or switches.
 - - Spends most of its time asleep to save battery. Wakes up, sends data to a parent (Router or Coordinator), and sleeps again.

Zigbee Network Topologies

- Zigbee supports multiple network topologies:
- **1. Star Topology:** All devices connect directly to the central Coordinator. (Simple but limited range).
- **2. Tree Topology:** Coordinator is the root, Routers form branches, End Devices are leaves.
- **3. Mesh Topology (Most Common):**
 - - Devices communicate with each other dynamically.
 - - **Self-Healing:** If a Router fails, data finds a new path through another Router.
 - - Highly reliable and can cover large areas by hopping messages across devices.

Key Features of Zigbee

- **Low Power Consumption:** End devices can run for years on a single coin-cell battery.
- **Low Data Rate:** Maximum 250 kbps (at 2.4 GHz). Sufficient for sensor data.
- **High Capacity:** Can support up to **65,000 devices** on a single network.
- **Secure:** Uses AES-128 encryption to secure data packets.
- **Self-Organizing & Self-Healing:** The mesh network automatically configures and repairs itself if a node goes down.

Zigbee vs. Wi-Fi vs. Bluetooth

- — Feature — Wi-Fi (802.11) — Bluetooth (LE) — Zigbee (802.15.4) —
- — : — — : — — : — — : — —
- — **Data Rate** — High (Gbps) — Medium (1-2 Mbps) — Low (250 kbps) —
- — **Power Usage** — High — Low — Extremely Low —
- — **Topology** — Star (BSS) — Star / Mesh — Star / Tree / Mesh —
- — **Max Devices** — ~250 per AP — Few / Mesh limits — Up to 65,000 —
- — **Use Case** — Internet, Video — Audio, Wearables — Sensors, Automation —

- **Smart Home Automation:** Smart bulbs (Philips Hue), smart locks, thermostats, window sensors.
- **Industrial Control:** Monitoring factory equipment, temperature, and humidity sensors across large warehouses.
- **Smart Metering:** Automated meter reading for electricity and water.
- **Healthcare:** Patient monitoring systems requiring low power wearable sensors.
- **Smart Agriculture:** Soil moisture sensors spread across large fields utilizing the mesh network to reach the central hub.

Limitations of Zigbee

- **Not for High Data Rates:** Cannot be used to transmit audio, video, or large files.
- **Requires a Hub/Gateway:** Unlike Wi-Fi, smartphones cannot connect to Zigbee directly. A Zigbee-to-Wi-Fi hub (Coordinator) is always required to control them via phone.
- **Interference:** Operates in the crowded 2.4 GHz band, which can suffer interference from Wi-Fi networks and microwaves.
- **Interoperability Issues:** Historically, different manufacturers implemented custom Zigbee profiles, though recent standards (Zigbee 3.0, Matter) aim to fix this.

- Zigbee is a low-power, low-data rate wireless standard designed for IoT and sensor networks.
- It builds upon the IEEE 802.15.4 PHY and MAC layers.
- A Zigbee network consists of a Coordinator, Routers, and sleeping End Devices.
- Mesh networking allows for extended range, reliability, and self-healing.
- Ideal for applications like smart homes, industrial monitoring, and smart metering, where battery life is more important than bandwidth.

- In the next lecture, we will explore networks that form entirely on their own without any infrastructure:
- **Mobile Adhoc Networks (MANET):**
 - - What happens when there is no cell tower or Wi-Fi router?
 - - How devices dynamically form a network and route data.
 - - Architecture and characteristics of MANETs.