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Introduction:
IoT Connectivity – Part I

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Communication Protocols

- The following communication protocols are important for IoT:
  - IEEE 802.15.4
  - Zigbee
  - 6LoWPAN
  - Wireless HART
  - Z-Wave
  - ISA 100
  - Bluetooth
  - NFC
  - RFID

IEEE 802.15.4

Introduction to IEEE 802.15.4

- This standard provides a framework meant for lower layers (MAC and PHY) for a wireless personal area network (WPAN).
- PHY defines frequency band, transmission power, and modulation scheme of the link.
- MAC defines issues such as medium access and flow control (frames).
- This standard is used for low power, low cost (manufacturing and operation), and low speed communication between neighboring devices (< ~75m).

Source: What's The Difference Between IEEE 802.15.4 And ZigBee Wireless? Fenzel, L.

Features of IEEE 802.15.4

- This standard utilizes DSSS (direct sequence spread spectrum) coding scheme to transmit information.
- DSSS uses phase shift keying modulation to encode information.
  - BPSK - 868/915 MHz, data transmission rate 20/40 kbps respectively.
  - OQPSK - 2.4 GHz, data transmission rate 250 kbps.
- DSSS scheme makes the standard highly tolerant to noise and interference and thereby improving link reliability.

Source: What's The Difference Between IEEE 802.15.4 And ZigBee Wireless? Fenzel, L.

Features of IEEE 802.15.4 (contd.)

- The preferable nature of transmission is line of sight (LOS).
- The standard range of transmission - 10 to 75m.
- The transmission of data uses CSMA-CA (carrier sense multiple access with collision avoidance) scheme.
- Transmissions occur in infrequent short packets for duty cycle (<1 %), thus reducing consumption of power.
- Star network topology and peer-to-peer network topology is included.

Source: What's The Difference Between IEEE 802.15.4 And ZigBee Wireless? Fenzel, L.

Variants of IEEE 802.15.4

Version	Feature
802.15.4 - 2003	Basic version. The modulation schemes and data rates were fixed for different frequency band – 868, 915 MHz, and 2.4 GHz.
802.15.4 - 2006	Also known as 802.15.4b. Provides higher data rate even on the lower frequency bands. In the 868 MHz, the data transmission rate is up to 100 kb/s while in 915 MHz, the data transmission rate is up to 250 kb/s. Uses OQPSK for all the frequency bands.

Source: Poole, I. IEEE 802.15.4 Technology & Standard.

Variants of IEEE 802.15.4 (contd.)

Version	Feature
802.15.4 a	Increases range capability. Defines two new physical layers – Direct Sequence ultra-wideband (UWB) – 249.6 - 749.6 MHz (sub-gigahertz band), 3.1 - 4.8 GHz (low band), and 6 - 10 GHz (high band). Chirp spread spectrum (CSS) approach in ISM band at 2.4 GHz.
802.15.4 c	This version provides 780 MHz band in China. It uses either O-QPSK or MPSK (Multiple frequency-shift keying) using data transmission rate 250 kb/s.
802.15.4 d	This version provides 950 MHz band in Japan. It uses either GFSK (Gaussian frequency-shift keying) using data rate 100 kb/s or BPSK using data rate 20 kb/s.

Source: Poole, I. IEEE 802.15.4 Technology & Standard.

Variants of IEEE 802.15.4 (contd.)

Version	Feature
802.15.4e	Defines MAC developments to IEEE 802.15.4 towards ISA SP100.11a application (industrial applications).
802.15.4f	Defines fresh PHYs for 433 MHz frequency band (RFID applications), 2.4 GHz frequency band and UWB.
802.15.4g	Defines fresh PHYs for smart utility networks for 902 - 928 MHz band (smart grid applications, majorly for the energy industry).

Source: Poole, I. IEEE 802.15.4 Technology & Standard.

Zigbee

Introduction to Zigbee

- Provides a framework for medium-range communication in IoT connectivity.
- Defines PHY (Physical) and MAC (Media Access Control) layers enabling interoperability between multiple devices at low-data rates.
- Operates at 3 frequencies –
  - 868 MHz (1 channel using data transmission rate up to 20 kbps)
  - 902-928MHz (10 channels using data transmission rate of 40 kbps)
  - 2.4 GHz (16 channels using data transmission rate of 250 kbps).

Source: Agarwal, T. ZigBee Wireless Technology Architecture and Applications.

Features of Zigbee

- The lower frequency bands use BPSK.
- For the 2.4 GHz band, OQPSK is used.
- The data transfer takes place in 128 bytes packet size.
- The maximum allowed payload is 104 bytes.
- The nature of transmission is line of sight (LOS).
- Standard range of transmission – upto 70m.

Source: Agarwal, T. ZigBee Wireless Technology Architecture and Applications.

Features of Zigbee (contd.)

- Relaying of packets allow transmission over greater distances.
- Provides low power consumption (around 1mW per Zigbee module) and better efficiency due to
  - adaptable duty cycle
  - low data rates (20 - 250 kbit/s)
  - low coverage radio (10 -100 m)
- Networking topologies include star, peer-to-peer, or cluster-tree (hybrid), mesh being the popular.

Source: Agarwal, T. ZigBee Wireless Technology Architecture and Applications.

Features of Zigbee (contd.)

- The Zigbee protocol defines three types of nodes:
  - **Coordinators** - Initializing, maintaining and controlling the network. There is one and only one per network.
  - **Routers** - Connected to the coordinator or other routers. Have zero or more children nodes. Contribute in multi hop routing.
  - **End devices** - Do not contribute in routing.
- **Star topology** has no router, one coordinator, and zero or more end devices.
- In **mesh** and **tree** topologies, one coordinator maintains several routers and end devices.

Source: Agarwal, T. ZigBee Wireless Technology Architecture and Applications.

Features of Zigbee (contd.)

- Each cluster in a cluster-tree network involves a coordinator through several leaf nodes.
- Coordinators are linked to parent coordinator that initiates the entire network.
- ZigBee standard comes in two variants:
  - **ZigBee**
  - **ZigBee Pro** - offers scalability, security, and improved performance utilizing many-to-one routing scheme.

Source: Agarwal, T. ZigBee Wireless Technology Architecture and Applications.

6LoWPAN

Introduction to 6LoWPAN

- 6LoWPAN is IPv6 over Low-Power Wireless Personal Area Networks.
- It optimizes IPv6 packet transmission in low power and lossy network (LLN) such as IEEE 802.15.4.
- Operates at 2 frequencies:
  - 2400–2483.5 MHz (worldwide)
  - 902–929 MHz (North America)
- It uses 802.15.4 standard in unslotted CSMA/CA mode.

Source: Olsson, J. 6LoWPAN demystified.

Features of 6LoWPAN

- 6LowPAN converts the data format to be fit with the IEEE 802.15.4 lower layer system.
- IPv6 involves MTU (maximum transmission unit) of 1280 bytes in length, while the IEEE 802.15.4 packet size is 127 bytes.
- Hence a supplementary adaptation layer is introduced between MAC and network layer that provides:
  - Packet fragmentation & packet reassembly
  - Compression of header
  - Routing of data link layer.

Source: Olsson, J. 6LoWPAN demystified.

Features of 6LoWPAN (contd.)

- Fragmentation is required to fit the intact IPv6 packet into a distinct IEEE 802.15.4 frame (> ~106 bytes).
- The fragmentation header allows 2048 bytes packet size with fragmentation.
- Using fragmentation and reassembly, 128-byte IPv6 frames are transmitted over IEEE 802.15.4 radio channel into several smaller segments.
- Every fragment includes a header.

Source: Sulthana, M. R. A Novel Location Based Routing Protocol For 6LoWPAN.

Features of 6LoWPAN (contd.)

- Header compression reduces the transmission overhead and allows efficient transmission of payload.
- IPv6 addresses are compressed in 6LoWPAN:
  - 8-byte UDP header
  - 40-byte IPv6 header
- Stateless auto configuration allows any device to create the IPv6 address automatically devoid of external dealing using a DHCP server.

Source: Sulthana, M. R. A Novel Location Based Routing Protocol For 6LoWPAN.

Features of 6LoWPAN (contd.)

- Data link layer routing is classified into two schemes:
  - **mesh-under** - utilizes link layer address to forward data packets.
  - **route-over** - utilizes network layer IP address.
- Provides link layer security (AES-128) from IEEE 802.15.4 such as authentication of link and encryption.

Source: Sulthana, M. R. A Novel Location Based Routing Protocol For 6LoWPAN.

Wireless HART

Introduction to Wireless HART

- WirelessHART is based on HART (Highway Addressable Remote Transducer).
- It is the first international industrial wireless standard (IEC 62591), based upon the standard IEEE 802.15.4.
- Functions in the 2.4GHz ISM band using data rate of up to 250 kb/s.
- 11 to 26 channels are supported, with a gap of 5MHz between two adjacent channels.
- The same channel can't be used consecutively.

Source: Feng, A. WirelessHART- Made Easy.

Features of Wireless HART

- Exploits IEEE 802.15.4 accustomed DSSS coding scheme.
- A WirelessHART node follows channel hopping every time it sends a packet.
- Modulation technique used is offset quadrature phase shift keying (OQPSK).
- Transmission Power is around 10dBm (adjustable in discrete steps).

Source: Feng, A. WirelessHART- Made Easy.

Features of Wireless HART (contd.)

- Maximum payload allowed is 127 bytes.
- It employs TDMA (time division multiple access) that allots distinct time slot of 10ms for each transmission.
- TDMA technology is used to provide collision free and deterministic communications.
- A sequence of 100 consecutive time slots per second is grouped into a super frame.
- Slot sizes and the super frame length are fixed.

Source: Salman, T. and Jain, R. (2017). A Survey of Protocols and Standards for Internet of Things.

Features of Wireless HART (contd.)

- The devices support multiple super frames with differing numbers of timeslots.
- At least one super frame is always enabled while additional super frames are enabled and disabled according to the demand of bandwidth.
- For any message, communication occurs in the alloted timeslot and frequency channel.
- Supports both star and mesh topologies.

Source: Salman, T. and Jain, R. (2017). A Survey of Protocols and Standards for Internet of Things.

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Thank You!!