PAN (Personal Area Networ)

- A personal area network (PAN) is a computer network for interconnecting electronic devices within an individual person's workspace.
- A PAN provides data transmission among devices such as computers, smartphones, tablets and personal digital assistants.
- A PAN may be wireless or carried over wired interfaces such as USB.
- A wireless personal area network (WPAN) is a PAN carried over a low-powered, short-distance wireless network technology such as
    - IrDA
    - Wireless USB
    - Bluetooth
    - Zigbee.
- The reach of a WPAN varies from a few centimeters to a few meters.
- IEEE 802.15 has produced standards for several types of PANs

IEEE 802.15

- IEEE (Institute of Electrical and Electronics Engineers)
- specifies wireless personal area network (WPAN) standards.
    - IEEE 802.15.1: WPAN / Bluetooth *
    - IEEE 802.15.2: Coexistence
    - IEEE 802.15.3: High Rate WPAN
    - IEEE 802.15.4: Low Rate WPAN *
    - IEEE 802.15.5: Mesh Networking
    - IEEE 802.15.6: Body Area Networks
    - IEEE 802.15.7: Visible Light Communication
    - IEEE P802.15.8: Peer Aware Communications
    - IEEE P802.15.9: Key Management Protocol
    - IEEE P802.15.10: Layer 2 Routing
    - IEEE 802.15.13: Multi-Gigabit/s Optical Wireless Communications

Zigbee

- Zigbee is an IEEE 802.15.4-based specification
- Designed for small scale projects which need wireless connection.
- Hence, Zigbee is a
    - low-power,
    - low data rate, and
    - close proximity (i.e., personal area) wireless ad hoc network.
- intended to be simpler and less expensive than other WPANs like Bluetooth, WiFi
- Key 802.15.4 features include:
    - real-time suitability by reservation of Guaranteed Time Slots (GTS).
    - collision avoidance through CSMA/CA.
    - integrated support for secure communications.
    - power management functions such as link speed/quality and energy detection.

   - Support for time and data rate sensitive applications because of its ability to operate either as CSMA/CA or TDMA access modes.

Architecture

- Zigbee system structure consists of three different types of devices as Zigbee Coordinator, Router, and End device
- Every Zigbee network must consist of at least one coordinator which acts as a root and bridge of the network
- The coordinator is responsible for handling and storing the information while performing receiving and transmitting data operations
- Zigbee routers act as intermediary devices that permit data to pass to and fro through them to other devices
- End devices have limited functionality to communicate with the parent nodes such that the battery power is saved
- The number of routers, coordinators, and end devices depends on the type of networks such as star, tree, and mesh networks

Protocol architecture

- only the lower layers are defined in the standard
- an IEEE 802.2 logical link control sublayer accessing the MAC through a convergence sublayer
- Implementations may rely on external devices or be purely embedded, self-functioning devices.

Physical layer

- bottom layer in the OSI, protocols layers transmit packets using it
- The physical layer (PHY) provides the data transmission service
- provides an interface to the physical layer management entity,
- which offers access to every physical layer management function and
- maintains a database of information on related personal area networks.
- the PHY manages the physical radio transceiver, performs channel selection along with energy and signal management functions.
- It operates on one of three possible unlicensed frequency bands:
  - 868.0–868.6 MHz: Europe, allows one communication channel
  - 902–928 MHz: North America, originally allowed up to ten channels
  - 2400–2483.5 MHz: worldwide use, up to sixteen channels

MAC layer

- The medium access control (MAC) enables the transmission of MAC frames through the use of the physical channel
- It offers a management interface and itself manages access to the physical channel and network
- Controls frame validation, guarantees time slots and handles node associations.

Network Layer:

- This layer takes care of all network-related operations such as network setup, end device connection, and disconnection to network, routing, device configurations, etc.

Application Support Sub-Layer:

- This layer enables the services necessary for Zigbee device objects and application objects to interface with the network layers for data managing services.
- This layer is responsible for matching two devices according to their services and needs.

Application Framework:

- It provides two types of data services as key-value pair and generic message services.
- The generic message is a developer-defined structure, whereas the key-value pair is used for getting attributes within the application objects.
- Zigbee Device Objects (ZDO) provides an interface between application objects and the Application Support Sublayer (APS) layer in Zigbee devices.
- It is responsible for detecting, initiating, and binding other devices to the network.

Bluetooth

- Bluetooth is a short-range wireless technology standard
- exchanging over short distances and building personal area networks (PANs).
- most widely used mode, transmission power is limited to 2.5 milliwatts
- very short range of up to 10 metres (33 ft).
- It operates on frequency in the ISM bands, from 2.402 GHz to 2.48 GHz.
- It is mainly used as an alternative to wire connections, to exchange files between nearby portable devices and connect cell phones and music players with wireless headphones.
- Bluetooth is managed by the Bluetooth Special Interest Group (SIG)
- The IEEE standardized Bluetooth as IEEE 802.15.1, but no longer maintains the standard.
- A manufacturer must meet Bluetooth SIG standards to market it as a Bluetooth device.
- The name "Bluetooth" was proposed in 1997 by Jim Kardach of Intel, one of the founders of the Bluetooth SIG.

Aim of Bluetooth

- Global usage
- Voice and data handling
- The ability to establish ad-hoc connections
- Very small size, in order to accommodate integration into variety of devices
- Negligible power consumption in comparison to other devices for similar use
- Competitively low cost of all units, as compared to their non-Bluetooth correspondents

Components of Bluetooth

- An RF portion for receiving and transmitting data
- A module with a baseband microprocessor
- Memory
- An interface to the host device (such as a mobile phone, Palm devices)

Bluetooth protocol stack

Bluetooth Radio

- The Bluetooth radio (layer) is the lowest defined layer of the Bluetooth specification.
- It defines the requirements of the Bluetooth transceiver device operating in the 2.4-GHz ISM band.

baseband and Link Control

- enables the physical RF link between Bluetooth units making a connection.
- The baseband handles channel processing and timing
- The link control handles the channel access control
- There are two different kinds of physical links
    - synchronous connection oriented (SCO)
        - an SCO link supports real-time audio traffic
    - asynchronous connectionless (ACL)
        - an ACL link carries data packets
- Audio is really not a layer of the protocol stack, but it is shown here because it is uniquely treated in Bluetooth communication.
- Audio data is typically routed directly to and from the baseband layer over an SCO link.

Link Manager Protocol

- The Link Manager Protocol (LMP) is responsible for link setup and link configuration between Bluetooth devices, managing and negotiating the baseband packet sizes.
- The LMP manages the security aspects, such as authentication and encryption, by generating, exchanging, and checking link and encryption keys.

HCI

- The HCI provides a command interface to the radio, baseband controller, and link manager.
- It is a single standard interface for accessing the Bluetooth baseband capabilities, the hardware status, and control registers.

L2CAP

- Logical Link Control and Adaptation Protocol (L2CAP) shields the upper-layer protocols from the details of the lower-layer protocols.
- It multiplexes between the various logical connections made by the upper layers.

RFCOMM

- Serial ports are one of the most common communications interfaces used in computing and communication devices.
- The RFCOMM protocol provides emulation of serial ports over L2CAP.
- RFCOMM provides transport capabilities for upper-level services that use a serial interface as a transport mechanism.
- RFCOMM provides multiple concurrent connections to one device and provides connections to multiple devices.

SDP (Service Discovery Protocol)

- SDP provides a means for applications to query services and characteristics of services.

- Unlike in an LAN connection, in which one connects to a network and then finds devices, in a Bluetooth environment one finds the devices before one finds the service.
- In addition, the set of services available changes in an environment when devices are in motion.
- Hence SDP is quite different from service discovery in traditional network-based environments.
- SDP is built on top of L2CAP.

Bluetooth Network Encapsulation Protocol (BNEP)

- Bluetooth-enabled devices will have the ability to form networks and exchange information. For these devices to interoperate and exchange information, a common packet format must be defined to encapsulate layer 3 network protocols.
- BNEP encapsulates packets from various networking protocols, and the packets are transported directly over L2CAP.
- BNEP is an optional protocol developed after Bluetooth specification version 1.1 but based on the 1.1 version of the specification.

Telephony Control Protocol Specification (TCS)

- defines the call control signaling for establishment of voice and data calls between Bluetooth devices.

- It is built on L2CAP.

- Adopted protocols such as OBEX (OBject EXchange) and the Internet Protocol (IP), are built on one of the protocols discussed earlier (e.g., OBEX is built on RFCOMM, and IP is built on BNEP).

Bluetooth Profiles

- To provide interoperability the end product developed by various vendors must follow a common standard defined in the profile
- The profile provides procedures and messages (termed as capabilities) that needs to be implemented to provide Bluetooth applications in a standardized ways

General Access Profile

- The main purpose of this profile is to provide its facilities to the lower layer profiles.
- Ensures that all other profiles are able to establish a baseband link
- Profile defines
  - Basic requirements for smooth functioning of devices
  - Generic procedures for device discovery
  - Link management
  - Procedures for security
  - Device parameters accessible to the user through user interface
- Operation Modes
  - Discoverability
  - Connectability
  - Pairability
  - Security

Serial Port Profile

- The Serial Port Profile defines the protocols and procedures that shall be used by devices using Bluetooth for RS232 (or similar) serial cable emulation
- This profile supports two types of devices
    - Type 1 devices emulating serial port to support serial port applications
    - Type 2 devices
- The Serial Port Profile uses RFCOMM for the purpose of serial port emulation
- The initiator is a device that sets the RFCOMM connection and the other device, which responds, is called responder
- Initially this profile has to acquire the Bluetooth address of the device at other end of the RFCOMM connection

Headset Profile

- This defines the facilities require to make and receive hands-free voice calls from headset to cellular phone
- It can also transfer voice calls to other devices.
- This profile defines two major roles:
    - Audio Gateway (AG)
    - Headset

General Object Exchange Profile

- Defines the protocols and procedures that shall be used by the applications providing the usage models
- The usage model can be, for example, Synchronization, File Transfer, or Object Push model
- Uses IrDA's OBEX objects to transfer the data between Bluetooth devices
- Two roles are define server device and client device
- Information is transferred using OBEX objects with the help of header that contains count, name, type
- Authentication process is mandatory

File Transfer Profile

- This profile transfers data between any numbers of Bluetooth devices
- It uses the capabilities provided by OBEX
- This profiles pulls or pushes the OBEX objects thus transferring the information
- The file transfer profile provides various operations required for this purpose
- This operations can be file copy, delete etc
- In addition to this, browsing capabilities using OBEX objects are provided
- Various OBEX operations are used to implement the file transfer profile

Bluetooth Versions

- Version 1.0
- Version 1.1
- Version 2.0: Enhance Data Rate

- Version 2.1: Secure Simple Pairing
- Version 3.0: High Speed with 802.11 WiFi Radio
- Version 4.0: Low Energy Protocol
- Version 4.1: Indirect IoT device connection
- Version 4.2: IPv6 protocol support
- Version 5.0: 4x range, 2x speed

Bluetooth Low Energy (Bluetooth LE / BLE / BTLE)

- a wireless personal area network technology designed by Bluetooth SIG
- The original specification was developed by Nokia in 2006 under the name Wibree
- which was integrated into Bluetooth 4.0 in December 2009 as Bluetooth Low Energy.
- intended to provide considerably reduced power consumption and cost while maintaining a similar communication range.
- Natively support Bluetooth Low Energy
  - Mobile OS - iOS, Android, Windows Phone and BlackBerry
  - Desktop OS - macOS, Linux, Windows 8, Windows 10 and Windows 11, .