UNIT- 8

Introduction to IEEE 802.15x Technologies

Wireless PAN is used to transfer information over short distances between private grouping of participant devices.

The goal of the standard is used to provide wireless connectivity with fixed, portable and moving devices either within or entering a particular operating space.

A POS is further defined as the space around an individual or object that typically extends ten meters in all directions and envelops the individual whether the person is stationary or in motion.

Basic WPAN characteristics

WLAN has been designed to support transportable types of computing like that provided by laptops/notebooks.

WPAN standard has been designed to support more mobile personal devices.

WPAN power levels and coverage areas

The use of wireless LAN enables the deployment of a LAN where the use of cables is either difficult or costly to install.

WPAN uses low power consumption to enable true mobility

Bluetooth WPAN overview

The Bluetooth wireless specification provides for communications over a relatively short range radio link that has been optimized for battery-operated, compact, personal devices.

The Bluetooth specification calls for the use of the 2.4 Ghz unlicensed ISM band.

A fast frequency hopping scheme is employed to prevent interference and signal fading.
Bluetooth WPAN ad hoc network topologies

**Piconet** – A piconet is formed by a Bluetooth device serving as a master and at least one or more Bluetooth devices acting as slaves. The piconet is defined by the frequency hopping scheme of the master. All devices that are taking part in a piconet are synchronized to the clock of the master of the piconet and hence the same frequency hopping sequence.
Scatternet – Scatternet is a collection of functioning piconets overlapping in both time and space, through the scatternet structure, a Bluetooth device may participate in several piconets at the same time.

Components of the Bluetooth architecture
The figure below shows Bluetooth specific protocols and non Bluetooth specific protocols. The LMP and L2CAP are Bluetooth specific where as the protocols within the other box are not.
IEEE 802.15.1 Bluetooth/WPAN

IEEE 802.15.1 Physical Layer Details
Channels, transmitter, and receiver specifications

- Transmitter classes
- Transmitter modulation
- Receiver specifications
  - See Table 10-2

<table>
<thead>
<tr>
<th>Power Class</th>
<th>Maximum output power ($P_{max}$)</th>
<th>Nominal output power</th>
<th>Minimum output power</th>
<th>Power control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100 mW (+20 dBm)</td>
<td>N/A</td>
<td>1 mW (0 dBm)</td>
<td>$P_{min} &lt; +4$ dBm to $P_{max}$ Optional: $P_{min}^2$ to $P_{max}$</td>
</tr>
<tr>
<td>2</td>
<td>2.5 mW (+4 dBm)</td>
<td>1 mW (0 dBm)</td>
<td>0.25 mW (-6 dBm)</td>
<td>Optional: $P_{min}^2$ to $P_{max}$</td>
</tr>
<tr>
<td>3</td>
<td>1 mW (0 dBm)</td>
<td>N/A</td>
<td>N/A</td>
<td>Optional: $P_{min}^2$ to $P_{max}$</td>
</tr>
</tbody>
</table>

1Minimum output power at maximum power setting
2The lower power limit $P_{min} < -30$ dBm is suggested but not mandatory

Bluetooth Link Controller Basics
Bluetooth system components
- 2.4 GHz Bluetooth transceiver
- Bluetooth link controller
- Bluetooth link manager
- Types of data transfers
  - Point-to-point
  - Point-to-multipoint
- See Figure 10-9

Bluetooth timeslot format
- Time division duplex scheme
- Bluetooth clock
- Single packet transmission
- Multislot packet transmission
- See Figure 10-10 and Figure 10-11
Bluetooth Link Controller Basics

**Types of physical links**

- Synchronous connection-oriented links
- **Asynchronous connectionless links**

**Packet formats**

- Access code types
- Packet header details
- See Figure 10-12 and Figure 10-13

**Packet formats**

- SCO packets
- High quality voice at 64 kbps
  - HV1, HV2, and HV3
- Data/voice packets
  - DV
- See Table 10-4

<table>
<thead>
<tr>
<th>Payload Type</th>
<th>Payload Header (bytes)</th>
<th>User Payload (bytes)</th>
<th>FEC</th>
<th>CRC</th>
<th>Symmetric Maximum Rate (kbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HV1</td>
<td>N/A</td>
<td>10</td>
<td>1/3</td>
<td>no</td>
<td>64.0</td>
</tr>
<tr>
<td>HV2</td>
<td>N/A</td>
<td>20</td>
<td>2/3</td>
<td>no</td>
<td>64.0</td>
</tr>
<tr>
<td>HV3</td>
<td>N/A</td>
<td>30</td>
<td>no</td>
<td>no</td>
<td>64.0</td>
</tr>
<tr>
<td>DV(^1)</td>
<td>1 D</td>
<td>10 + (0–9) D</td>
<td>2/3 D</td>
<td>yes D</td>
<td>64.0 + 57.6 D</td>
</tr>
</tbody>
</table>

\(^1\)Items followed by “D” relate to data field only

ACL packets
- Packet data may be either user data or control data.
- DMI, DM3, and DM5
- DH1, DH3, and DH5
- AUX1
  - See Table 10-3

<table>
<thead>
<tr>
<th>Payload Type</th>
<th>Payload Header (bytes)</th>
<th>User Payload (bytes)</th>
<th>FEC</th>
<th>CRC</th>
<th>Symmetric Maximum Rate (kbps)</th>
<th>Asymmetric Maximum Rate (kbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM1</td>
<td>1</td>
<td>0–17</td>
<td>2/3</td>
<td>yes</td>
<td>108.8</td>
<td>108.8 108.8</td>
</tr>
<tr>
<td>DH1</td>
<td>1</td>
<td>0–27</td>
<td>no</td>
<td>yes</td>
<td>172.8</td>
<td>172.8 172.8</td>
</tr>
<tr>
<td>DM3</td>
<td>2</td>
<td>0–121</td>
<td>2/3</td>
<td>yes</td>
<td>258.1</td>
<td>387.2 54.4</td>
</tr>
<tr>
<td>DH3</td>
<td>2</td>
<td>0–138</td>
<td>no</td>
<td>yes</td>
<td>390.4</td>
<td>585.6 86.4</td>
</tr>
<tr>
<td>DM5</td>
<td>2</td>
<td>0–224</td>
<td>2/3</td>
<td>yes</td>
<td>286.7</td>
<td>477.8 36.3</td>
</tr>
<tr>
<td>DH5</td>
<td>2</td>
<td>0–339</td>
<td>no</td>
<td>yes</td>
<td>433.9</td>
<td>723.2 57.6</td>
</tr>
<tr>
<td>AUX1</td>
<td>1</td>
<td>0–29</td>
<td>no</td>
<td>yes</td>
<td>185.6</td>
<td>185.6 185.6</td>
</tr>
</tbody>
</table>

Transmitter/receiver timing
- Synchronization with the master clock
- Bluetooth device states
  - Connection state
  - Hold state
  - Park and sniff modes
• Clock resynchronization
• See Figure 10-14

Bluetooth channel control
• Master device’s roll in the piconet
• The Bluetooth clock
• Basic clock cycles
• Clock offset during synchronization
• See Figure 10-15

• Bluetooth Link Controller Operational States
  – Possible operational states
  – Sequencing of operations
  – Major states
    – Standby
    – Connection

Substates
• Page, page scan, inquiry, inquiry scan, inquiry response, slave response, and master response
Bluetooth access procedures

- Inquiry procedure and paging procedure
- Page and inquiry substates
- Master, slave, and inquiry response substates
- Channel hopping sequences
- See Figure 10-17
Connection state
- Control messages are exchanged between the Bluetooth link managers.
- Active, sniff, and hold mode
- Park mode

Scatternet operation
- Hopping sequence selection
  - 10 types of hopping sequences
  - Sequence selected by
    - Device clock and address
  - See Figure 10-18

Bluetooth addresses and encryption
- Lower address part
- Upper address part
• Nonsignificant address part
• See Figure 10-20

IEEE 802.15.1 Protocols and Host Controller Interface
  – Link manager protocol operations
    • Transactions
      – Link setup, security, and control
      – Logical link control and adaptation protocol
    – See Figure 10-23
Answers to Problems and Questions

Chapter 10

Section 10.1

1. A wireless personal area network is one designed to transfer wireless data over short distances (in the order of meters).

2. A personal operating space in the context of a wireless PAN is defined to be the space around an individual or object that typically extends 10 meters in all directions and also envelops the individual.

3. The basic differences between a wireless LAN and a wireless PAN are: the power levels (100 mW versus 1 mW), the coverage area (100 m versus 10 m), the media control techniques (AP versus master/slave), and the network lifespan (continuous versus transient).

4. The Bluetooth standard was developed by the Bluetooth Special Interest Group (SIG). It was initially developed to reduce the need for proprietary interconnecting cables between different digital devices.

Section 10.2

5. A basic application of a wireless PAN is to transfer data between portable digital devices without the need for interconnecting cables.

6. The transmitting power for a WPAN is approximately 1 mW, while the output power for a WLAN is typically 100 mW. The typical range for a wireless LAN is in the 100s of meters versus a maximum of approximately 10 meters for a wireless PAN.

7. The basic function of the master device for a WPAN is to control the ad hoc wireless network that has been formed. The slave devices of an ad hoc wireless PAN are controlled by the master device.
8. The lifespans of wireless LANs and wireless PANs are very different. Once an AP has been added to a wired LAN, the wireless LAN portion of the network stays in existence until the AP is deactivated.

9. A wireless PAN piconet is a configuration of IEEE 802.15 devices. A piconet is formed by a Bluetooth device serving as a master and at least one or more (up to seven maximum) Bluetooth devices acting as slaves.

10. A wireless PAN scatternet is a collection of functioning piconets overlapping in both time and space.

11. Full duplex operation is supported by the Bluetooth standard by using time division multiplexing (also known as duplex operation).

Section 10.3

12. A wireless PAN Class 3 device is one that has a nominal maximum output power of 1 mW or 0 dBm.

13. The present maximum power output of a wireless PAN device is 100 mW or +20 dBm.

14. Wireless PAN power control is required for Class 1 devices. If a device can provide an output power of 100 mW, it must be able to control its output power down to +4 dBm or less. Power control is achieved through the use of link management protocol commands.

Section 10.4

15. The Bluetooth system supports both circuit-switched and packet-switched data by supporting both synchronous and asynchronous data links through a time-slotted transmission format.

16. The Bluetooth synchronous connection-oriented (SCO) link is a symmetric, point-to-point link between the piconet master and a single specific slave.
17. The Bluetooth asynchronous connectionless (ACL) link appears as a packet-switched connection between the master and all the active piconet slaves. Data may be exchanged by the master with any slave on a slot-by-slot basis.

18. The information encoded by the “TYPE” field of a packet header is the 16 (4 bits) possible packet types that can be supported by the Bluetooth standard.

19. The maximum symmetric data rate allowed by the Bluetooth standard is 64 kbps.

20. The maximum and minimum asymmetric data rates allowed in the forward direction by the Bluetooth standard are 723.2 kbps and 108.8 kbps, respectively.

21. Timing synchronization for a Bluetooth system is achieved by the piconet slaves adjusting their clocks to be time synchronized with the master device’s clock.

Section 10.5

22. The basic steps needed to set-up a piconet are as follows: the Bluetooth devices are able to be in two possible major states: Standby and Connection. The Bluetooth devices are able to move between sub-states under the control of the Bluetooth link controller and the Bluetooth link manager. The sub-states are: page, page scan, inquiry, inquiry scan, inquiry response, slave response, and master response.

23. A wireless PAN device must be in the “Connection” state before any packets may be exchanged.

24. The function/purpose of the Bluetooth “sniff” mode is to save battery power. In this mode, the slave only listens to timeslots on a reduced periodic basis.

25. For a wireless PAN device, the “hold” mode is a type of operation into which a slave device may enter. In this mode, the slave may perform other operations and actually participate in
another piconet. While in the hold mode, a slave may go into a sleep mode to save battery power. The master and slave agree upon the length of the hold state.

26. For a wireless PAN device, the “park” mode is a type of operation into which the slave device may enter. In this mode, the slave device goes into a low power mode. The slave gives up its active piconet address but receives two other addresses that can be used to bring it out of the hold mode (one address is used by the master to bring the slave out of the park mode and the other address is used by the slave for the same purpose).

27. A Bluetooth device is uniquely identified by its unique 48-bit Bluetooth device address.

**Section 10.6**

28. The function/purpose of the link manager protocol (LMP) is to set-up a communications link and perform security and control functions.

29. The function/purpose of the host control interface is to provide a command level interface to the Bluetooth baseband controller and link manager.