0. Overview

In this lecture we will cover the following topics:

10. Wired Ethernet-based LANs
   10.1 IEEE Standards
   10.2 Traditional (Standard) Ethernet
   10.3 Changes in the Standard
   10.4 Fast Ethernet
   10.5 Gigabit Ethernet
   10.6 Summary (part 10)

11. Wireless LANs
   11.1 IEEE 802.11
   11.2 Bluetooth
   11.3 Summary (part 11)
10.1 IEEE STANDARDS

In 1985, the Computer Society of the IEEE started a project, called Project 802, to set standards to enable intercommunication among equipment from a variety of manufacturers. Project 802 is a way of specifying functions of the physical layer and the data link layer of major LAN protocols.

Topics discussed in this section:
Data Link Layer
Physical Layer

IEEE standard for LANs
10.2 TRADITIONAL (STANDARD) ETHERNET

The original Ethernet was created in 1976 at Xerox’s Palo Alto Research Center (PARC). Since then, it has gone through four generations. We briefly discuss the Standard (or traditional) Ethernet in this section.

Topics discussed in this section:
MAC Sublayer
Physical Layer

Ethernet evolution through four generations

- Standard Ethernet (10 Mbps)
- Fast Ethernet (100 Mbps)
- Gigabit Ethernet (1 Gbps)
- Ten-Gigabit Ethernet (10 Gbps)
802.3 MAC frame

- Data link layer is divided into logical link control (LLC) sublayer and medium access control (MAC) sublayer.
- MAC Sublayer
  - Access Method: CSMA/CD
  - Frame contains destination and source physical address.
- No Acknowledging procedure and thus known as unreliable.
- Preamble: Alternating 0s and 1s; used for synchronizing; 7 bytes (56 bits).
- Start Frame Delimiter (SFD): 10101011 indicates the start of the frame. Last two bits alerts that the next field is destination address.
- Length/Type: if less than 1518, it indicates the length of data field. If greater than 1536, it indicates the type of PDU.
- Data: 46 to 1500 bytes; CRC: CRC-32

Minimum and maximum lengths

- Minimum length restriction because:
  - Collision must be before a physical layer sends a frame out of the station.
  - If the entire frame is sent out before a collision is detected, it is too late. The MAC layer has already discarded the frame, thinking that the frame has reached the destination.
- Maximum length restriction is historical.
Frame length:
Minimum: 64 bytes (512 bits)
Maximum: 1518 bytes (12,144 bits)

Example of an Ethernet address in hexadecimal notation

- Each station has a network interface card (NIC)
- Physical address: 6-byte [48 bits]
- It is written in hexadecimal notation using a hyphen to separate bytes from each other.

06:01:02:01:2C:4B

- Source address is always a unicast address – frame from only on station.
- Destination address can be unicast [one to one] or multicast [a group of people] or broadcast [all members of the network].
The least significant bit of the first byte defines the type of address. If the bit is 0, the address is unicast; otherwise, it is multicast.

The broadcast destination address is a special case of the multicast address in which all bits are 1s.

Example

Define the type of the following destination addresses:

a. 4A:30:10:21:10:1A  
b. 47:20:1B:2E:08:EE  
c. FF:FF:FF:FF:FF:FF

Solution

To find the type of the address, we need to look at the second hexadecimal digit from the left. If it is even, the address is unicast. If it is odd, the address is multicast. If all digits are F’s, the address is broadcast. Therefore, we have the following:

a. This is a unicast address because A in binary is 1010.

b. This is a multicast address because 7 in binary is 0111.

c. This is a broadcast address because all digits are F’s.
Example

Show how the address 47:20:1B:2E:08:EE is sent out on line.

Solution
The address is sent left-to-right, byte by byte; for each byte, it is sent right-to-left, bit by bit, as shown below:

```
11100010 00000100 11011000 01101000 00010000 01110111
```

Categories of Standard or Traditional Ethernet

```
Standard Ethernet
common implementations

10Base5 10Base2 10Base-T 10Base-F
Bus, thick coaxial Bus, thin coaxial Star, UTP Star, fiber
```
Encoding in a Standard Ethernet implementation

10 Mbps data

Manchester encoder

Station

Twisted pairs or fibers

Manchester decoder

10 Mbps data

10Base5 implementation

- Transceiver (Medium attachment Unit): Medium-independent. It creates the appropriate signal for each particular medium. There is a MAU for each type of medium used in 10-Mbps Ethernet.
- Transceiver is a transmitter and receiver. It transmits signals over the medium; it receives signals over the medium; it also detects collisions.
- 10Base5 is called as Thick Ethernet or Thicknet; Uses coaxial cable.
- Uses Bus topology.
- Transceiver cable is called as Attachment unit interface (AUI) cable.
10Base2 implementation

- Thin Ethernet or Cheapernet.
- Uses Bus topology with an internal transceiver or a point-to-point connection via an external transceiver.
- Internal transceiver does not need AUI cable.

10Base-T implementation

- Twisted-pair Ethernet.
- Physical star topology
- Stations are connected to a hub with an internal transceiver or an external transceiver.
10Base-F implementation

- Fiber Link Ethernet.
- Uses star topology to connect stations to a hub
- Normally an external transceiver called fiber-optic MAU is used.
- Transceiver is connected to the hub by using two pairs of fiber-optic cables.

Summary of Standard Ethernet implementations

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>10Base5</th>
<th>10Base2</th>
<th>10Base-T</th>
<th>10Base-F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media</td>
<td>Thick coaxial</td>
<td>Thin coaxial</td>
<td>2 UTP</td>
<td>2 Fiber</td>
</tr>
<tr>
<td></td>
<td>cable</td>
<td>cable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum length</td>
<td>500 m</td>
<td>185 m</td>
<td>100 m</td>
<td>2000 m</td>
</tr>
<tr>
<td>Line encoding</td>
<td>Manchester</td>
<td>Manchester</td>
<td>Manchester</td>
<td>Manchester</td>
</tr>
</tbody>
</table>
10.3 CHANGES IN THE STANDARD

The 10-Mbps Standard Ethernet has gone through several changes before moving to the higher data rates. These changes actually opened the road to the evolution of the Ethernet to become compatible with other high-data-rate LANs.

**Topics discussed in this section:**
- Bridged Ethernet
- Switched Ethernet
- Full-Duplex Ethernet

Sharing bandwidth

- Without bridges, all the stations share the bandwidth of the network.
- Bridges divide the network into two. Bandwidth-wise, each network is independent.
A network with and without a bridge

- With bridges, 10 Mbps network is shared only by 6 [actually 7 as bridge acts as one station] stations.

Collision domains in an unbridged network and a bridged network

- Using bridges, collision domain becomes much smaller and the probability of collision is reduced tremendously.
Switched Ethernet

- A layer 2 switch is an N-port bridge with additional sophistication that allows faster handling of the packets.

![Diagram of switched Ethernet]

Full-duplex switched Ethernet

- As there are two links, one each for sending and receiving, we don't need CSMA/CD here.
- No flow or error control here.
- Flow and error control is provided by a new sublayer, called the MAC control, which is added between the LLC and MAC sublayer.

![Diagram of full-duplex switched Ethernet]
10.4 FAST ETHERNET

Fast Ethernet was designed to compete with LAN protocols such as FDDI or Fiber Channel. IEEE created Fast Ethernet under the name 802.3u. Fast Ethernet is backward-compatible with Standard Ethernet, but it can transmit data 10 times faster at a rate of 100 Mbps.

Topics discussed in this section:
MAC Sublayer
Physical Layer

Fast Ethernet topology

a. Point-to-point
b. Star
## Fast Ethernet Implementations

- Two wire or four wire.
  - Two wire: 100Base-X: With twisted pair (100Base-TX) or Fiber optic (100Base-FX)
  - Four wire: Twisted pair (100BaseT4)

### Summary of Fast Ethernet implementations

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>100Base-TX</th>
<th>100Base-FX</th>
<th>100Base-T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media</td>
<td>Cat 5 UTP or STP</td>
<td>Fiber</td>
<td>Cat 4 UTP</td>
</tr>
<tr>
<td>Number of wires</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Maximum length</td>
<td>100 m</td>
<td>100 m</td>
<td>100 m</td>
</tr>
<tr>
<td>Block encoding</td>
<td>4B/5B</td>
<td>4B/5B</td>
<td></td>
</tr>
<tr>
<td>Line encoding</td>
<td>MLT-3</td>
<td>NRZ-I</td>
<td>8B/6T</td>
</tr>
</tbody>
</table>
10.5 GIGABIT ETHERNET

The need for an even higher data rate resulted in the design of the Gigabit Ethernet protocol (1000 Mbps). The IEEE committee calls the standard 802.3z.

Topics discussed in this section:
- MAC Sublayer
- Physical Layer
- Ten-Gigabit Ethernet

Note
In the full-duplex mode of Gigabit Ethernet, there is no collision; the maximum length of the cable is determined by the signal attenuation in the cable.
Gigabit Ethernet implementations

- **Access**: Half-duplex using CSMA/CD or Full-duplex with no need for CSMA/CD
- **1000Base-X**: Two wire implementation
  - Short wave optical fiber (1000Base-SX)
  - Long wave optical fiber (1000Base-LX)
  - Short copper jumpers (1000Base-CX) using STP.
- **1000Base-T**: Four-wire version using twisted-pair cable [UTP].
### Summary of Gigabit Ethernet implementations

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>1000Base-SX</th>
<th>1000Base-LX</th>
<th>1000Base-CX</th>
<th>1000Base-T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media</td>
<td>Fiber short-wave</td>
<td>Fiber long-wave</td>
<td>STP</td>
<td>Cat 5 UTP</td>
</tr>
<tr>
<td>Number of wires</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Maximum length</td>
<td>550 m</td>
<td>5000 m</td>
<td>25 m</td>
<td>100 m</td>
</tr>
<tr>
<td>Block encoding</td>
<td>8B/10B</td>
<td>8B/10B</td>
<td>8B/10B</td>
<td></td>
</tr>
<tr>
<td>Line encoding</td>
<td>NRZ</td>
<td>NRZ</td>
<td>NRZ</td>
<td>4D-PAM5</td>
</tr>
</tbody>
</table>

### Summary of Ten-Gigabit Ethernet implementations

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>10GBase-S</th>
<th>10GBase-L</th>
<th>10GBase-E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media</td>
<td>Short-wave 850-nm multimode</td>
<td>Long-wave 1310-nm single mode</td>
<td>Extended 1550-nm single mode</td>
</tr>
<tr>
<td>Maximum length</td>
<td>300 m</td>
<td>10 km</td>
<td>40 km</td>
</tr>
</tbody>
</table>
10.6 SUMMARY (part 10)

- Ethernet is the most widely used local area network protocol.
- The IEEE 802.3 standard defines 1-persistent CSMA/CD as the access method for first-generation 10-Mbps Ethernet.
- The data link layer of Ethernet consists of the LLC sublayer and the MAC sublayer.
- The MAC sublayer is responsible for the operation of the CSMA/CD access method.
- Each station on an Ethernet network has a unique 48-bit address imprinted on its network interface card (NIC).
- The minimum frame length for 10-Mbps Ethernet is 64 bytes; the maximum is 1518 bytes.
- The physical layer of 10-Mbps Ethernet can be composed of four sublayers: the physical layer signaling (PLS) sublayer, the attachment unit interface (AUI) sublayer, the medium attachment unit (MAU) sublayer, and the medium-dependent interface (MDI) sublayer.
- The common baseband implementations of 10-Mbps Ethernet are 10Base5 (thick Ethernet), 10Base2 (thin Ethernet), 10Base-T (twisted-pair Ethernet), and 10Base-FL (fiber link Ethernet).
- The 10Base5 implementation of Ethernet uses thick coaxial cable. The 10Base2 implementation of Ethernet uses thin coaxial cable. The 10Base-T implementation of Ethernet uses twisted-pair cable that connects each station to a port in a hub. The 10Base-FL implementation of Ethernet uses fiber-optic cable.
- A bridge can raise the bandwidth and separate the collision domains on an Ethernet LAN.
- A switch allows each station on an Ethernet LAN to have the entire capacity of the network to itself.

10.6 SUMMARY continued (part 10)

- Full-duplex mode doubles the capacity of each domain and deletes the need for the CSMA/CD method.
- Fast Ethernet has a data rate of 100 Mbps.
- In Fast Ethernet, autonegotiation allows two devices to negotiate the mode or data rate of operation.
- The Fast Ethernet reconciliation sublayer is responsible for the passing of data in 4-bit format to the MII.
- The Fast Ethernet MII is an interface that can be used with both a 10- and a 100-Mbps interface.
- The Fast Ethernet PHY sublayer is responsible for encoding and decoding.
- The common Fast Ethernet implementations are 100Base-TX (two pairs of twisted-pair cable), 100Base-FX (two fiber-optic cables), and 100Base-T4 (four pairs of voice-grade, or higher, twisted-pair cable).
- Gigabit Ethernet has a data rate of 1000 Mbps.
- Gigabit Ethernet access methods include half-duplex using traditional CSMA/CD (not common) and full-duplex (most popular method).
- The Gigabit Ethernet reconciliation sublayer is responsible for sending 8-bit parallel data to the PHY sublayer via a GMII interface.
- The Gigabit Ethernet GMII defines how the reconciliation sublayer is to be connected to the PHY sublayer.
- The Gigabit Ethernet PHY sublayer is responsible for encoding and decoding.
- The common Gigabit Ethernet implementations are 1000Base-SX (two optical fibers and a shortwave laser source), 100Base-LX (two optical fibers and a long-wave laser source), and 100Base-T (four twisted pairs).
IEEE has defined the specifications for a wireless LAN, called IEEE 802.11, which covers the physical and data link layers.

Topics discussed in this section:
- Architecture
- MAC Sublayer
- Physical Layer

Basic service sets (BSSs)
- IEEE Specification for Wireless LAN: IEEE 802.11, which covers the physical and data link layers.
- Basic Service Set (BSS) is made of stationary or mobile wireless stations and a possible central base station, known as the access point (AP).
- BSS without AP is a stand-alone network and cannot send data to other BSSs. It is what is called as adhoc architecture.
A BSS without an AP is called an ad hoc network; a BSS with an AP is called an infrastructure network.

Extended service sets (ESSs)

- Extended Service Set (ESS) is made up of two or more BSSs with APs.
- BSSs are connected through a Distributed System, which is usually a wired LAN.
- Nodes can be mobile or stationary.
- A mobile can belong to more than one BSS at the same time.
- Communication among stations in different BSS is via APs.
- Communication among stations within a single BSS might be direct.
**MAC layers in IEEE 802.11 standard**

- Wireless LAN cannot implement CSMA/CD for three reasons
  - Station must be able to send and receive data at the same time.
  - Collision may not be detected because of the hidden terminal problem.
  - Distance between stations in wireless LANs can be great. Signal fading could prevent a station at one end from hearing a collision at other end.
- Before sending a frame, source senses the medium by checking the energy level at the carrier frequency.
  - Backoff until the channel is idle.
  - After the channel is found idle, the station waits for a period of time called the Distributed interframe space (DIFS); then the station sends a control frame called request to send (RTS).
- After receiving RTS, the destination waits for a period called Short interframe space (SIFS), the destination station sends a control frame, called Clear to Send (CTS) to source. This control frame indicates that the destination station is ready to receive data.
- Source sends data after waiting for SITS
- Destination sends ACK after waiting for SITS.
CSMA/CA and NAV

- RTS frame indicates the duration of time that the source needs to occupy the channel.
- Stations that are affected by this transmission create a timer called a **Network Allocation Vector** (NAV) that shows how much time must pass before these stations are allowed to check the channel for idleness.
- Each time a station accesses the system and sends an RTS frame, other stations start their NAV. In other words, each station, before sensing the physical medium to see if it is idle, first checks its NAV to see if it has expired.
Addresses

<table>
<thead>
<tr>
<th>To DS</th>
<th>From DS</th>
<th>Address 1</th>
<th>Address 2</th>
<th>Address 3</th>
<th>Address 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>Destination</td>
<td>Source</td>
<td>BSS ID</td>
<td>N/A</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>Destination</td>
<td>Sending AP</td>
<td>Source</td>
<td>N/A</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>Receiving AP</td>
<td>Source</td>
<td>Destination</td>
<td>N/A</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Receiving AP</td>
<td>Sending AP</td>
<td>Destination</td>
<td>Source</td>
</tr>
</tbody>
</table>

Addressing mechanisms

- **Direct transfer:**
  - To DS = From DS = 0.
  - Both stations are within a BSS.

- **Data is coming from an AP (Distribution System):**
  - To DS = 0 and From DS = 1.
  - ACK should be sent to the AP.

- **Data is going to an AP (Distribution System):**
  - To DS = 1 and From DS = 0.
  - ACK should be sent to the original station.

- **Distribution System is wireless:**
  - Frame is going from one AP to another.
  - Four addresses to indicate original sender, final destination and two intermediate APs.
  - No address needed if the distribution system is wired LAN.
Physical layers

<table>
<thead>
<tr>
<th>IEEE</th>
<th>Technique</th>
<th>Band</th>
<th>Modulation</th>
<th>Rate (Mbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11</td>
<td>FHSS</td>
<td>2.4 GHz</td>
<td>FSK</td>
<td>1 and 2</td>
</tr>
<tr>
<td></td>
<td>DSSS</td>
<td>2.4 GHz</td>
<td>PSK</td>
<td>1 and 2</td>
</tr>
<tr>
<td></td>
<td>Infrared</td>
<td></td>
<td>PPM</td>
<td>1 and 2</td>
</tr>
<tr>
<td>802.11a</td>
<td>OFDM</td>
<td>5.725 GHz</td>
<td>PSK or QAM</td>
<td>6 to 54</td>
</tr>
<tr>
<td>802.11b</td>
<td>DSSS</td>
<td>2.4 GHz</td>
<td>PSK</td>
<td>5.5 and 11</td>
</tr>
<tr>
<td>802.11g</td>
<td>OFDM</td>
<td>2.4 GHz</td>
<td>Different</td>
<td>22 and 54</td>
</tr>
</tbody>
</table>

Industrial-Scientific-Medical (ISM) band

- The 2.4GHz ISM band is divided into 79 bands of 1MHz
Physical layer of IEEE 802.11 FHSS

- In Frequency Hopping Spread Spectrum (FHSS) the sender sends on one carrier frequency for a short amount of time, then hops to another carrier frequency for the same amount of time, and so on. After N hop-pings, the cycle is repeated.

- Spreading makes it difficult for unauthorized persons to make sense of the transmitted data.

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Physical layer of IEEE 802.11 DSSS

- In Direct Sequence Spread Spectrum (DSSS) each bit sent by the sender is replaced by a sequence of bits called a chip code.

- To avoid buffering, the time needed to send one chip code must be the same as the time needed to send one original bit.

- DSSS is implemented at the physical layer and uses a 2.4GHz ISM band.
Physical layer of IEEE 802.11a OFDM

• IEEE 802.11a describes the orthogonal frequency-division multiplexing (OFDM) method for signal generation in the 5GHz ISM band.

• OFDM is the same as FDM with one major difference:
  • All the subbands are used by one source at a given time
  • Sources contend with one another at the data link layer for access

• OFDM uses PSK (18Mbps) and QAM (54Mbps) for modulation

Physical layer of IEEE 802.11b

• IEEE 802.11b describes the high-rate DSSS method for signal generation at 2.4GHz ISM band.

• This is similar to DSSS except for the encoding method, which is called **complementary code keying** (CCK)

• CCK encodes 4 or 8 bits to one CCK symbol
11.2 BLUETOOTH

Bluetooth is a wireless LAN technology designed to connect devices of different functions such as telephones, notebooks, computers, cameras, printers, coffee makers, and so on. A Bluetooth LAN is an ad hoc network, which means that the network is formed spontaneously.

Topics discussed in this section:
Architecture
Bluetooth Layers
Baseband Layer
L2CAP

Piconet

- A Bluetooth network is called a piconet, or a small net.
- It can have up to eight stations, one of which is called the master; the rest are called slaves.
- Maximum of seven slaves. Only one master.
- Slaves synchronize their clocks and hopping sequence with the master.
- But an additional eight slaves can stay in parked state, which means they can be synchronized with the master but cannot take part in communication until it is moved from the parked state.
**Scatternet**

- Piconets can be combined to form what is called a scatternet.
- A slave station in one piconet can become the master in another piconet.
- Bluetooth devices has a built-in short-range radio transmitter.

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**Bluetooth layers**

- Radio Layer: Roughly equivalent to physical layer of the Internet model. Physical links can be synchronous or asynchronous.
  - Uses Frequency-hopping spread spectrum [Changing frequency of usage]. Changes it modulation frequency 1600 times per second.
  - Uses FSK with Gaussian bandwidth filtering to transform bits to a signal.
- Baseband layer: Roughly equivalent to MAC sublayer in LANs. Access is using Time Division (Time slots).
  - Length of time slot = dwell time = 625 microsec. So, during one frequency, a sender sends a frame to a slave, or a slave sends a frame to the master.
- Time division duplexing TDMA (TDD-TDMA) is a kind of half-duplex communication in which the slave and receiver send and receive data, but not at the same time (half-duplex). However, the communication for each direction uses different hops, like walkie-talkies.
Single-secondary communication

- Also called Single-slave communication
  - Master uses even-numbered slots
  - Slave uses odd-numbered slots

Multiple-secondary communication

- Also called Multiple-slave communication
  - Master uses even-numbered slots
  - Slave sends in the next odd-numbered slot if the packet in the previous slot was addressed to it.
Physical Links

- **Synchronous connection-oriented (SCO)**
  - Latency is important than integrity.
  - Transmission using slots.
  - No retransmission.

- **Asynchronous connectionless link (ACL)**
  - Integrity is important than latency.
  - Does like multiple-slave communication.
  - Retransmission is done.

- **L2CAP (Logical Link Control and Adaptation Protocol)**
  - Equivalent to LLC sublayer in LANs.
  - Used for data exchange on ACL Link. SCO channels do not use L2CAP.
  - Frame format has 16-bit length [Size of data coming from upper layer in bytes], channel ID, data and control.
  - Can do Multiplexing, segmentation and Reassembly, QoS [with no QoS, best-effort delivery is provided] and Group management [Can do like multicast group, using some kind of logical addresses].

11.3 SUMMARY (part 11)

- The IEEE 802.11 standard for wireless LANs defines two services: basic service set (BSS) and extended service set (ESS). An ESS consists of two or more BSSs; each BSS must have an access point (AP).
- The physical layer methods used by wireless LANs include frequency-hopping spread spectrum (FHSS), direct sequence spread spectrum (DSSS), orthogonal frequency-division multiplexing (OFDM), and high-rate direct sequence spread spectrum (HR-DSSS).
- FHSS is a signal generation method in which repeated sequences of carrier frequencies are used for protection against hackers.
- One bit is replaced by a chip code in DSSS.
- OFDM specifies that one source must use all the channels of the bandwidth.
- HR-DSSS is DSSS with an encoding method called complementary code keying (CCK).
- The wireless LAN access method is CSMA/CA.
- The network allocation vector (NAV) is a timer for collision avoidance.
- The MAC layer frame has nine fields. The addressing mechanism can include up to four addresses.
- Wireless LANs use management frames, control frames, and data frames.
- Bluetooth is a wireless LAN technology that connects devices (called gadgets) in a small area.
- A Bluetooth network is called a piconet. Multiple piconets form a network called a scatternet.
- The Bluetooth radio layer performs functions similar to those in the Internet model’s physical layer.
- The Bluetooth baseband layer performs functions similar to those in the Internet model’s MAC sublayer.
- A Bluetooth network consists of one master device and up to seven slave devices.
- A Bluetooth frame consists of data as well as hopping and control mechanisms. A frame is one, three, or five slots in length with each slot equal to 625 µs.
References


