Module 5

Embedded Communications

Lesson
27
Wireless Communication

Instructional Objectives

After going through this lesson the student would be able to

- Describe the benefits and issues in wireless communication
- Distinguish between WLAN, WPAN and their different implementations like Ricochet, HiperLAN, HomeRF and Bluetooth
- Choose a particular wireless communication standard to suit an application

Wireless Communication

Third generation wireless technologies are being developed to enable personal, high-speed interactive connectivity to wide area networks (WANs). The ***IEEE 802.11x*** wireless technologies finds themselves with an increasing presence in corporate and academic office spaces, buildings, and campuses. Furthermore, with slow but steady inroads into public areas such as airports and coffee bars. WAN, LAN and PAN technologies enable device connectivity to infrastructure-based services - either through campus or corporate backbone intranet.

The other end of coverage spectrum is occupied by the short-range ***embedded wireless connectivity technologies*** that allow devices to communicate with each other directly without the need for an established infrastructure. At this end of the coverage spectrum the wireless technologies like Ricochet, Bluetooth etc. offer the benefits of ***omni-directionality*** and the elimination of the ***line-of-sight*** requirement of RF-based connectivity. The embedded connectivity space resembles a communication bubble that follows people around and empowers them to connect their personal devices with other devices that enter the bubble. Connectivity in this bubble is spontaneous and ephemeral and can involve several devices of diverse computing capabilities, ***unlike*** wireless LAN solutions that are designed for communication between devices of sufficient computing power and battery.

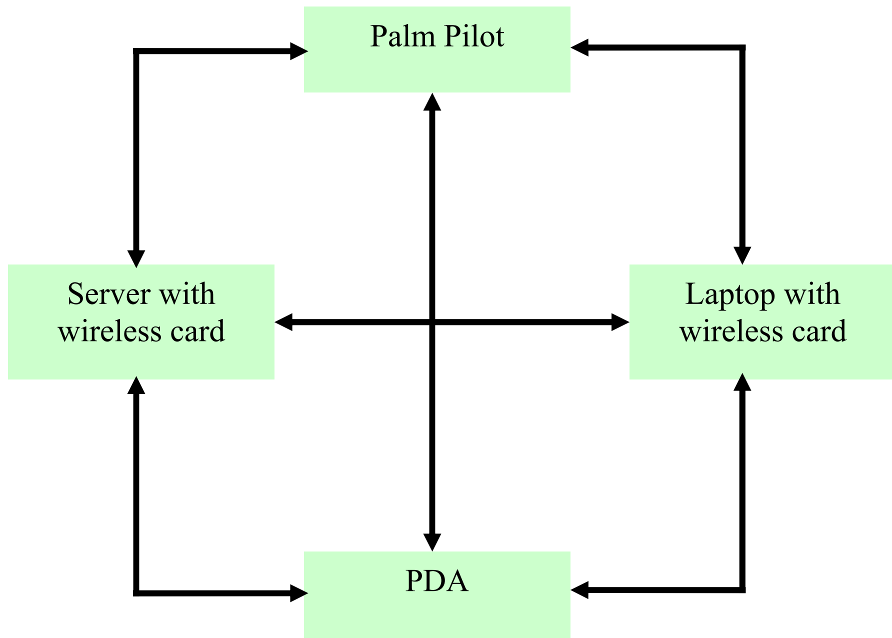
The table below shows a short comparison of various technologies in the wireless arena.

Properties	*INFRARED*	*WI-FI(IEEE 802.11x)*	*BLUETOOTH*
Range	5 m >	100m <	10 m >
Transmission Rate	4Mb/s	11Mbits/s	1Mbits/s
Connection Limit	One	Multiple	Omni
Miscellaneous	Blocked by wall	Can penetrate walls	Can penetrate walls
Direction	Line of Site	Omni	Multiple
Hop Frequency	-	Low-2.5Hops/s	High-1600Hops/s *Can't support large Data Blocks.....!*
RF Output Power	-	100mW-1 W	1mW-100mW
Application Area	Ad-hoc networks	Local Area Networks	Ad-hoc Networks

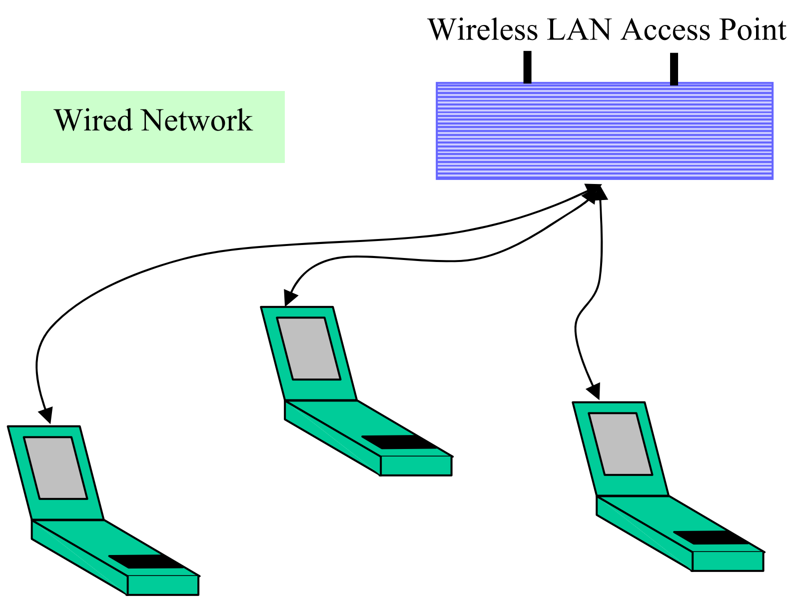
In this lesson we look at the most commonly adopted prospects of different wireless technologies mentioned above.

WLANs-IEEE 802.11X

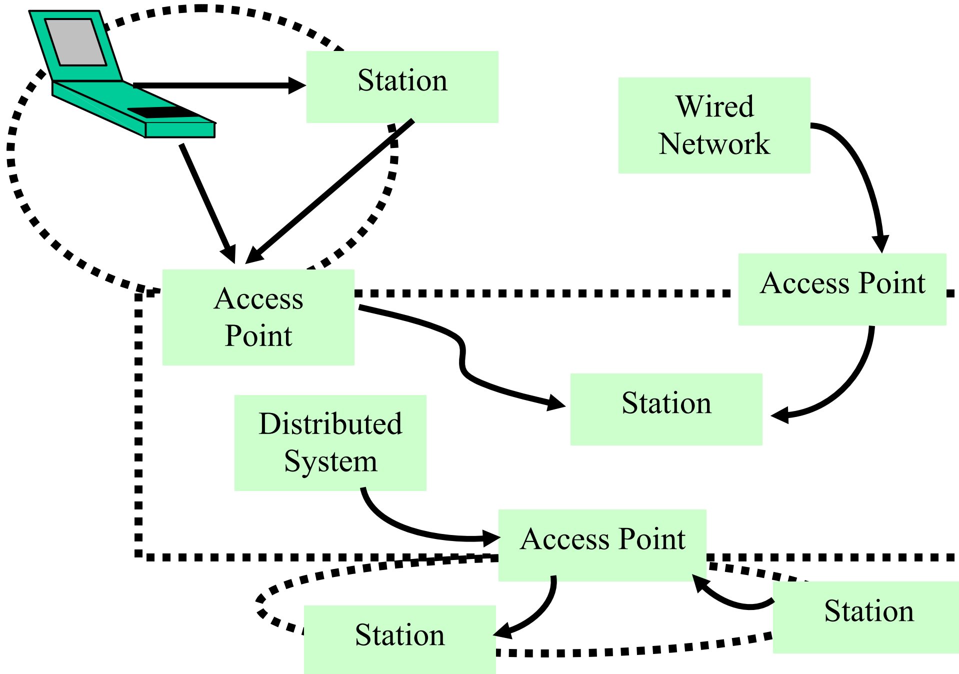
This is the most prominent technology standard for WLANs (Wireless Local Area Networks). This comprises of a PHY (Physical Layer) and MAC (Physical and Medium Access Control). This allows specific carrier frequencies in the 2.4 GHz range bandwidths with data rates of 1 or 2 Mbps. Further enhancements to the same technology has lead to the modern day protocol known as the **802.11b** which provides a basic data rate of **11Mbps** and a fall-back rate of **5.5Mbps**.All these technologies operate in the internationally available **2.4GHz ISM band**. Both IEEE 802.11 and 802.11b standards are capable of providing communications between a number of terminals as an ad hoc network using peer-to-peer mode (see figures at the end) or as a client/server (see figures at the end) wireless configuration or a complicated distributed network (see figures at the end). All these networks require Wireless Cards (PCMCIA-Personal Computer Memory Card International Association-Cards) and wireless LAN Access points. There are two transmission types for these technologies: Frequency Hopping Spread Spectrum **(FHSS)** and Direct Sequence Spread Spectrum **(DSSS)**. Whereas FHSS is primarily used for low power, low-range applications, the DSSS is popular with Ethernet-like data rates. In the ad-hoc network mode, as there is no central controller, the wireless access cards use the CSMA/CA(Carrier Sense Multiple Access with Collision Avoidance) protocol to resolve shared access of the channel. In the client/server configuration, many PCs and laptops, physically close to each other (20 to 500 meters), can be linked to a central hub (Known as the **access point**) that serves as a bridge between them and the wired network. The wireless access cards provide the interface between the PCs and the antenna while the access point serves as the wireless LAN hub. The access point is as high as the ceiling of a roof and can support 115-250 users for receiving, buffering and transmitting data between the WLAN and the wired network. Access points can be programmed to select one of the hopping sequences, and he PCMCIA cards tune in to the corresponding sequence. The WLAN bridge could also be implemented using line-of-sight directional antennas. Handover and roaming can also be supported across the various access points. Encryption is also supported using the optional shared-key RC4 (Ron's Code 4 or Rivest's Cipher) algorithm.



Peer-to-Peer wireless mode



Client/Server wireless configuration



Wired distributed network

WPANs-802.15X

WPANs (Wireless Personal Area Networks) work as short-range wireless networks. The various WPAN protocols and their interfaces have been and are being standardized by the IEEE 802.15 WG (WPAN Working Group). There are four divisions of this standardization.

1. Under the IEEE 802.15 WPAN/Bluetooth Task Group

This group deals with support and development of applications requiring medium-rate WPANs (e.g. Bluetooth). These WPANs are supposed to handle technicalities for PDA communications, Cell-phones and also possess the QoS for voice applications.

2. Under the IEEE 802.15 Coexistence Task Group

This division deals with developing specifications on the unlicensed ISM band. This standard also called 802.15.2 is developing recommendations to facilitate coexistence of WPANs (802.15) and WLANs (802.11) such that applications like Bluetooth and Microwaves could operate flawlessly in the ISM range.

3. Under the IEEE 802.15 WPAN/High Rate Task Group

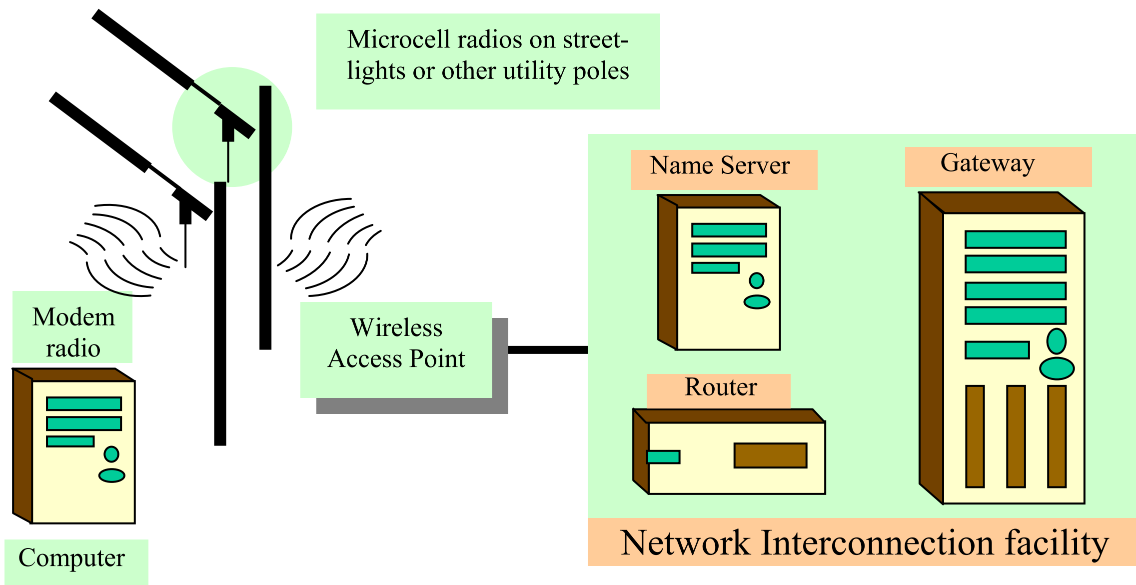
This division deals with the development of high-rate **(20Mb/s or higher)** WPANs. Besides a high rate the new standard provides low-power and low-cost solutions, addressing the needs of portable consumer digital imaging and multimedia applications.

4. Under the IEEE 802.15 WPAN/Low Rate Task Group

This group deals with standardization of ultra-low complexity, cost, and power for a low-data rate **(200Kb/s or less)** connectivity among inexpensive fixed, portable, and moving devices. A unique capability this standard is supposed to achieve is location awareness. The targeted applications are sensors, interactive toys, smart badges, remote controls, and home automation.

Ricochet

This provides a secure mobile access to the desktop from outside an office. This service is provided by MERICOM a commercial Internet Service Provider **(ISP)**. This was primarily provided at the airports and some selected areas. The Ricochet Network is a wide area wireless network system using spread spectrum packet switching technique and Metricom's patented frequency hopping, checker architecture. The network operates within the license-free (902-928) MHz) ISM band. A Ricochet wireless micro cellular data network (MCDN) is shown in the figure below.



Ricochet Wireless Microcellular data network

It consists of shoebox sized radio transceivers, also called microcell radios, and are typically mounted to streetlights or utility poles. The microcells require only a small amount of power from the streetlight itself with the help of a special adapter. Each micro cell radio employs **162 frequency-hopping** channels and uses a randomly selected hopping sequence. This allows for a very secure network to all subscribers. Within a **20-sq-mile radius containing about 100 microcell radios** Richochet installs wired access points (WAPs) to collect and convert RF packets into a format for transmission through a T1 connection. The Richochet Network has a backbone called the **name server**, by checking the subscriber serial number. Data packets between a Ricochet modem and a micro cell radio may take different routes during transmissions. They can be routed to another Richochet modem or to one of the Internet gateways, a telephone system, an X.25 network, and LANs or other corporate intranets, The telephone system gateway provides telephone modem access (TMA), which can also be used to connect to online internet services.

Services

Richochet provides immediate, dependable, and secure connections without the cost and complexities of land-based phone lines, dial-up connections, or cellular modems. Richochet modem features are its **28,800 bps, 24-hour access**. The Richochet wireless network is based on frequency hopping, spread-spectrum packet radio technology, with transmissions randomly hopping every two-fifths of a second over 162 channels.

HomeRF

This technology comes under ad-hoc networking which spans an area such as enclosed home or an office building or a warehouse floor in a workshop. A specification for wireless communications in home called the shared wireless access protocol (SWAP) has been developed. Some common applications targeted are:

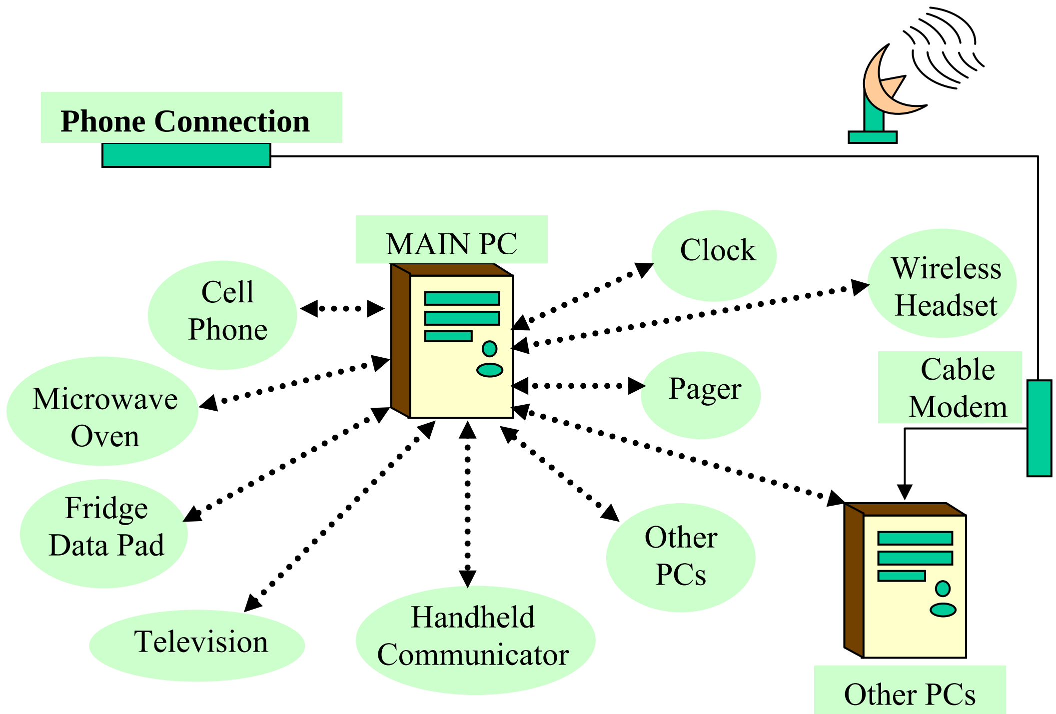
- access to a public network telephone (isochronous multimedia) and Internet (data)
- entertainment networks (cable television, digital audio and video with IEEE 1394
- transfer and sharing of data and resources (printer, Internet connection, etc.), and home control and automation.

Advantages of home RF

In HomeRF same connection can be shared for both voice and data among the devices, at the same time. This technology provides a platform for a broad range of interoperable consumer devices for wireless digital communication between PCs and consumer electronic devices anywhere in and around the home.

The Working Group

The working group comprises of Compaq Computer Corp., Ericsson Enterprise Networks, Hewlett-Packard Co., IBM, Intel Corp., Microsoft Corp., Motorola Corp. and several others. A typical home RF is shown below.



Architecture-HomeRF

Typical characteristics

- Uses the 2.4 GHz ISM band
- Data rate: 2 Mbps and 1 Mbps
- Range: 50m
- Mobility Ω 10m/s
- Topology: Packet-Oriented
- Supports both centralized communication (Infrastructure) and ad-hoc (Infrastructure-less) communication
- Support for simultaneous voice and data transmissions
- Provides Six audio connections at 32kbps with ≤ 20ms latency
- Maximum data throughput 1.2 Mbps
- Supports Low-Power paging mode
- Provides QoS to voice-only devices and best effort for data-only devices.

HiperLAN

"HiperLAN" or "High-performance LAN" has been designed specifically for an ad-hoc environment.

Main characteristics of HiperLAN

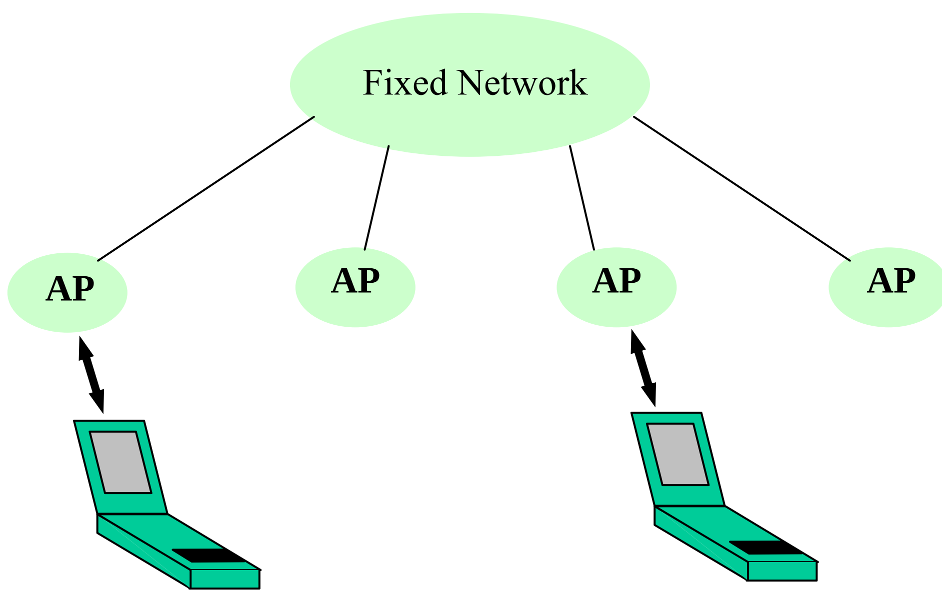
- Can support both multimedia data and asynchronous data at rates as high as 23.5 Mbps.
- Employs 5.15 GHz and 1.71 GHz frequency bands
- Range : 50m
- Mobility ≤ 10m/s

- Topology : Packet-Oriented
- Supports both centralized and ad-hoc communication.
- Supports 25 audio connections at 32kbps and latency=10ms and, a video connection of 2 Mbps with 100ms latency and data rate=13.4Mbps.It supports MPEG or other state-of-the-art real-time digital audio and video standards.
- HiperLANs are available in two types :
  - **TYPE 1 :** This has distributed MAC with QoS provisions and is based on GMSK (Gaussian minimum shift keying)
  - **TYPE 2:** This has a centralized scheduled MAC and is based on OFDM.

Objectives of HiperLAN

- Provide QoS to build multiservice networks
- Provide strong security
- Handoff when moving between local area and wide area
- Increased throughput
- Ease of use, deployment, and maintenance
- Affordability and Scalability

A typical HiperLAN system is shown in the figure below:



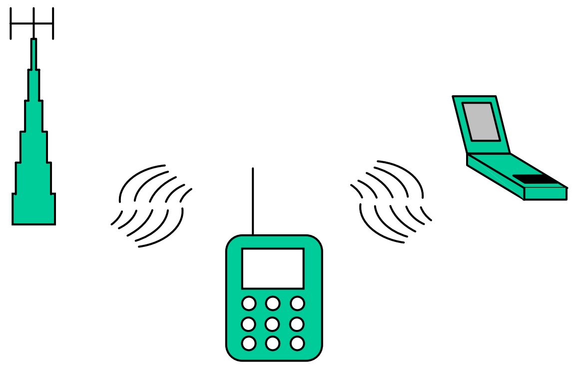
HiperLAN System

Bluetooth & Infrared communication

Bluetooth has been designed to allow low-bandwidth wireless connections. It was started by a group of companies including Ericsson, Intel, IBM, Nokia and Toshiba – known collectively as a Bluetooth Special Interest Group **(SIG)** in 1998. Some other companies like Microsoft, Lucent, 3COM, Motorola etc joined it in 1999.The effort got focused on to develop a reliable universal link for short-range RF communication.

INFRARED WIRELESS COMMUNICATION and BLUETOOTH

Infrared technology is another dominant in the field of wireless communications. This has been incorporated in remote controls, notebook computers, personal digital assistants etc. It uses the invisible spectrum of light for transmissions. The **IrDA *(Infrared Data Association)*** has specified one standard method for infrared communications, which is commonly used with mobile phones and notebook to handheld computers. Like Bluetooth, IrDA has also been designed for short-range and low-power applications. In addition, the spectrum it utilizes is also unlicensed. Also, like Bluetooth it also defines a physical layer and a software protocol stack and, hence, promotes interoperable communications. The difference lies in transmission speeds and signal paths (Infrared requires *line-of-sight* paths where RF can penetrate through objects).
A typical use of Bluetooth to connect a Laptop is as shown below.



A Bluetooth Connection

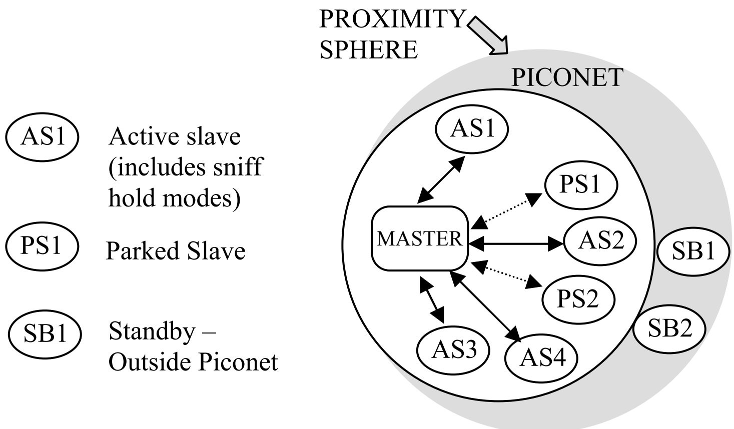
Bluetooth provides many options to the user. For instance, Bluetooth radio technology built into both cellular telephone and a laptop replaces the cable used today to connect a laptop to a cellular phone. Printers, desktops, FAX machines, keyboards, joysticks and virtually any other digital device can be networked by the Bluetooth system. Bluetooth also provides a universal bridge to existing data networks and mechanism to form small private ad hoc groups of connected devices away from fixed network architectures.

"Bluetooth" wireless communication technologies operate in the 2.4 GHz range. There are certain propositions related to RF Communication in the 2.4 GHz spectrum which the device developers must follow. This is important for an organized use of the spectrum because it is globally unlicensed. As such it is bound by specific regulations put forth by various countries in their respective territories. In context to wireless communications the RF Spectrum has been divided into **79** channels where bandwidth is limited to **1 MHz** per channel. ***Frequency Hopping*** spread spectrum communications must be incorporated. Also proper mechanism for interference anticipation and removal should also be there. This is essential on account of the fact that the 2.4 GHz spectrum is unlicensed and, hence, more vulnerable to signal congestion because of increasing number of new users trying to communicate within the bandwidth.

Bluetooth Communication Topology

The Bluetooth network model is based upon the concept of ***proximity networking*** which implies that as soon as two or more devices come within a range of eachother they should be able to establish a connection. This enables the structuring of **PAN *(Personal Area Network)***. There are two different communication topologies of Bluetooth PANs are ***piconet*** and ***scatternet***. They are described in brief below.

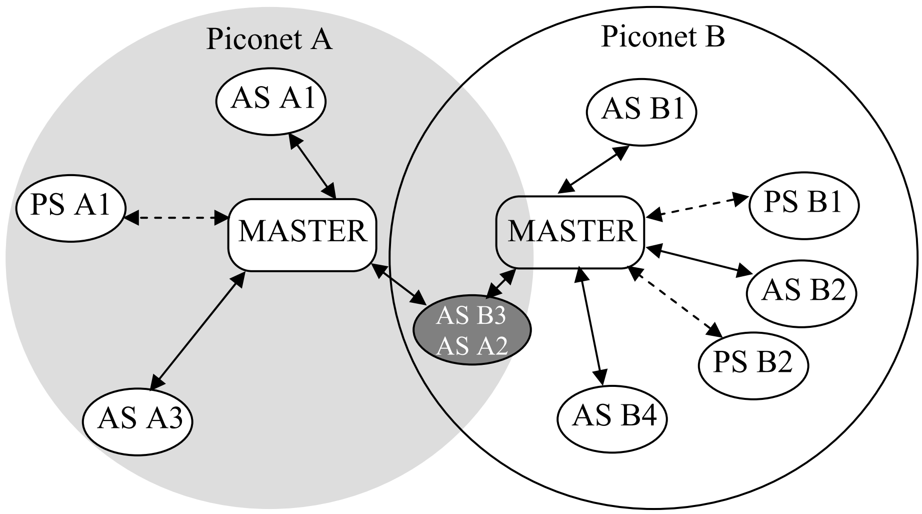
The Piconet



A PICONET

A piconet consists of *single* master and all slaves in its proximity, which are communicating with it. The slaves may be in active, sniff, hold or park modes at any instant of time. There can be upto ***seven*** slaves and ***any*** number of parked slaves and standby devices in the vicinity of the master. The above figure shows a typical piconet. The figure shows two spheres. The white filled inscribed sphere comprises the piconet where the ellipses represent the devices or slaves and the box represents the master. Thus, there is only one master and several slaves. The slave names starting from `A' represent the Active slaves and these are linked to the master with continuous lines meaning `ACTIVE'. The slave names starting with `P' represent the parked slaves. Dashed lines are shown connecting it to the master meaning that the connection is not continuous but the devices are in the piconet i.e., `PARKED'. Some other slaves with names starting form `S' indicate the slaves, which are in STAND-BY and these, are actually outside the piconet but inside the proximity sphere.

The Scatternet



A SCATTERNET

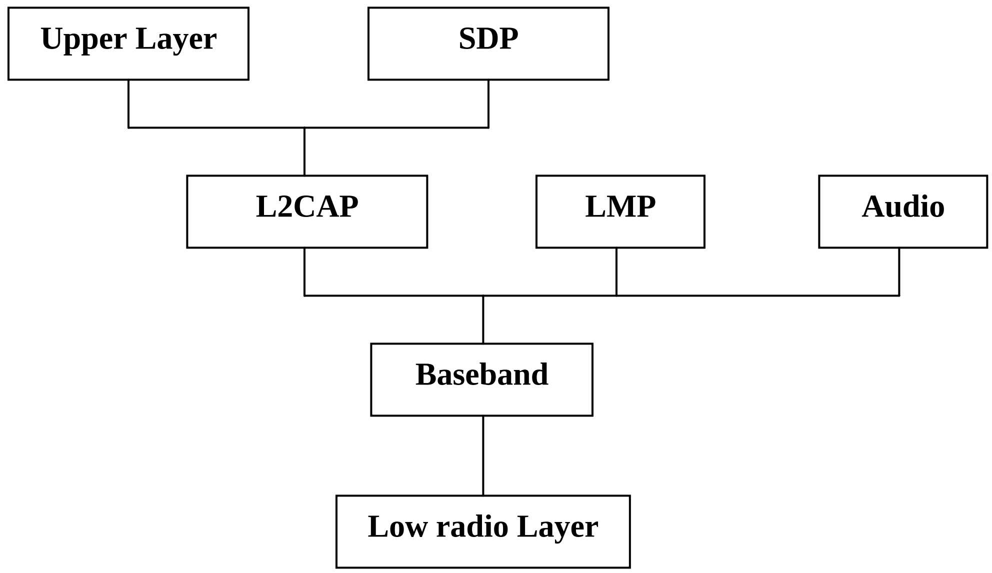
Scatternet is formed when two or more piconets fall in each other's proximity. More precisely, a scatternet is formed when two or more piconets at least partially overlap in time and space. Within a Scatternet a slave can participate in multiple piconets by establishing connections and synchronizing with different masters in its proximity. A single device may act as master in one piconet and at the same time as slave in another one. A practical example of scatternet is mobile communication in which devices move frequently in and out of proximity of other devices. Figure above shows a typical Scatternet.

Bluetooth Specifications

Typical Bluetooth specifications have been characterized in the table below.

Bluetooth Radio : Specifications		
Modulation	Gaussian frequency-shift Keying (GPSK)	BT product : modulation index : 0.28-0.35
Symbol Rate	1 Msymbols per sec	Using binary GFSK,this translates into 1Mbps raw link speed:Bit Transmission Time:1 μsec
Frequency-Hopping Rate	1,600 hopss (Typical)	Residence Time : 625 μsec / hop
Transmit Power	*Class 3* : 0 dBm (1 mW) *Class 2* : 4 dBm (2.5 mW) *Class 1* :20 dBm (100 mW)	A typical Bluetooth radio: optional power control to below -30dBm
Receiver Sensitivity	a Bluetooth receiver must attain a raw *bit error rate* (BER) of 0.1% with an input signal level of -70 dBm or lower	The -70 dBm sensitivity level shall be attained for any input signal generated by any compliant Bluetooth transmitter.

Bluetooth Core Protocols

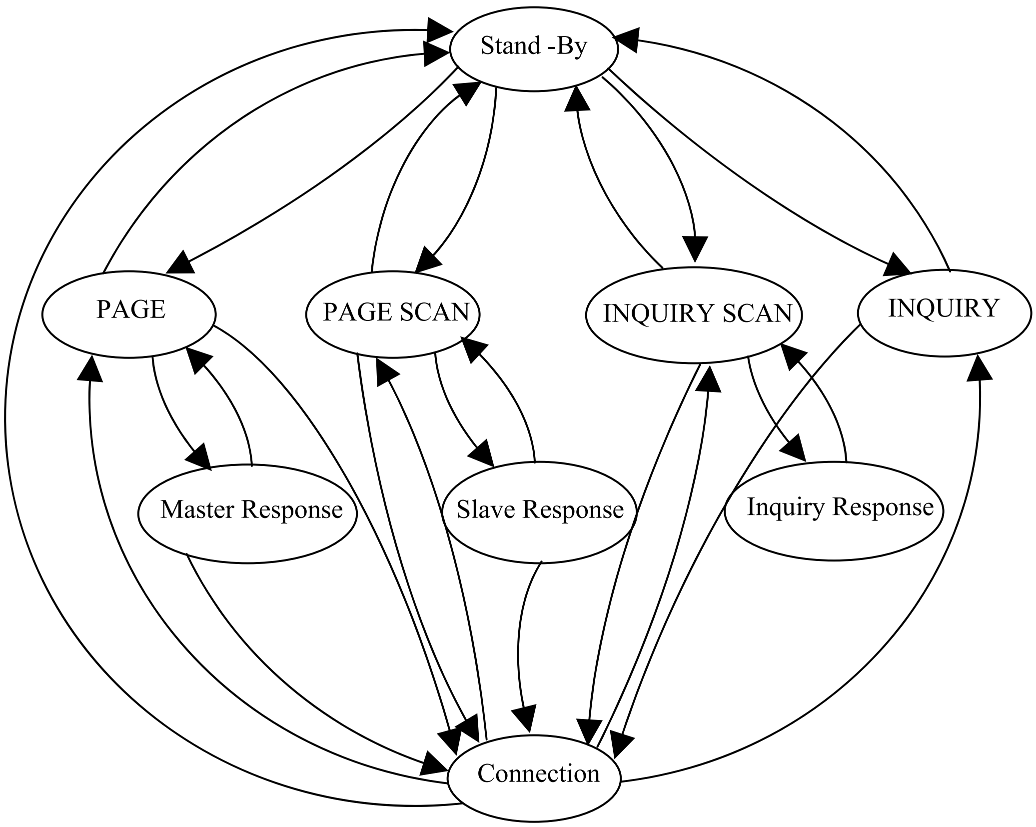


Bluetooth Core Protocols

A brief description is as follows.
Service Discovery Protocol (SDP) provides means for application to discover which services are provided by or available through a Bluetooth device. It also allows applications to determine the characteristics of those available services. Logical Link Control and adaptation layer protocol (L2CAP) supports higher-level protocol multiplexing, packet-segmentation and reassembly, and the conveying of QoS (Quality of Service) information. The link managers (on either side) for link step and control use Link Manager Protocol (LMP). The baseband and link control layer enables physical RF link between Bluetooth units forming piconet. It provides two different packets, SCO and ACL, which can be transmitted in a multiplexing manner on the same RF link.
Different master/Slave pairs of the same piconet can use different link types, and the link type may change arbitrarily during a session. Each link type supports up to sixteen different packet types. Four of these are control packets and are common for both SCO and ACL links. Both link types use a TDD scheme or full-duplex transmissions. The SCO link is symmetric and typically supports time-bounded voice traffic. SCO packets are transmitted over reserved intervals. Once the connection is established, both master and slave units may send SCO packet types and allow both voice and data transmission-with only the data portion being retransmitted when corrupted.

Operational States

OPERATIONAL STATES OF THE BLUETOOTH DEVICES



OPERATIONAL STATE MACHINE

State Description

- **STANDBY —**This is the *default* state and the lowest power consuming one too. Only the Bluetooth clock operates in the low-power mode.
- **INQUIRY —** In this state a device seeks and gets familiar with the identity of other devices in its proximity. The other devices must have their ***Inquiry Scan*** state **ENABLED** if they want to entertain the query from other devices.
- **PAGE —** In this state master of a *piconet* invites other devices to join in. To entertain this request the invitee must have its ***Page Scan*** state **ENABLED**.

A device may ***bypass*** the inquiry state if the identity of the device it is wanting to page is previously known *(see the figure above)*. The figure above also indicates that any member of a *piconet* **— *not necessarily the master, may*** still perform INQUIRY and PAGE operations for additional devices, thus, paving way for a ***Scatternet***.