Bluetooth

Bluetooth is a short-range wireless technology, originally developed as a cable replacement technology to connect various small battery driven devices. Bluetooth is an open standard that permits Personal Area Networks (PAN) to be set up instantly among different devices.

Origin
Created in 1994 by the Swedish company Ericsson mainly to replace the cables connecting their mobile phones and its accessories. This technology was named as Bluetooth in 1999 after the foundation of the Special Interest Group (SIG) in memory of a Danish Viking king Harald Blatand, who united and controlled Denmark and Norway. This name was adopted because Bluetooth is expected to unify the telecommunications and computing industries. The purpose of the SIG is to define both Bluetooth specifications and certifications. In 2001 appeared the first consumer products for mass production and in the same year specification 1.1 was released.

Bluetooth technology
Bluetooth correspond to a radio interface between two mobile equipments or between equipments and a transmitter/receiver. The purpose of this interface is to make a network allowing the interconnection of different types of devices. Bluetooth operates in the unlicensed Industrial Scientific Medical (ISM) band at 2.4 GHz to 2.4835, which is also used by other technologies such as Wireless Local Area Network (WLAN), Microwave ovens, Digitally Enhanced Cordless Telephones (DECT).

Connection scheme
Bluetooth provides a point to point or point to multipoint connection. In the point to multi point connection, the physical radio channel is shared by a group of devices that are synchronized to a common clock and frequency-hopping pattern. The device that provides synchronization reference is said to be a master and all other devices are said to be slaves. A group of devices synchronized in this manner forms a pico-network. Bluetooth devices may operate either as a master or as a slave unit. Master initiates the exchange of data and the slave responds to it. A master can actively communicate up to 7 slaves while another 255 slaves can be registered in non-communicating power saving mode.

Furthermore, two or more piconets can be interconnected, forming a topology, what is called a scatternet. Bluetooth standard allows multiple roles to a single device i.e a device can be master in one piconet and a slave in one or more other piconets. The node or device with multiple roles acts as gateway to the adjacent piconets, but the restriction is, a node can be active only in one piconet at a time. So this node act as switch or bridge i.e it switches to the hopping frequency sequence of the other piconet. The bridge node participate or active in multiple piconets on a time division basis. More about the scatternet is dealt in the next section.

For transmission, a slotted channel is applied with a nominal slot length of 625 microseconds. For a full duplex transmission, a Time-Division Duplex (TDD) scheme is used. In this scheme master transmits in even numbered time slots while the slave transmits in odd-number time slots. All communications will be in between master
and slave within a piconet with a maximum radius of 100m (class 1). Direct slave-to-slave communication is not possible

**Data Communication**
Communication in a piconet is organized so that the master polls each slave according to a polling scheme. A slave is only allowed to transmit after having been polled by the master. A slave will start its transmission in the slave to master time slot after it has received a packet from the master. The master may or may not include data in the packet used to poll a slave.

1. **Packets on the physical links**
The two types of connections that can be established between a master and a slave are Synchronous Connection Oriented (SCO) link and Asynchronous Connection-Less (ACL) link.

**SCO link**: SCO link is a point-to-point link between a master and a slave. SCO provides circuit-switched connection where data is regularly exchanged. SCO packets are never retransmitted. The master maintains the SCO link by using the reserved time slots at regular intervals. SCO packets are given high priority than ACL packets. The maximum throughput is 64Kb/s for full duplex.

**ACL Link**: ACL is a point to multi point link between the master and all the slaves (more than one slave) of the piconet. Broadcast packets are sent on ACL links. The ACL link provides a packet switched connection between the master and all active slaves. For most ACL packets, packet retransmission is applied to assure data integrity; this is used for non real-time transmission. ACL can support symmetric or asymmetrical and packet switching. In asymmetric connection, the maximum bit rate is 723.2Kb/s in one way and 57.6Kb/s in the other way. In symmetrical connection, it is 433.9Kb/s in both ways.

2. **Frequency Hop Spread Spectrum**
Bluetooth uses Frequency Hop Spread Spectrum (FHSS) as an interference avoidance technique. The binary data in the baseband level of Bluetooth is modulated by using Gaussian Frequency Shift Keying (GFSK). Then they are transmitted using a carrier determined by a frequency synthesizer.

Instead of producing only a single carrier frequency, the synthesiser is controlled by a hop code generator that causes it to change carrier frequency at a nominal rate of 1,600 hops per second. One Bluetooth data packet is sent per hop. A device uses one frequency in one time slot. Then, by a frequency hop, it will change of frequency in the next time slot and so on. Thus, for two devices to communicate using FHSS, they must be properly synchronised in order to hop together from channel to channel. All the synchronisation parameters are determined by the piconet master. The master passes the FHSS synchronisation parameters to a slave during the page process (explained in the next section). When another device wants to enter the piconet, it has to acknowledge this continuation of frequency hoping to be able to fallow it.

**Packet types**
Bluetooth has a wide variety of packet types based on the type of links like Synchronous Connection Oriented (SCO) and Asynchronous Connectionless (ACL) being used.
ACL packets: These packets are used over asynchronous links. User data or control data can be transmitted with these packets. These packets are classified into 7 types which contain a CRC code and are retransmitted (except AUX1 type) if no acknowledge of proper reception is received.

**States of Bluetooth devices**
There are two main states in the Bluetooth link controller: standby and connected
- The standby state is the default state in the Bluetooth unit. In this state, the Bluetooth unit is in low power mode where the energy consumption of the device is highly reduced
- The connected state means that the device participates in a piconet or scatternet

**The other sub states**
**Inquiry**: The master will search, which units are in range, and what their device address and clocks to initialise the communication. This request will be repeated as long as a unit has not been found

**Inquiry scans**: Used by a slave to listen to an Inquiry

**Inquiry response**: The state of the device switches from the Inquiry scan substate to the Inquiry response substate when it answers to the master Inquiry by sending its address and its clock state.

After receiving the Inquiry response, a connection is established for the paging procedure.

**Paging**: Used by a master to establish a piconet with a particular slave whose Bluetooth device address is known.

**Page Scan**: Used by a slave to listen to its page.

**Slave response**: State of the device after receiving the message from the master for a connection. Then the slave will send its Access Code to the master.

**Master response**: After the reception of the slave response, the master will send a packet called Frequency Hopping Synchronisation (FHS) which will permit the slave to be synchronised with the master clock

**Connected**: The connection has been established and packets can be exchanged

**Active**: The Bluetooth unit actively participate on the channel. The master schedules the transmission based on traffic demand to and from the different slaves. Regular transmissions are made by the master to keep the slaves synchronised to the channel.

Once connected, the unit is able to transmit and receive data. To save battery power, there are three low power modes are available: Sniff, Hold and Park (in decreasing order of power efficiency). These modes are useful for:

- Enabling more than seven slaves to be in a piconet
- To provide a means for a device to participate in more than one piconet.
- Giving the master time to bring other slaves into its piconets
- Conserving energy

The main goal of these modes is to reduce the time for a device receiver to remain on. It allows the devices to adjust the power depending on the range of communication. The lower power level covers a distance of about 10 meters, while the higher power level can cover about 100 meters.

Each of the power saving mode is explained more clearly

**Sniff**
The sniff mode enables a device to switch of its receivers duty cycle for a certain period called Tsniff. For a normal piconet operation Tsniff = 2 time slots, but it can be up to 65,536 time slots or about 41 seconds between sniffs. The slave keep it’s AM_ADDR while in the sniff mode.

**Hold**
Sniff is periodic, but the hold mode is one time exit from the obligations of the piconet and it can be used when no data needs to be transmitted for long time interval(up to 41sec without re-synchronisation). An internal timer determines when the unit will be reactivated. In this mode, a salve does not receive any asynchronous packets and only listens to determine if it should become active again. It does not affect SCO traffic. In the hold mode a device can scan, page, inquire or attend another piconet. During this mode the device is still considered an active member of the piconet. Thus, it remains synchronised with the master.

**Park**
It is the most powerful of all the power saving modes. When a salve enters a park state, it releases the AM_ADDR and receives an 8-bit parked member address (PM_ADDR) and an 8-bit access request address (AR_ADDR). The AR_ADDR determines a time window during which a parked device can request to be unparked. When the master want to issue an unpark command or other communication commands, PM_ADDR is taken place by AM_ADDR.

**Role Switching**
Bluetooth specification allows multiple roles to a single device. A device can be a master or a slave in a piconet. A device can request a switch in role with respect to another device. A master can request a slave in the piconet for a change of role. After the switch, the master will be slave and the slave that is accepted the switch will be the new master.

The procedure involved here is: the device (slave), wishing for the switch sends a request packet to the other device (Master). Then the master accept the request by sending a accept packet. The new master sends a FHS packet, which contains the lower part of the Bluetooth CLK. Forming scatternets with role switch is explained more clearly in the next section.