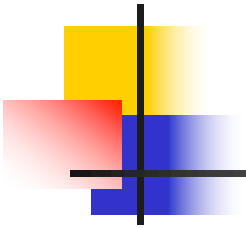
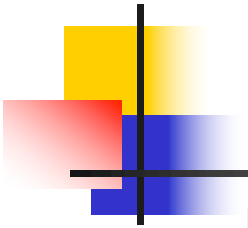
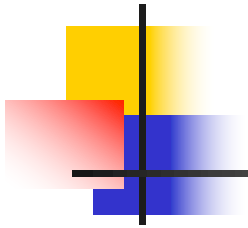
BLUETOOTH



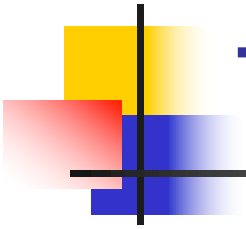
- What is Bluetooth?
- Goals
- Requirements
- Usage Models
- Bluetooth Architecture
- Security



- Bluetooth is a new standard developed by a group of electronics manufacturers that will allow any sort of electronic equipment -- from computers and cell phones to keyboards and headphones -- *to make its own connections, without wires, cables or any direct action from a user.*
- A key difference with other existing wireless technologies is that bluetooth enables *combined usability models based on functions provided by different devices*.

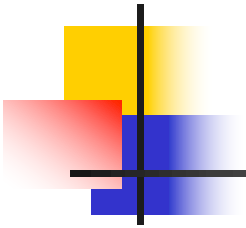


- The Bluetooth Special Interest Group comprises more than 1000 companies.The major companies who created the technology include
  - Intel
  - 3 com
  - Ericcson
  - IBM
  - Motorola
  - Nokia
  - Toshiba

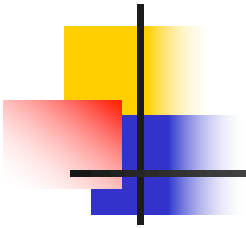


The Name –Bluetooth?

- The name is attributed to Harald Bluetooth was king of Denmark around the turn of the last millennium.
- Choosing this name for the standard indicates how important companies from the Baltic region (nations including Denmark, Sweden, Norway and Finland) are to the communications industry



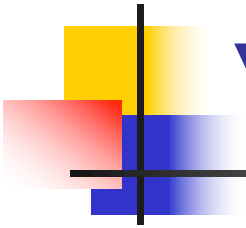
- Present wireless technology like ***infra red*** data communication has two problems – 1)*Line of Sight* 2) *One to One*
- Using ***data synchronizing*** – e.g. hot syn on a PDA --- problem of using the right cradle and cable.
- **BLUETOOTH OVERCOMES THESE PROBLEMS**



- It provides agreement at the physical level -- Bluetooth is a radio-frequency standard.
- Provides agreement at the data link level where products have to agree on
  - ✓ when bits are sent
  - ✓ how many will be sent at a time
  - ✓ how the parties in a conversation can be sure that the message received is the same as the message sent

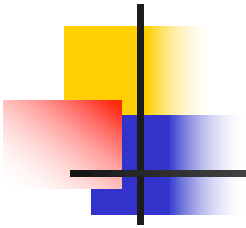
The Basic Idea

- Bluetooth is a standard for a small , cheap radio chip to be plugged into computers, printers, mobile phones, etc
- Bluetooth chip is designed to replace cables.Information normally carried by the cable, is transmitted at a special frequency to a receiver Bluetooth chip.
- These devices can form a quick ad-hoc secure *"piconet"* and start communication.
- Connections in the *"piconets"* can occur even when mobile.



“Piconet”

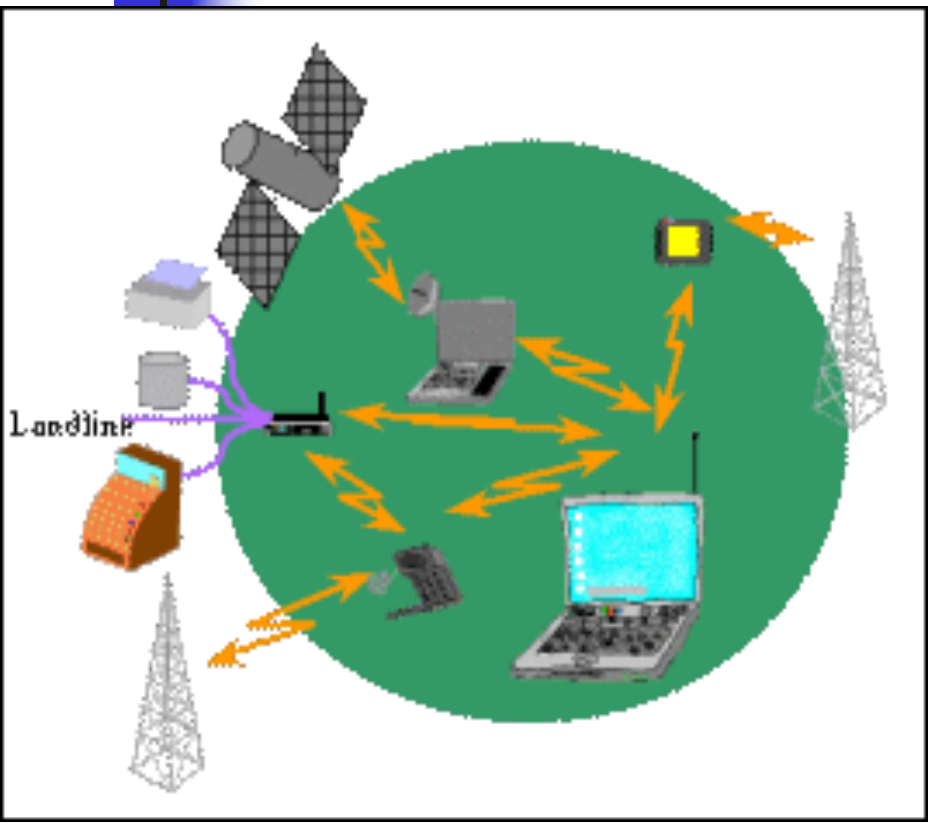
- A collection of devices connected via Bluetooth technology in an ad hoc fashion.
- A ***piconet*** starts with two connected devices, and may grow to eight connected devices.
- All Bluetooth devices are peer units and have identical implementations. However, when establishing a piconet, one unit will act as a ***Master*** and the other(s) as ***slave***(s) for the duration of the piconet connection.



Requirements

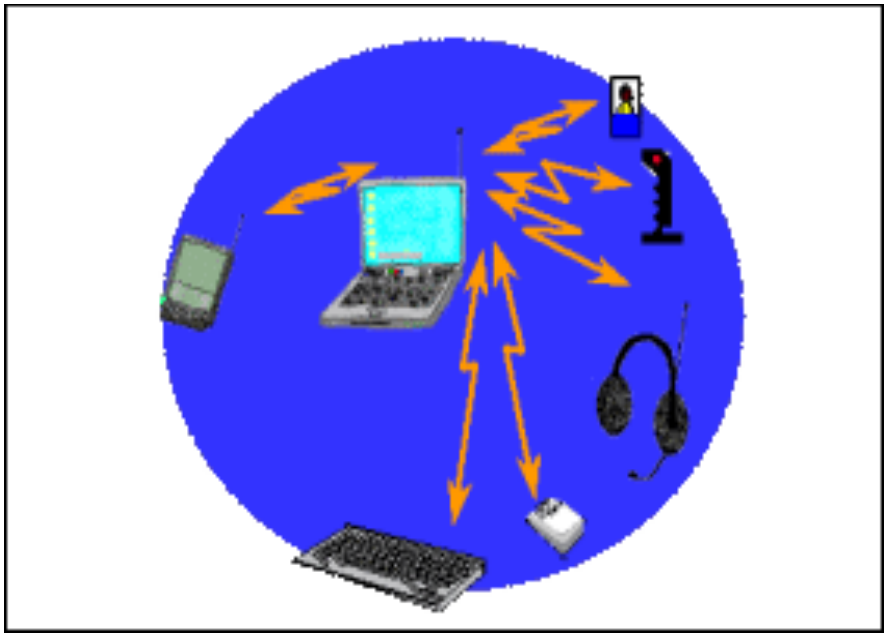
- Low cost as cables – chip $5
- Secure as cables – must support authentication and encryption
- Must support both data and voice.
- Must connect to a variety of devices.
- Must be able to function in a noisy environment.
- Data rates – 721kbps , using the 2.45Ghz radio frequency band –I.S.M (Industrial, scientific and medical)
- Must support many simultaneous and private “piconets”.
- Must be low power, compact and global.

Usage Models- Voice/Data Access Points



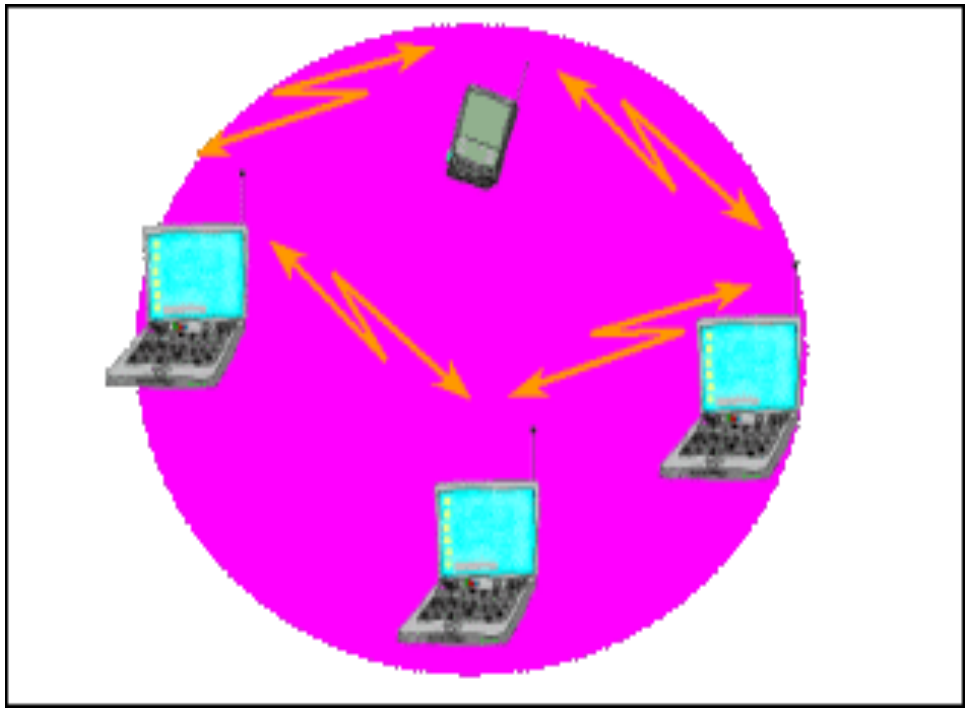
- Connecting a computing device to a communicating device.
- Allows any device with a bluetooth chip to connect to the internet while located within the range of the access point.
- Example- a notebook could link to the internet using a mobile phone as an access point.
- Envisions public data access points

Usage models-Peripheral Interconnects



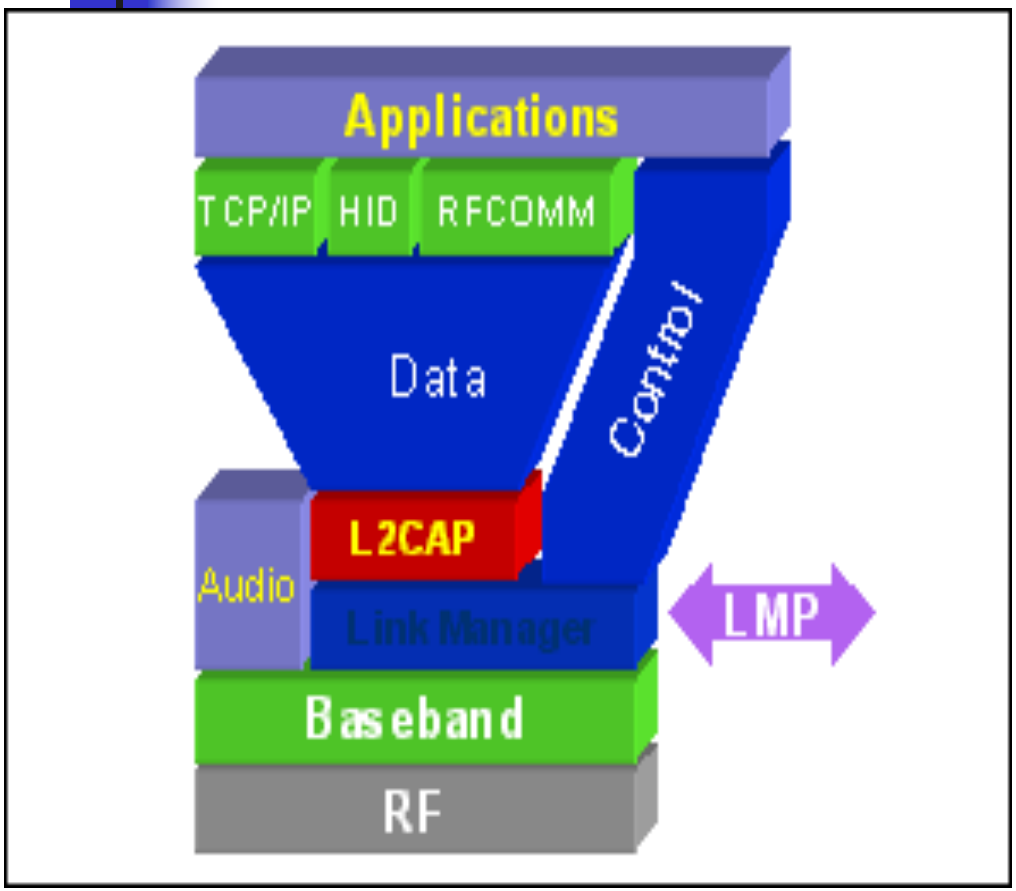
- Standard peripheral devices like keyboard, mice, headsets etc working over a wireless link.
- The same device can be used in multiple functions e.g a headset can access phones while in the office and can interface with a cellular phone when mobile.

Usage model- Personal Area Networking.(PAN)

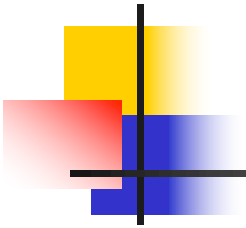


- Allows dynamic formation and breakdown of “PICONETS”--ad-hoc personal networks.

Bluetooth Architecture

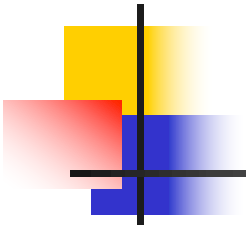


- *Core Specification* - Deals with the lower layers of the architecture and describes how the technology works.
- *Profile Specification* - Focuses on how to build interoperating devices using the core technology.



RF Layer

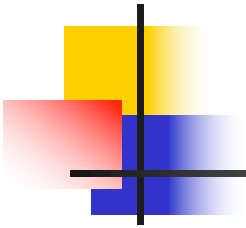
- The Radio (layer) is the lowest defined layer of the Bluetooth specification.
- It defines the requirements of the Bluetooth transceiver device operating in the 2.4GHz ISM band.



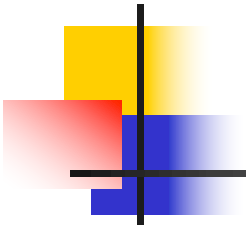
- In order to minimize interference the nominal antenna power is 1 mW which can be extended to 100mW.
- The low power limits the range to about 10 centimeters to 10 meters. With higher power of 100mW range of 100meters can be achieved.
- It uses a packet switching protocol based on a technology called ***spread-spectrum frequency hopping*** to spread the energy across the ISM band.

Spread-Spectrum frequency hopping

- A device will use 79 individual randomly chosen frequencies within a designated range, changing from one to another on a regular basis.
- The designated range is from 2.402GHz to 2.480GHz, in steps of 1MHz.
- The frequency hopping is done at a rate of 1600 times a second.
- This allows more devices to use the limited time slice and secondly reduces the chance of two transmitters being on the same frequency at the same time.



- *Baseband layer* – This layer defines the timing, framing, packets and flow control on the link.
- *Link Manager* – Responsible for managing connection states(authentication & encryption), enforcing fairness among slaves & power mangt.
- *Logical Link Layer* – Handles multiplexing, segmentation and reassembly of large packets and device discovery.
- *Audio* – The audio data is directly mapped to the baseband layer.



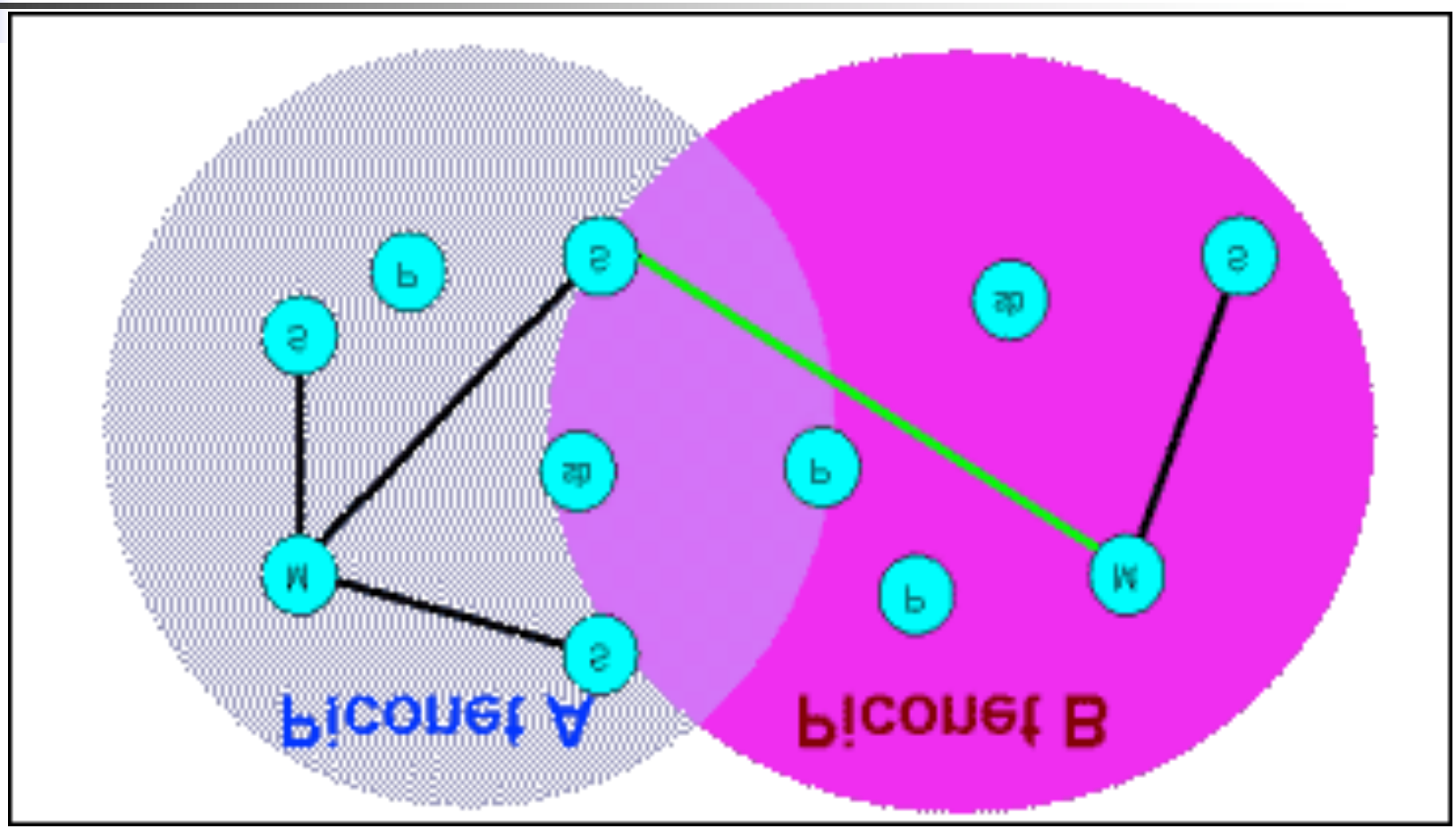
Bluetooth Frame

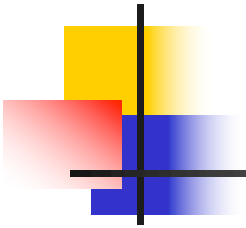
- Each frame consists of a transmit packet and a receive packet.
- Each packet may have either 1, 3 or 5 slots of 625ùs.
- Single slot packet – max data rate of 172Kbps
- Multislot frames support higher rates– 721Kbps or a max. of 3 voice channels.

Network Topology

- All units have a unique global ID(BD_Addr) address(48 bits)
- The unit that initializes the connection is assigned as the master which controls the traffic of the connection.
- A master can simultaneously connect upto seven slaves.
- The master/slave roles can be swapped.
- A device can be a master in only one “piconet” at a time.

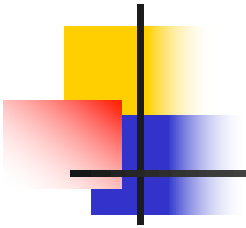
Network Topology



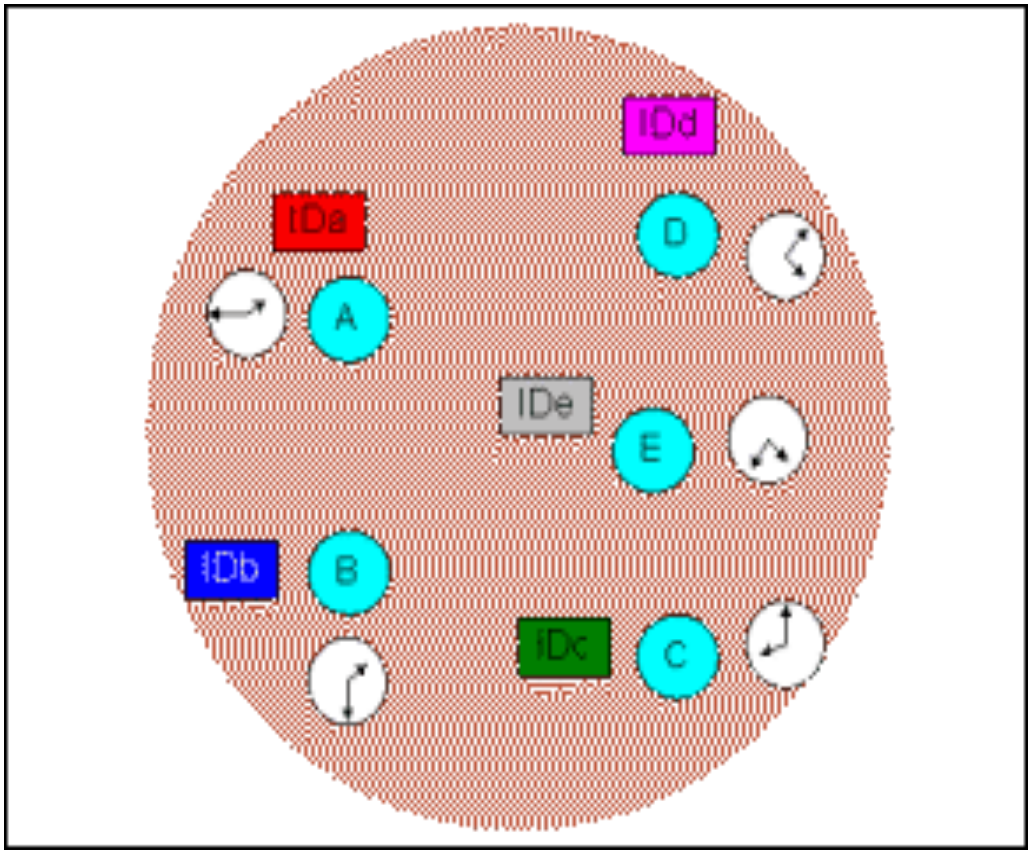


Forming a piconet

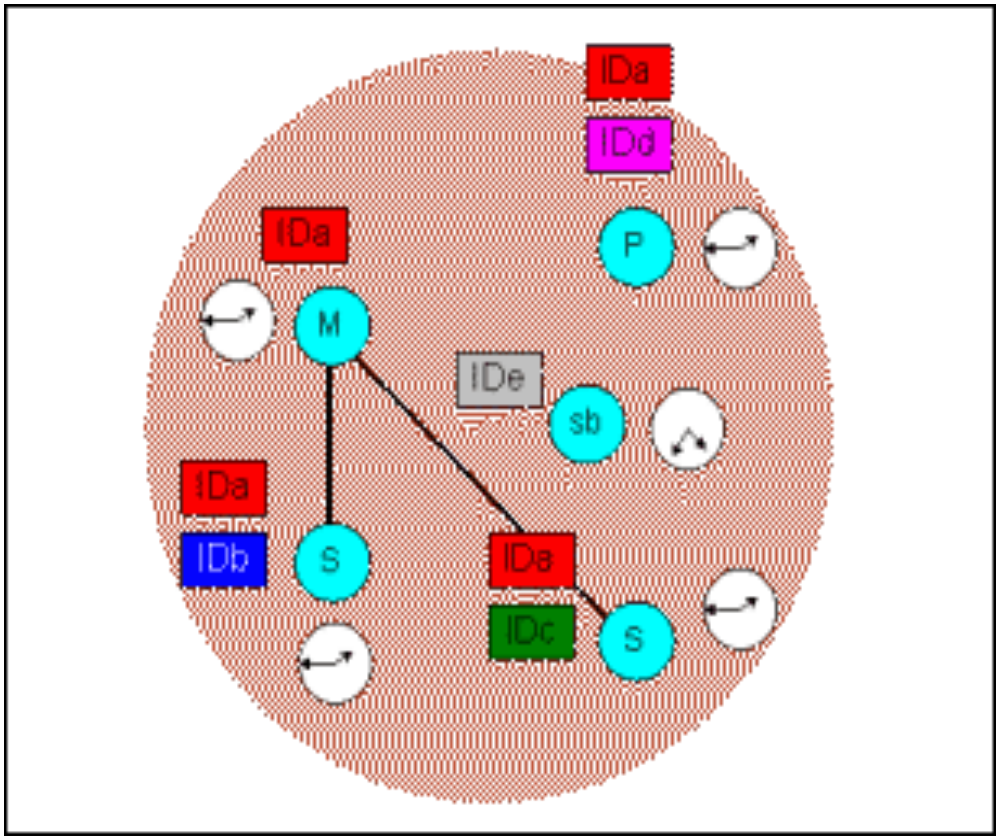
- Needs two parameters --- a) Hopping pattern of the radio it wishes to connect. b) Phase within the pattern i.e. the clock offset of the hops.
- The global ID defines the hopping pattern.
- The master shares its global ID and its clock offset with the other radios which become slaves.
- The global ID and the clock parameters are exchanged using a FHS (Frequency Hoping Synchronization) packet.



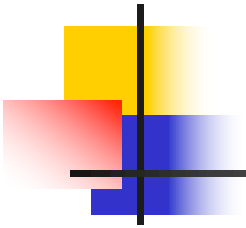
- Devices not connected to a piconet are in *STANDBY* mode, using low power.
- A connection is made by either a *PAGE* command if the address is known or by the *INQUIRY* command followed by a *PAGE*
- When a radio sends an *INQUIRE* command, all the listening radios respond with their FHS packets, which tells the inquiring radio of all the radios in the area.
- All listening radios perform a page scan and/or an inquiry scan every 1.25 seconds.
- The master radio sends an FHS to the paged radio.



- Shows a bunch of bluetooth devices in proximity of each other.
- Each device has its own ID and its clock offset



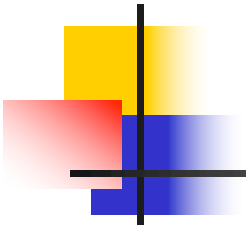
- Radio A has become the master and has formed a piconet with B and C as the slaves.
- Both B and C now share A's ID and and clock offset.



- When a radio joins a piconet it is assigned a 3 bit *Active Member Address(AMA).*
- Once the piconet has eight radios, the master assigns puts a radio into the *PARK* mode.
- This is one of the low power states, in which the radio releases its AMA for a 8 bit *PMA* (Passive Member Address).
- The freed AMA can be assigned to another radio wishing to join the piconet.
- Though upto 256 radios can actively reside on a piconet, only 8 of them with AMA's can transfer data.

Inquiry Scan

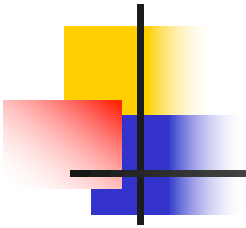
- One radio performs a page function on a special Inquiry ID global address.
- Listening radios perform an inquiry scan on a unique sequence of 32 channels.
- The radio will listen every 1.25 seconds on each of these 32 channels for 10ms and will then repeat the same for the next channel.
- The inquiring radio issues a number of pages on the inquire channels and then listens for a response for 1.25 seconds for 16 of the 32 channels.



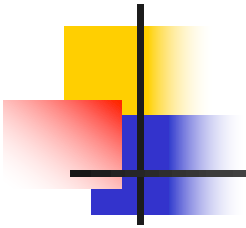
- If a listening radio was doing a page scan on one of these inquire channels it will respond with its FHS packet.
- The sequence is repeated for the second set of 16 channels.
- After an inquire scan is performed the inquiring radio will have a list of all the FHS packets of all the radios within its range.

Page Scan

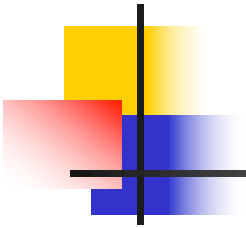
- A page scan is done by a radio in the Standby mode if the address of the device to connect is known.
- Each radio has a unique sequence of 32 paging frequencies and 32 response frequencies based on its Global ID.
- The radio will listen for a page of its global ID on each of the 32 paging frequency for 10ms, changing frequency every 1.25 seconds.
- The paging radio will continuously page using the paged radio's Global ID on one of the set of 16 paging frequency for 1.25seconds.



- The paging radio estimates the 16 frequencies on which to start paging based on the last known clock offset.
- If the paging radio receives no response then it will page on the remaining 16 frequencies for the next 1.25 seconds.
- Connecting time α Clock offset
- Clock offset α how recently were they were connected.



- Once a radio joins the piconet and has an AMA it can direct data to other devices on the piconet.
- In order to remain in the connected state within a piconet, the radio needs to maintain the frequency hopping pattern and offset while consuming low power.
- To achieve this the connected radios can be placed in either *PARK*, *HOLD* or *SNIFF* modes.

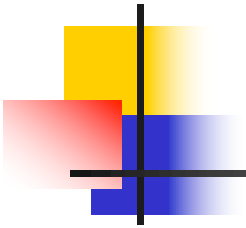


HOLD MODE

- When data needs to be transmitted very infrequently, thus conserving power.
- In this mode only an internal timer is running.
- No data is transferred when in HOLD mode.
- The master can put slaves on HOLD mode.

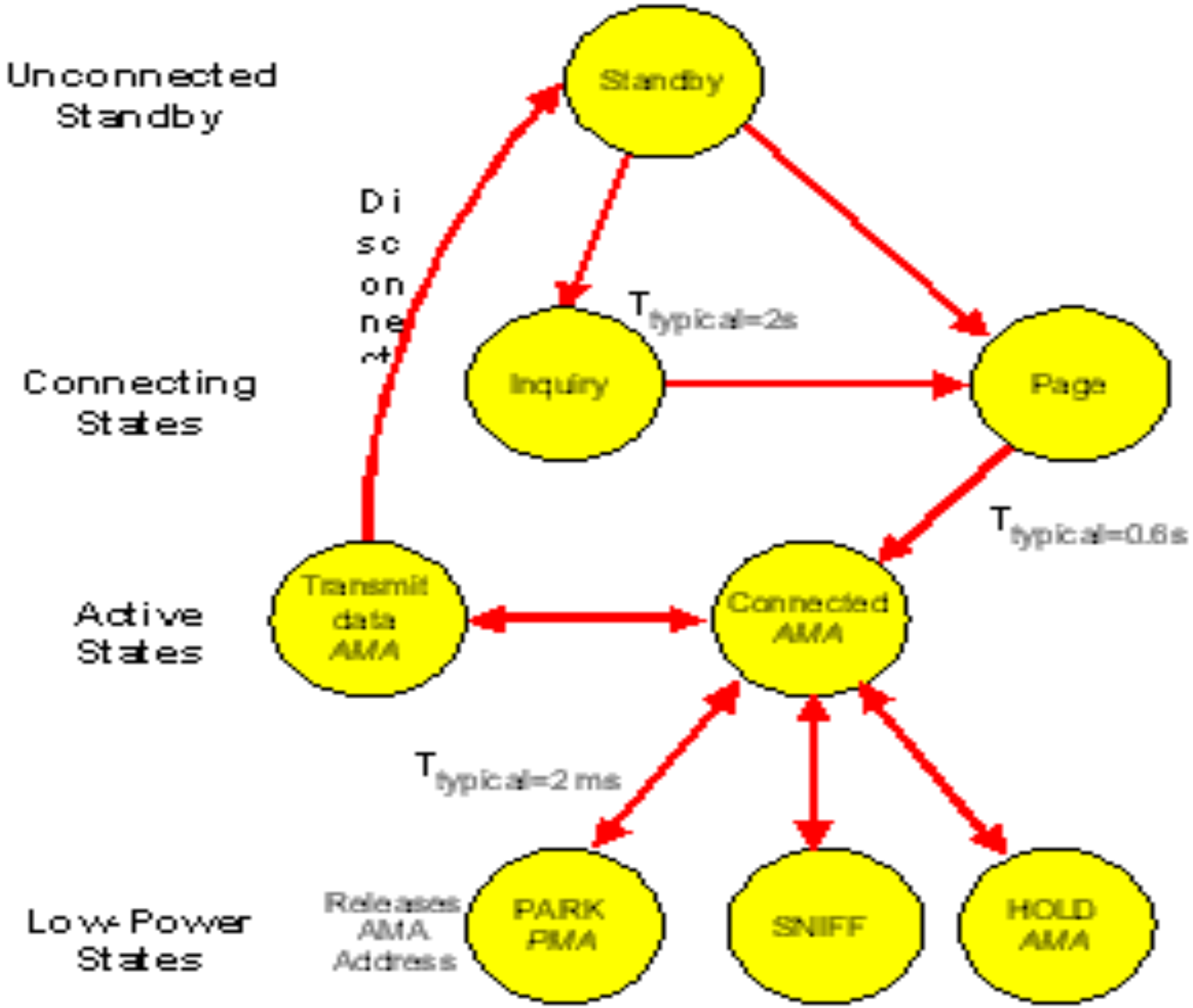
SNIFF MODE

- A slave device listens to the piconet at a reduced rate.
- The SNIFF interval is programmable.
- In both the HOLD and SNIFF states the device retains its AMA.



PARK MODE

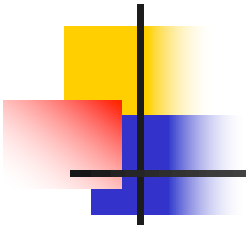
- The device has given up the AMA and has become passive.
- The parked device will occasionally listen to see if the master has sent any broadcast data asking it to become active.


Unconnected Standby
Standby
Disconnect
Connecting States
Inquiry
T typical=2s
Page
T typical=0.6s
Active States
Transmit data AMA
Connected AMA
T typical=2 ms
Low-Power States
Releases AMA Address
PARK PMA
SNIFF
HOLD AMA

Types of Links and Packets

Synchronous Connection Oriented(SCO)

- Point to point full duplex link.
- Typically used for voice data.
- These packets do not use CRC and are not retransmitted.
- Needs an asynchronous connectionless (ACL) type link to be first established.



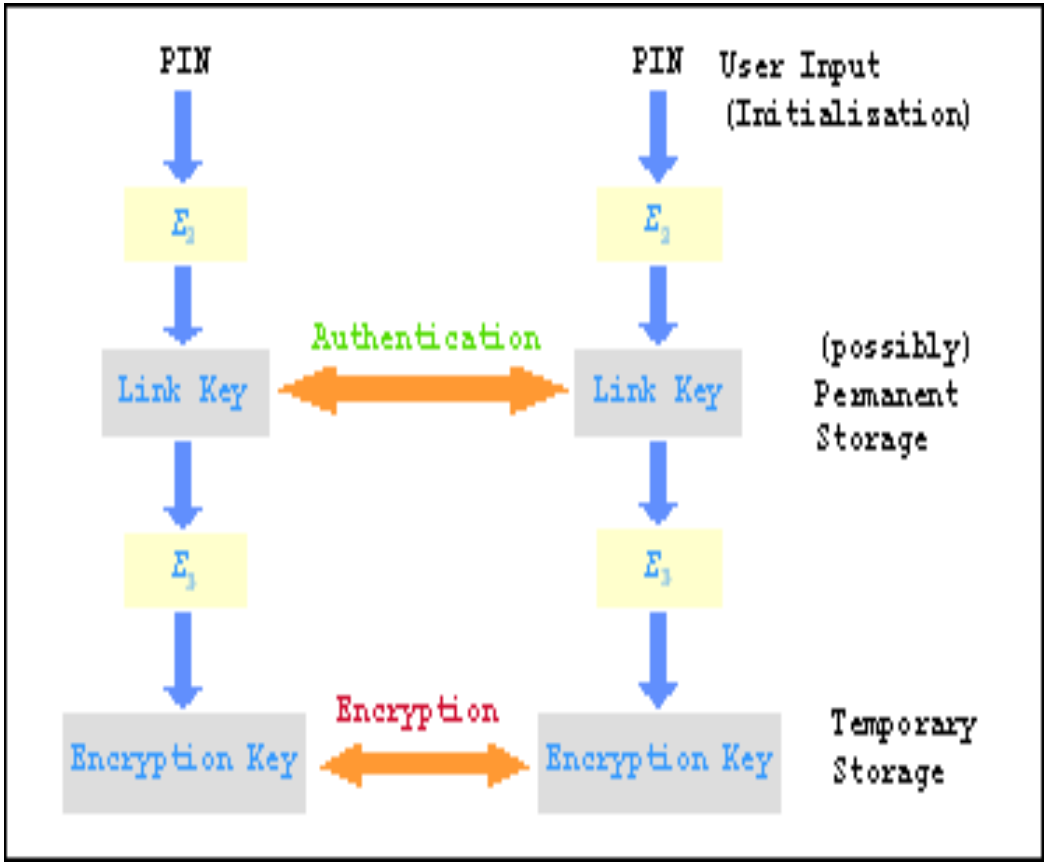
Asynchronous Connectionless Link

- This is a packet switched link between a master and slave.
- Supports both isochronous and asynchronous data.

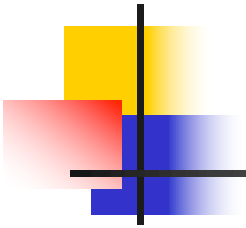
Error Correction Schemes

- Forward error correction(1/3 and 2/3)
- Automatic Repeat Request scheme.

Security



- **Authentication and encryption is provided at the Link Manager layer.**
- **The PIN is translated into a 128 bit link key which is used for authentication.**
- **After authentication the radios will settle on a suitable length encryption key to be used.**
- **Bluetooth relies on PIN codes to establish trusted relationships between devices.**



References

- Bluetooth Architecture Overview

  James Kardach
- www.bluetooth.com
- www.palowireless.com