Bluetooth

- Bluetooth technology is a short-range wireless communication technology that is simple, secure, and everywhere.
- The key features of Bluetooth technology
- Less complication
- Less power consumption
- Available at cheaper rates
- Robustness.

Bluetooth can provide consumers with the ability to do the following.

- Make calls from a wireless headset connected remotely to a cell phone.
- Eliminate cables linking computers to printers, keyboards and the mouse.
- Hook up MP3 players wirelessly to other machines to download music.
- Set up home networks so that a couch potato can remotely monitor air conditioning, the oven and children's Internet surfing.
- Call home from a remote location to turn appliances on or off, set the alarm and monitor activity.

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History of Bluetooth

version	year	Data rate
V1.0	1999	
V1.1	2002	
v1.2	2003	1Mbps
v2.0 + Enhanced Data Rate	04 November 2004	3Mbps
V3.0 + High Speed (traffic is carried over a collocated 802.11 link.)	21 April 2009	24 Mbps
V4.0 (3 in 1) Bluetooth Smart	30 June 2010	• Classic Bluetooth • Bluetooth high speed • Bluetooth low energy
V4.2	December 2, 2014	• IoT flexible • Smarter • faster

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Bluetooth Application Areas

- ## Data and voice access points
  - Real-time voice and data transmissions by effortless wireless connection of portable and stationary communication devices.

- ## Cable replacement
  - Eliminates need for numerous cable attachments for connection (range of radio is approximately 10 m, but can be extended to 100 m with an optimal amplifier.)
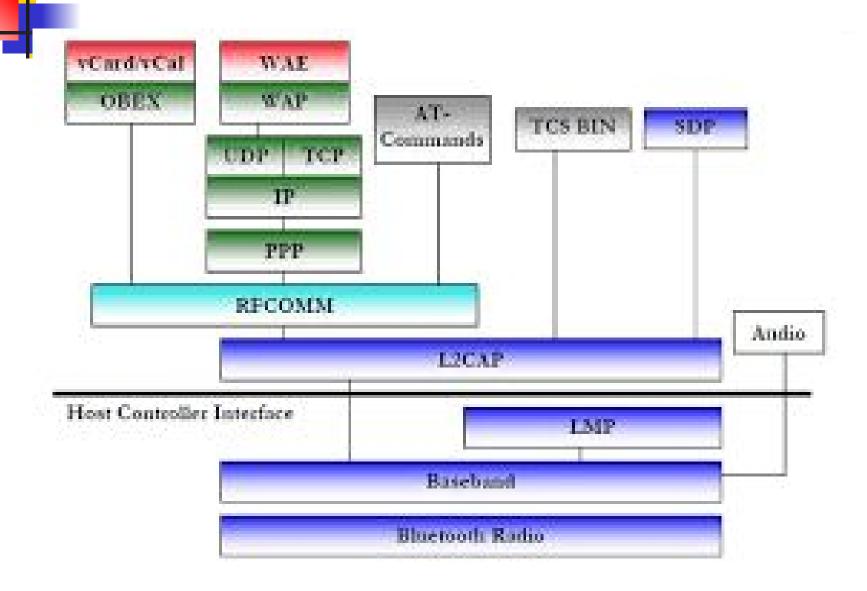
- ## Ad hoc networking
  - Device with Bluetooth radio can establish connection with another when in range

Bluetooth Protocol Architecture

- The protocol architecture of the bluetooth consists of following in a **Bluetooth protocol stack**:

• Core protocols consisting 5 layer protocol stack viz. radio, baseband, link manager protocol, logical link control and adaptation protocol, service discovery protocol.

• Cable replacement protocol, RFCOMM

• Telephony Control Protocols

• Adopted protocols viz. PPP,TCP/UDP/IP,OBEX and WAE/WAP

Core Protocols

Radio: This protocol specification defines air interface, frequency bands, frequency hopping specifications, modulation technique used and transmit power classes.

Baseband: Addressing scheme, packet frame format , timing and power control algorithms required for establishing connection between bluetooth devices within piconet defined in this part of protocol specification.

Link Manager protocol: It is responsible to establish link between bluetooth devices and to maintain the link between them. This protocol also includes authentication and encryption specifications. Negotiation of packet sizes between devices can be taken care by this.

Logical link control and adaptation protocol: This L2CAP protocol adapts upper layer frame to baseband layer frame format and vice versa. L2CAP take care of both connection oriented and connectionless services.

Service discovery protocol: Service related queries including device information can be taken care at this protocol so that connection can be established between bluetooth devices.

- **Cable replacement protocol**

Serial ports are popular to provide serial communication between devices. Bluetooth uses RFCOMM as cable replacement protocol. RFCOMM functions as virtual serial port and does transport of binary digital data bits. It basically emulates RS232 specifications over bluetooth physical layer.

- **Telephony Control Protocols**

TCS-BIN is the protocol used here which is a bit oriented one. It specifies call control signals and mobility management procedures. These signals take care of establishing speech and data calls.

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- **Adopted protocols**

These protocols are already defined by other standard bodies which are incorporate without any change in the bluetooth protocol stack architecture. The protocols are PPP,TCP/UDP/IP,OBEX and WAE/WAP.

Radio Specification

- Classes of transmitters
  - Class 1: Outputs 100 mW for maximum range
    - Power control mandatory
    - Provides greatest distance, have a range of 100 meters
  - Class 2: Outputs 2.5 mW at maximum, have a range of 10 meters
    - Power control optional
  - Class 3: Nominal output is 1 mW, have a range of up to 1 meter
    - Lowest power

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Bluetooth Radio and Baseband Parameters

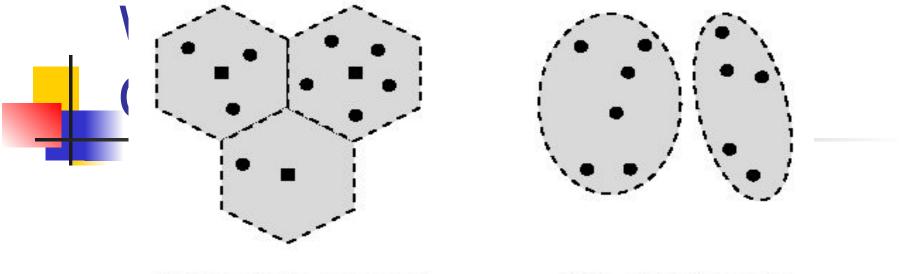|	
Topology	Up to 7 simultaneous links in a logical star
Modulation	GFSK (Gaussian FSK, Mini Deviation 115kHz)
Peak data rate	1 Mbps
RF bandwidth	220 kHz (–3 dB), 1 MHz (–20 dB)
RF band	2.4 GHz, ISM band
RF carriers	23/79
Carrier spacing	1 MHz
Transmit power	0.1 W
Piconet access	FH-TDD-TDMA
Frequency hop rate	1600 hops/s
Scatternet access	FH-CDMA

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Piconets and Scatternets

- **Piconet**
  - Basic unit of Bluetooth networking (ad hoc fashion)
  - Master and one to seven slave devices (3-bit address)
  - Master determines channel and phase (synchronise)
  - Star network, with the master as the centre node
  - Two piconets may exist within radio range of each other
  - Difference piconets will randomly collide on the same frequency (Frequency hopping is not synchronised between piconets)
  - star network

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Scatternet

When connecting two piconets the result will be a scatternet

- Device in one piconet may exist as master or slave in another piconet
- Allows many devices to share same area
- Makes efficient use of bandwidth

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(a) Cellular system (squares represent
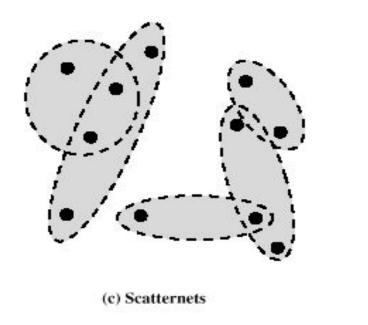stationary base stations)

(b) Conventional ad hoc systems

(c) Scatternets

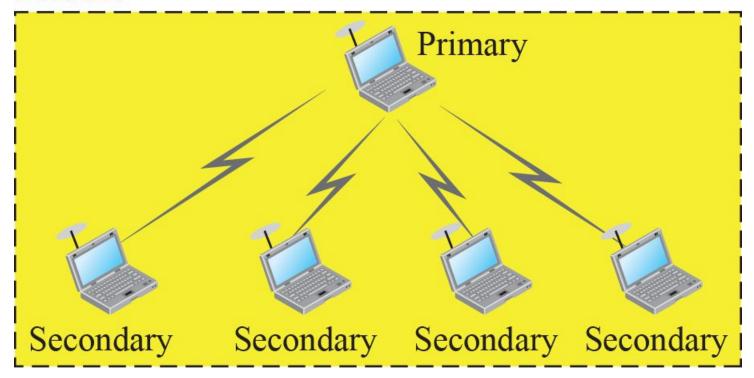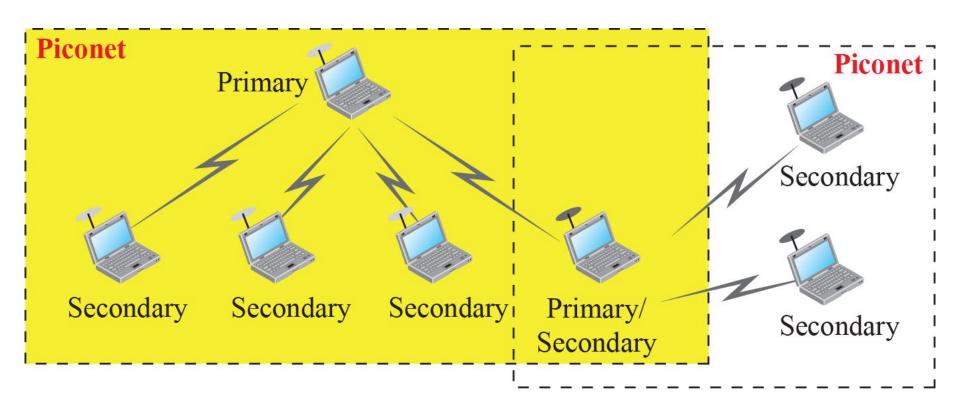**Figure 15.5 Wireless Network Configurations**
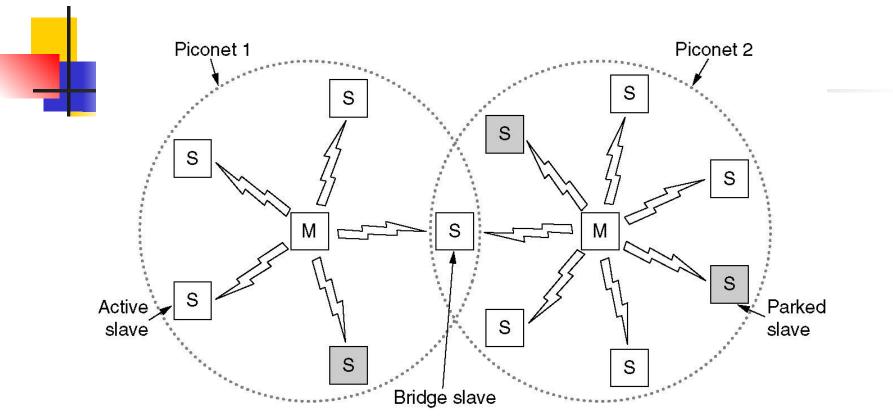
Piconet

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Figure : Scatternet

Scatternet

Maximum of seven slavers/secondaries, additional secondaries can be in the parked states, which is synchronised with the primary, but cannot take part in communication until it is moved from the parked state to the active state (an active station must goto the parked state.)

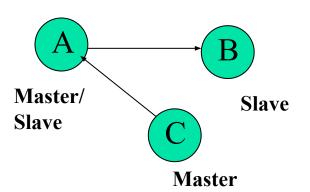# Master/Slave Switching

Role switching enable two devices to switch roles in a piconet.

A connects to B, (A becomes the Master of piconet consisting of A and B)

C wants to join in the piconet.

C connects to A. C is the Master of second piconet consisting of C and A. (A is the slave in the 2nd piconet.)

A —→ B
Master   Slave

A —→ B
Master/
Slave   Slave
C
Master

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Bluetooth Layers
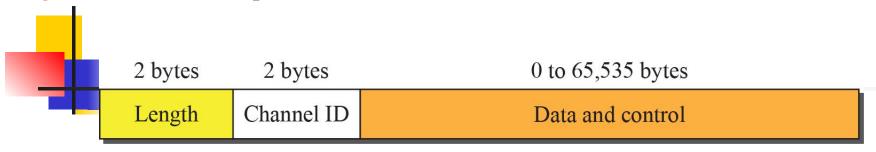
Figure : L2CAP data packet format

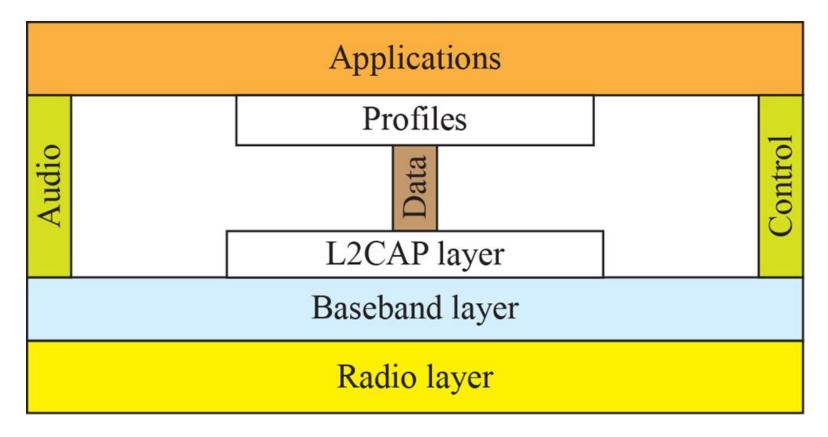| 2 bytes	2 bytes	0 to 65,535 bytes
Length	Channel ID	Data and control

16-bit length field difines the size of the data, in bytes, coming from the upper layers (up to 2^{15} -1=65535 bytes).

Channel ID (CID) defines a unique identifier for the virtual channel created at this level.

The L2CAP has duties of multiplexing, segmentation and reassembly, QoS and group management.

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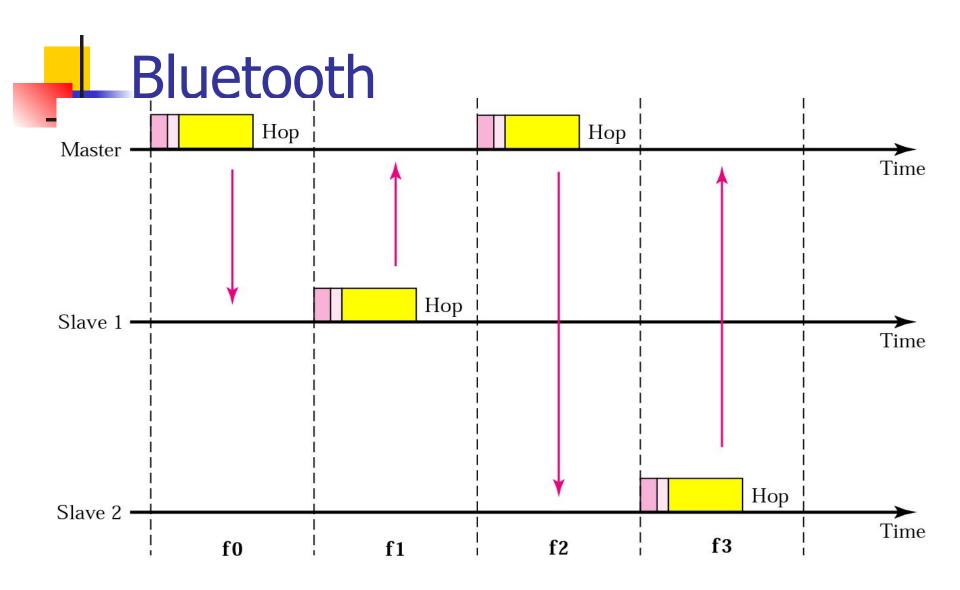
Baseband layer

➢ Equivalent to the MAC sublayer in LAN

➢ Access method is TDD (time-division duplex)-TDMA

➢ Time slot is 625 μs (one frequency is used)

➢ Slaves cannot communication directly with one another

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Bluetooth
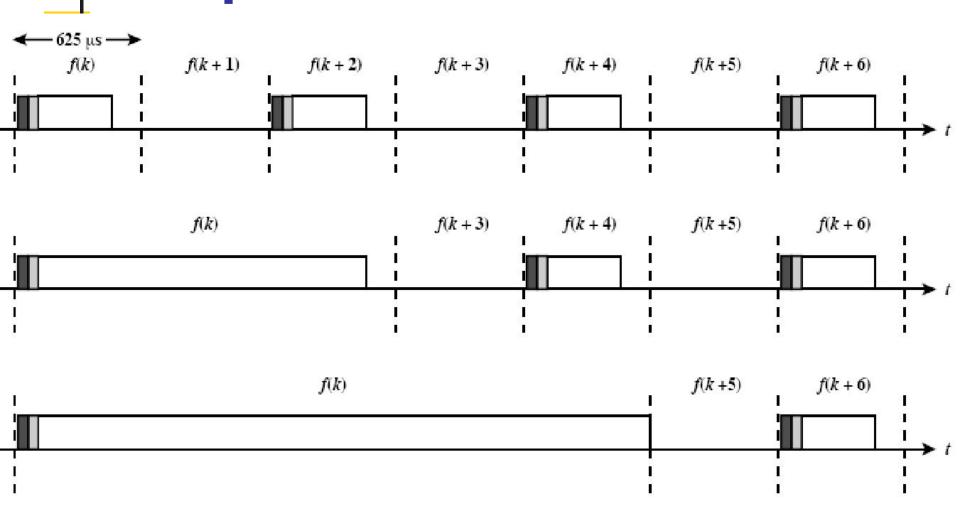
- Time is divided in 625 μsec, 3x625 μsec, or 5x625 μsec slots.
- Master uses even numbered slots.
- Slaves use odd numbered slots that are designated by the master.

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Bluetooth

Examples of Multislot Packets

Max rate: 5 slot unprotected packetwith ACL, 721 kbps in forward, 57.6 kbps in the reverse   25

Bluetooth links

Two types of logical links are defined between master and slave.
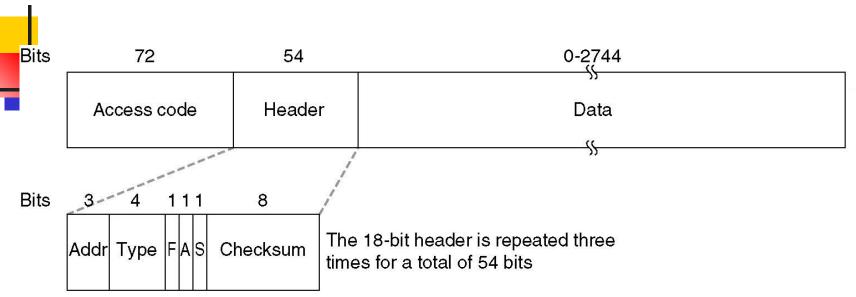
❑Asynchronous ConnectionLess (ACL) links are used bursty data traffic with no QoS guarantee. Frames can be lost and retransmitted on ACL links. Point-to-multipoint. Master-to all slaves.

❑Synchronous Connection Oriented (SCO) links are used for real-time traffic (typically telephony). This type of link is allocated a fixed slot in each direction. There are no retransmissions. Instead there is forward error correction on SCO. Point-to-point

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Bluetooth Link Security

- Elements:
    - Authentication – verify claimed identity
    - Encryption – privacy
    - Key management and usage
- Security algorithm parameters:
    - Unit address
    - Secret authentication key
    - Secret privacy key
    - Random number

Bluetooth frame format

Bits	72	54	0-2744
	Access code	Header	Data

Bits	3	4	1 1 1	8	
	Addr	Type	F A S	Checksum	The 18-bit header is repeated three times for a total of 54 bits

- Access code: contain synchronisation bits and the identifier of the primary to distinguish the frame of one piconet from that of another (in case there are several masters within the radio range).
- Address defines up to 7 secondary nodes.
- Type defines link type (e.g., SCO, ACL)
- F: Flow control bit
- A: Acknowledgement bit
- S: Sequence number

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Bluetooth radio layer

- Band: 2.4 GHz ISM Band is used with 79 channels of 1 MHz each.
- FHSS: (frequency-hopping spread spectrum)
- Bluetooth physical layer uses FHSS at 1600 hops/sec.
- Dwell time (time spent in one carrier) is 1s/1600=625 µsec.
- It takes 250-260 µsec to settle in one carrier frequency.
- The radio designated as the **master** makes the determination of the channel (frequency hopping sequence) and phase (timing offset, i.e., when to transmit) that shall be used by all devices on this piconet.
- A slave may only communicate with the master and may only communicate when granted permission by the master.
- Modulation: GFSK (FSK with Gaussian bandwidth filtering)

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Frequency Hopping in Bluetooth

- Provides resistance to interference and multipath effects
- Provides a form of multiple access among co-located devices in different piconets

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Frequency Hopping
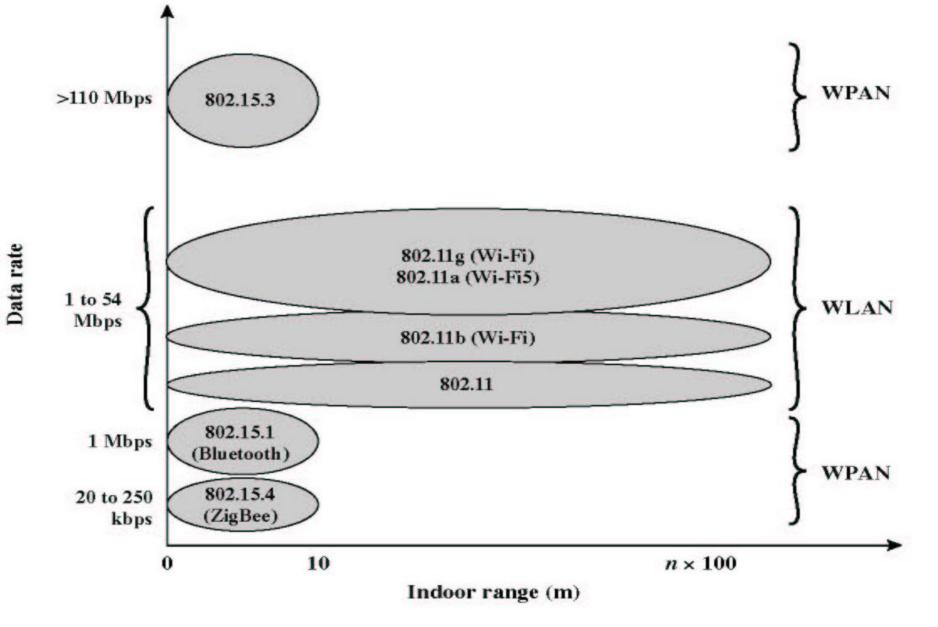
- Total bandwidth divided into 1MHz physical channels
- FH occurs by jumping from one channel to another in pseudorandom sequence (1600 hops/Sec)
- Slot is 1/1600 = 625 μsec.
- Packet length is 1, 3 or 5 slots. (2 or 4 hop frequencies have been skipped)
- Hopping sequence shared with all devices on piconet, which is a function of Master's Bluetooth address.
- Piconet access:
    - Bluetooth devices use time division duplex (TDD)
    - Access technique is TDMA
    - FH-TDD-TDMA

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IEEE 802.15 is a working group of the Institute of Electrical and Electronics Engineers (IEEE) IEEE 802 standards committee which specifies wireless personal area network (WPAN) standards.

1 Task Group 1: WPAN / Bluetooth

2 Task Group 2: Coexistence

3 Task Group 3: High Rate WPAN

4 Task Group 4: Low Rate WPAN

    4.1 WPAN Low Rate Alternative PHY (4a)

    4.2 Revision and Enhancement (4b)

    4.3 PHY Amendment for China (4c)

    4.4 PHY and MAC Amendment for Japan (4d)

    4.5 MAC Amendment for Industrial Applications (4e)

    4.6 PHY and MAC Amendment for Active RFID (4f)

    4.7 PHY Amendment for Smart Utility Network (4g)

5 Task Group 5: Mesh Networking

6 Task Group 6: Body Area Networks

7 Task Group 7: Visible Light Communication

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IEEE 802.15 Protocol Architecture

Logical link control (LLC)					
802.15.1 MAC	802.15.3 MAC		802.15.4 MAC		
802.15.1 2.4-Ghz 1 Mbps	802.15.3 2.4-Ghz 11, 22, 33, 44, 55 Mbps	802.15.3a ? >110 Mbps	802.15.4 868-MHz 20 kbps	802.15.4 915-MHz 40 kbps	802.15.4 2.4-GHz 250 kbps

Figure showing wireless standards plotted by Data rate (vertical axis) versus Indoor range (m) (horizontal axis).

- Data rate: >110 Mbps — 802.15.3 — WPAN
- Data rate: 1 to 54 Mbps — 802.11g (Wi-Fi), 802.11a (Wi-Fi5); 802.11b (Wi-Fi); 802.11 — WLAN
- Data rate: 1 Mbps — 802.15.1 (Bluetooth) — WPAN
- Data rate: 20 to 250 kbps — 802.15.4 (ZigBee) — WPAN

Horizontal axis: Indoor range (m), marked at 0, 10, $n \times 100$.

Latest technology: Bluetooth smart v4.0 (June 2010), v4.1(Dec 2013) &v4.2 (Dec 2014)

30 June 2010

Three specifications in one –

- Classic Bluetooth technology,
- Bluetooth low energy technology, known as Wibree

  it is aimed at very low power applications running off a coin cell

  "Bluetooth Smart Ready" for hosts and

  "Bluetooth   Smart" for sensors

- Bluetooth high speed technology, based on Wi-Fi.

all which can be combined or used separately in different devices according to their functionality

Bluetooth Smart Ready products

Manufacturer	Product Name	Type of Product
Apple	iPad (Air, Mini, 3rd & 4th gen)	Tablet
Apple	iPhone (5s, 5c, 5 & 4s)	Phone
Apple	iPod touch	Portable Media Player
Apple	MacBook Air	Laptop
Apple	MacBook Pro	Laptop
Apple	Mac mini	Computer
Apple	Apple TV	Smart TV console
Google	Nexus 5, Nexus 4	Phone
Google	Nexus 7, Nexus 10	Tablet
BlackBerry	Q10	Phone
BlackBerry	Z10	Phone
connectBlue	OBS421	Module
DISH	Hopper	DVR
DISH	Hopper with Sling	DVR
Fujitsu	Arrows	Tablet
Fujitsu	Lifebook Series	Laptop Tablet
Fujitsu	Stylistic Series	Laptop Tablet
HTC	One, One Max	Phone
Microsoft	Surface	Tablet
Motorola	Droid RAZR, Ultra, Maxx, Mini	Phone
Motorola	Moto G, X	Phone
NEC	LaVie Series	Laptop
NEC	VersaPro Series	Laptop
Panasonic	CF-LX3	Laptop
Samsung	All-In-One PC 700A3D	Laptop
Samsung	ATIV Smart PC	Laptop
Samsung	Galaxy Series	Phone
Sony	VAIO S Series	Laptop
Sony	Xperia Series	Phone
Sony	Xperia Series	Tablet

Samsung I9300 Galaxy S III

GENERAL	2G Network	GSM 850 / 900 / 1800 / 1900
	3G Network	HSDPA 850 / 900 / 1900 / 2100
	SIM	Micro-SIM
	Announced	2012, May
	Status	Available. Released 2012, May
BODY	Dimensions	136.6 x 70.6 x 8.6 mm (5.38 x 2.78 x 0.34 in)
	Weight	133 g (4.69 oz)
DISPLAY	Type	Super AMOLED capacitive touchscreen, 16M colors
	Size	720 x 1280 pixels, 4.8 inches (~306 ppi pixel density)
	Multitouch	Yes
	Protection	Corning Gorilla Glass 2
		- TouchWiz UI
SOUND	Alert types	Vibration; MP3, WAV ringtones
	Loudspeaker	Yes
	3.5mm jack	Yes
MEMORY	Card slot	microSD, up to 64 GB
	Internal	16/32/64 GB storage, 1 GB RAM
DATA	GPRS	Class 12 (4+1/3+2/2+3/1+4 slots), 32 - 48 kbps
	EDGE	Class 12
	Speed	HSDPA, 21 Mbps; HSUPA, 5.76 Mbps
	WLAN	Wi-Fi 802.11 a/b/g/n, dual-band, DLNA, Wi-Fi Direct, Wi-Fi hotspot
	Bluetooth	Yes, v4.0 with A2DP, EDR
	NFC	Yes
	USB	Yes. microUSB v2.0 (MHL), USB On-the-go

Bluetooth Low Energy Wireless Technology

- Ultra-low peak, average and idle mode power consumption
- Ability to run for years on standard coin-cell batteries
- Low cost
- Multi-vendor interoperability
- Enhanced range

Used in
watches and toys
pedometers and glucose monitors

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Bluetooth High Speed Technology

- Power Optimization
- Improved Security
- Enhanced Power Control
- Lower Latency Rates

V2.1 + Enhanced Data Rate

- Lower Power Consumption
- Improved Security

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