Bluetooth: Overview of architecture, PHY and MAC

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Contents

1. Introduction to Bluetooth

2. Overall Bluetooth Architecture and Mapping with OSI

2.1 Physical Layer (PHY) issues

2.1.1 Functions

2.1.2 Regulatory requirements

2.1.3 Transmitter characterstics

2.1.4 Receiver characterstics

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Contents (continued...)

2.2 Medium Access Control (MAC) issues

2.2.1 Baseband specifications

2.2.2 Link Managaer Protocol

2.2.3 L2CAP Specification

2.3 Control Specification Issues

2.4 SAP interfaces and issues

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Contents (continued...)

3. Bluetooth 2 – EDR

4. Future Bluetooth

5. Further Comments and Conclusion

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1. Introduction to Bluetooth

- Bluetooth is a specification of Wireless Personal Area Networks (WPANs).
- Bluetooth is also known as **IEEE 802.15.1**.
- The Bluetooth technology uses a short-range radio link that has been optimized for small-size personal devices.
- Bluetooth connections are created in ad-hoc manner to exchange information between devices such as mobile phones, laptops, printers, digital cameras etc.

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1. Introduction to Bluetooth (Continued.....)

- Bluetooth WPAN can be connnected in communications with other LANs through the use of Gateway.
- Bluetooth operates in the unlicensed 2.4 GHz ISM band.

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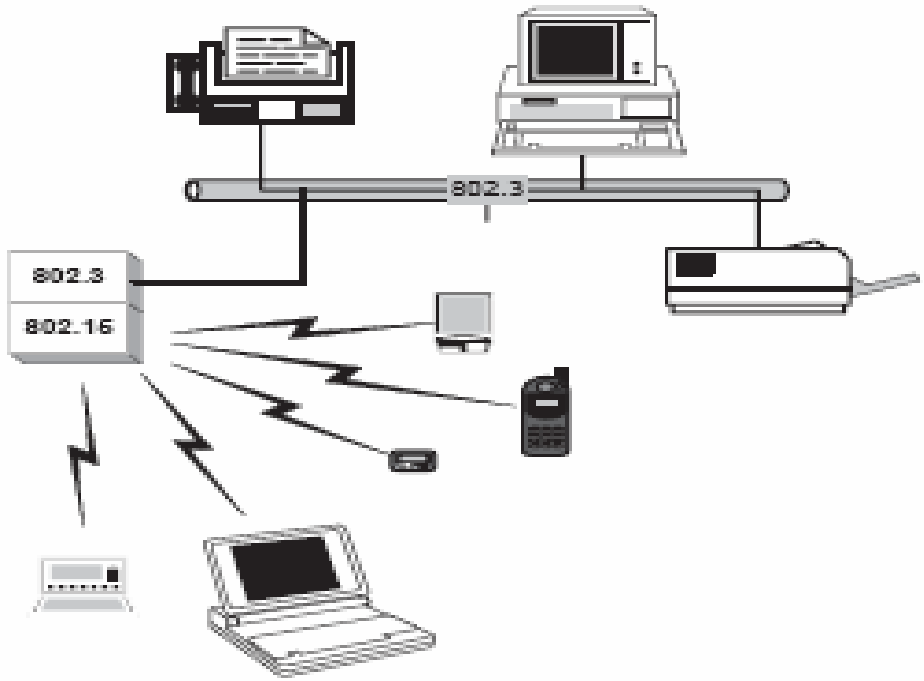
1. Introduction to Bluetooth (Continued.....)



Bluetooth in connection with other LAN

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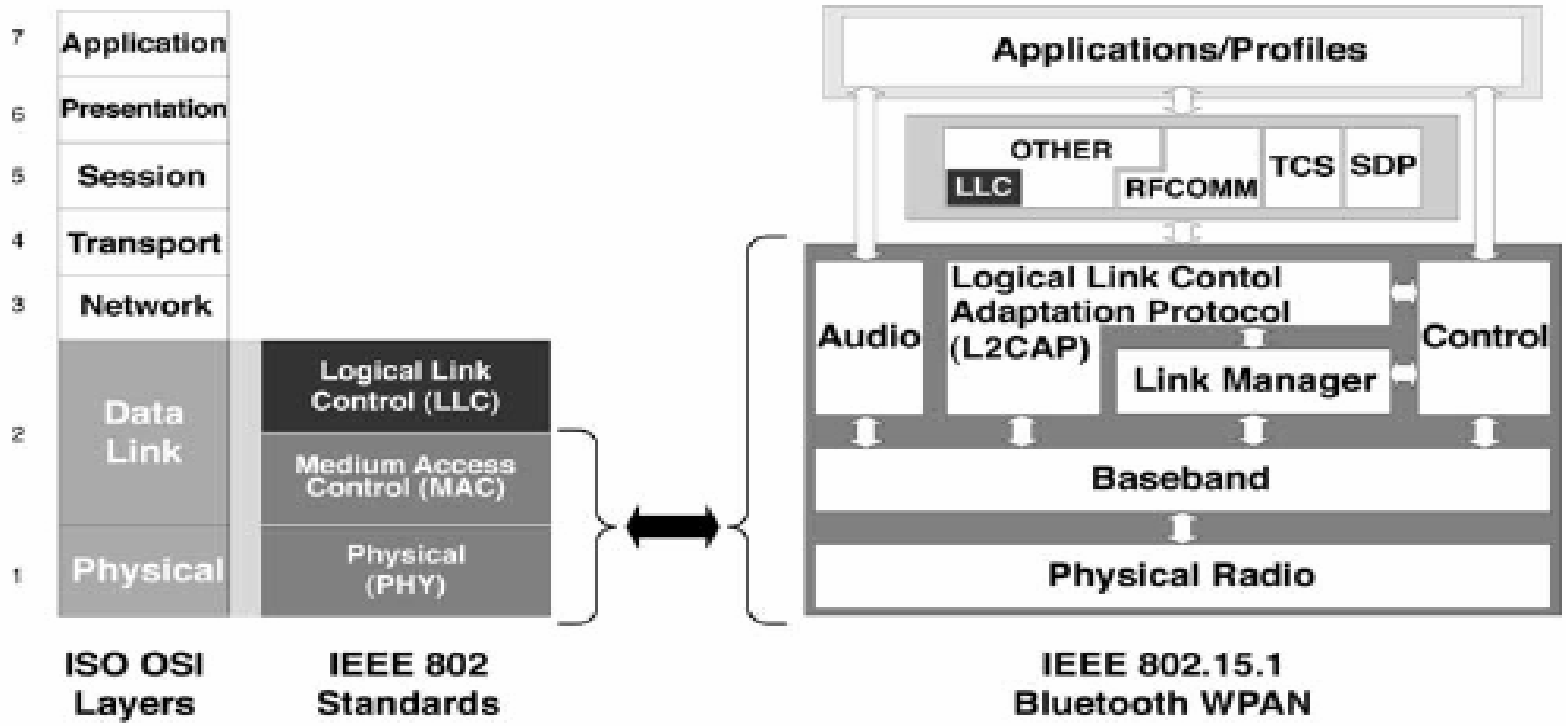
2. Overall Bluetooth Architecture and Mapping with OSI and IEEE 802



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2.1 Physical Layer (PHY) issues

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2.1.1 Functions

- Responsible for transferring bits between adjacent systems over the air interface.
- Receives a bit stream from the MAC sublayer and transmits the bit stream via radio waves to the associated station or vice versa.

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2.1.2 Regulatory requirements

- The Bluetooth transceivers operate in 2.4 GHz ISM band.
- Products implementing the reduced frequency band will not work with the products that implement full band.

Geography	Regulatory range (GHz)
US, Europe and most other Countries	2.400-2.4835
France	2.4465-2.4835

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2.1.3 Transmitter Charecterstics

- The equipment can be divided into three power class categories.
- GFSK (Gaussian Frequency Shift Keying) is used with Bandwidth Time (BT) product of 0.5.

Power class	Maximum Output Power	Nominal Output power	Minimum Output power
1	100 mW	N/A	1 mW
2	2.5 mW	1 mW	0.25 mW
3	1 mW	N/A	N/A

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2.1.4 Receiver Charecterstics

- The Bluetooth receiver sensitivity level is approximately -70 dBm or better.
- The receiver should have the capability to measure its signal strength and determine wheather the transmitter should increase or decrease the power. This is the RSSI measurement.

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2.1.4 Receiver Charecterstics (Continued....)

- RSSI measurement compares the received signal level with two thresholds. The lower threshold is approximately -56 dBm.

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2.2 Medium Access Control (MAC) Issues

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2.2.1 Baseband Specification

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2.2.1.1 Some General Ideas

- The Symbol rate is 1 Msymbols/s.
- TDD is used.
- Information is exchanged along the channel in terms of packets.
- A packet can take single slot, or it can cover upto 5 slots.
- Bluetooth can support up to three simultaneous synchronous voice channels, or it can support a channel which simultaneously supports asynchonous data and synchronous voice.

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2.2.1.1 Some General Ideas (Continued...)

- Bluetooth supports point-to-point connection as well as point-to-multipoint connections.
- In multipoint connection the channel is shared between some devices forming *piconet*.
- In a piconet one device act as the master and others are slave. Upto seven slaves can be there in a piconet.

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2.2.2 Physical Channels

- The channel is divided into time slots. Each time slot is 625 *micro-seconds* in length.
- TDD scheme is used between the master and slave for transmission purpose.
- The Master starts its transmission in the even-numbered slot only whereas the slaves start to transmit in the odd-numbered only.

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2.2.1.2 Physical Links

- There are two different types of link that can be defined between the master and the slave.
- Synchronous Connection Oriented (SCO) link.
- Asynchronous Connection Less (ACL) link.

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2.2.1.2 Physical Links (Continued....)

- The SCO link is defined as a symmetric, point-to-point link between the master and the slave.
- The SCO link can be thaught to be a circuit-switched connection.
- The master can support upto 3 SCO links to the same slave or different slaves.
- The master sends SCO packets in the regular interval known as *Tsco* in the master-to-slave slots.

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2.2.1.2 Physical Links (Continued....)

- ACL link is a point-to-multipoint link between the master and all the slaves participating in the piconet.
- The master can establish an ACL link on the per-slot basis with any slave.
- ACL links provide a packet-switched connection.

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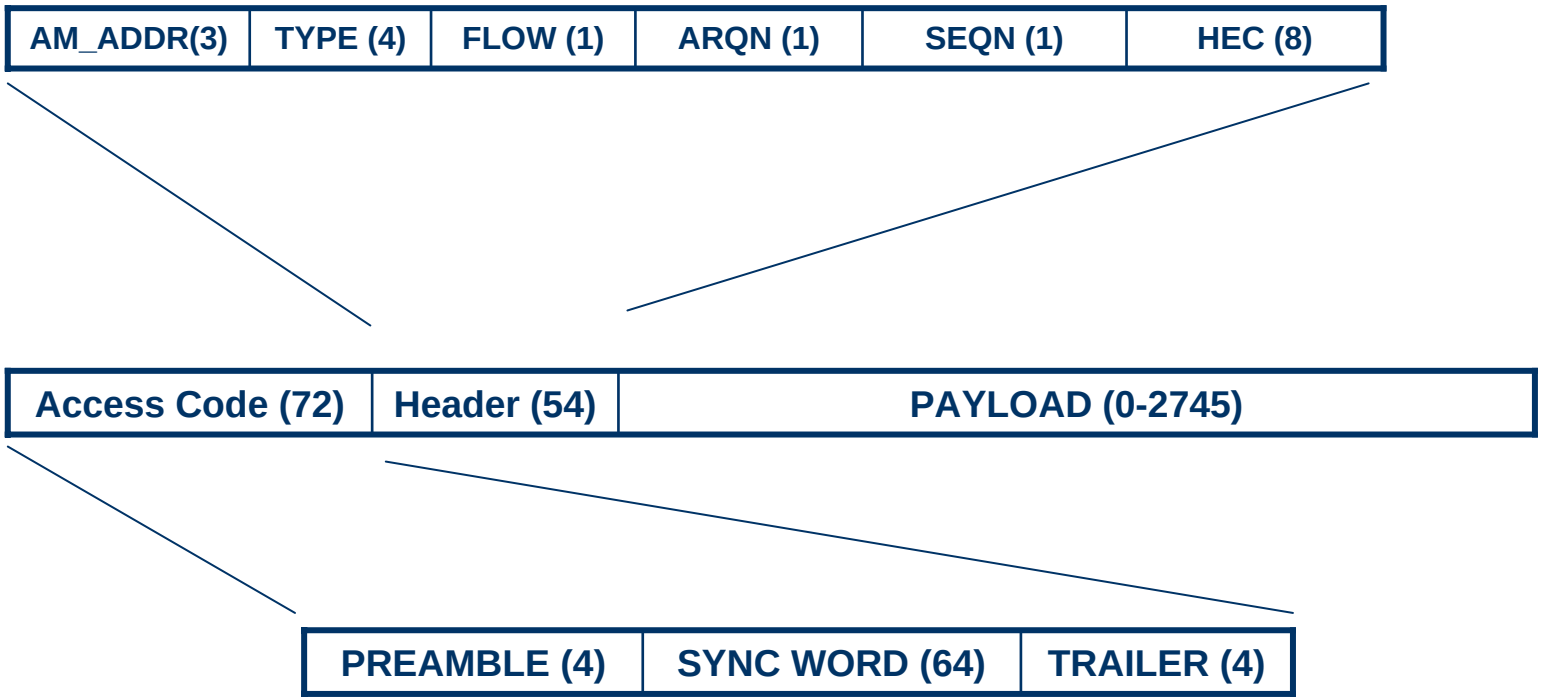
2.2.1.3 Baseband Packet Format



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2.2.1.4 Error correction scheme

Three error correction schemes can be used:

- 1/3 rate forward error correction (FEC)
- 2/3 rate forward error correction (FEC)
- Automatic Repeat Request Scheme (ARQ)

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2.2.1.5 Baseband Modes

During the connection, a Bluetooth device can be in the following modes:

- In ***Active mode*** an unit actively participates in the channel.
- In ***Sniff mode*** the duty cycle of the slave's listen activity is reduced.
- In ***Hold mode*** the unit does not need to send data for relatively long time.
- In ***Park mode*** the unit will have very little activity consuming very low power.

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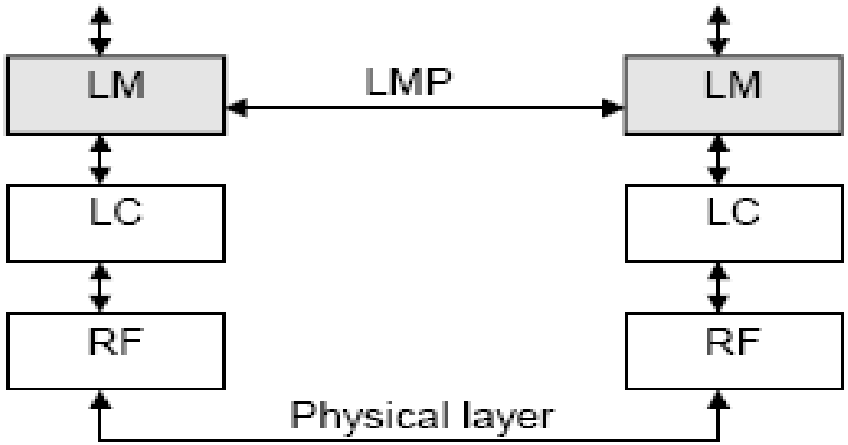
2.2.2 Link Manager Protocol (LMP)

- LMP is used for link setup and control.



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2.2.2 Link Manager Protocol (Continued...)

- Link manager of the receiving side filters out the signal.
- Link manager messages have higher priority than the user data.
- LM messages should not be delayed by the user traffic.

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2.2.2 Link Manager Protocol (Continued...)

- Link Control (LC) provides the reliability to the LMP.
- LM PDUs are sent in single-slot packets.
- The header length is 1 byte.The two least significant bits determine the message type. If these two bits are set, then it is an LMP message.

Two least significant bits	Information
00	Undefined
01	Continuing L2CAP message
10	Start L2CAP message
11	LMP message

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2.2.2 Link Manager Protocol (Continued....)

Opcode and Transaction ID	Content

- Each PDU is assigned a 7-bit opcode that is used to uniquely identify different types of PDUs.
- 1 bit transaction ID are also used. This transaction ID with the 7 bits opcode are placed in the first byte of the payload body.
- Transaction ID is inserted as the LSB.

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2.2.2 Link Manager Protocol (Continued....)

- LMP also ensures security.
- The authentication procedure is based on the Challenge-Response scheme.
- The receiver sends a PDU containing the challenge (a random number).
- The sender calculates the response by using a secret key and sends it to the receiver.
- The receiver checks wheather the response is correct or not.

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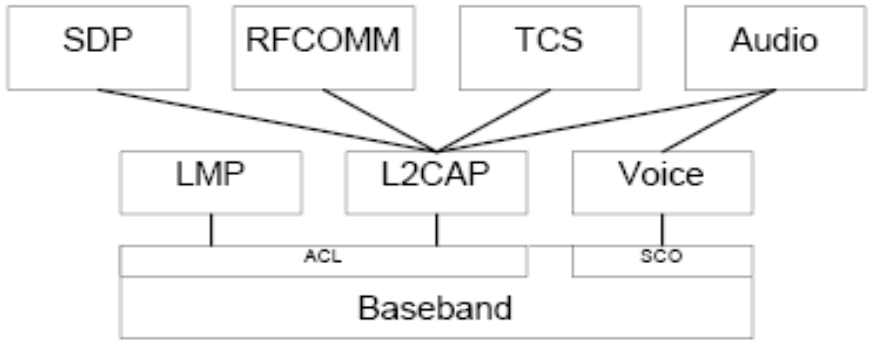
2.2.3 Logical Link control and Adaptation Protocol

- L2CAP defines the logical link control and adaptation layer protocol specifications.



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2.2.3 Logical Link control and Adaptation Protocol (Continued.....)

- L2CAP provides connection-oriented or connectionless data services to the higher layers.
- It has the capablity of protocol multiplexing, segmentation and reassembly and group management operations.
- L2CAP allows higher layers to transmit and receive packets upto 64 Kilobytes.

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2.2.3 Logical Link control and Adaptation Protocol (Continued.....)

- L2CAP lies above the Baseband protocol in the protocol stack and provides communication with some other communication protocols such as SDP, RFCOMM and TCS..
- L2CAP is defined only for ACL links. It is not defined for SCO links.

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2.2.3 Logical Link control and Adaptation Protocol (Continued.....)

Requirements:

- L2CAP should be simple and low overhead.
- It should not take excessive power and also excessive memory.
- The complexity should be acceptable even for the small hand held devices.
- L2CAP distinguishes between the upper layer protocols.

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2.3 Control Specifications

- It describes the functional specification of the control interface management.
- It is based on the HCI interface.
- It provides a HCI based command interface to the Baseband controller and link manager.
- HCI commands can be used to access the Bluetooth hardware capabilities.

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2.4 Service Access Point Interfaces issues

- It describes the functions, features, protocol, services and SAP between the MAC and LLC layer. These are the same as the IEEE 802 standards.

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3. Bluetooth 2 - EDR

- It was specified in November, 2004.
- Maximum data rate is about 3 Mbps.
- Backward compatible with previous versions.
- Two new modulation schemes are necessary in addition to the previously used GFSK.These are DQPSK and 8DPSK.
- DQPSK is mandatory while 8DPSK is optional.

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3. Bluetooth 2 – EDR (Continued....)

Improvements from the previous versions:

- 3 times faster transmission speed.
- Low Power consumption.
- Better BER performence.

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4. Future Bluetooth

The next version is given a code name ***Lisbon***. It includes a number of features to increase the security, usability and quality of service.The newly added features are:

- Automatic encryption change.
- Extended inquiry response.
- QOS imoprovement.
- Sniff subrating.

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4. Future Bluetooth (Continued.....)

- The next version after Lisbon is ***Seattle***. It will be called Bluetooth 3.0. It will adopt UWB enabling a very fast data transfer of 480 Mbit/s.

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5. Further Comments and Conclusion

- Bluetooth meets the demands requiring connectivity solutions that respect the primary functionality of the personal devices those are limited in weight, power requirements, cost, ease of use, or other traits in a significant way.
- Bluetooth is slightly different from the WLAN from the Power level & Coverage and Lifespan of the network point of view. In a simple word, we can say the devices for Bluetooth is more mobile than the WLAN.

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