RADFORD UNIVERSITY

Wireless Communication

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Key Reference:
Prof. Jong-Moon Chung's Lecture Notes at Yonsei University

Wireless Communications

- Bluetooth
- Wi-Fi
- Mobile Communications
- LTE
- LTE-Advanced
- 5G Technology

Bluetooth

Bluetooth

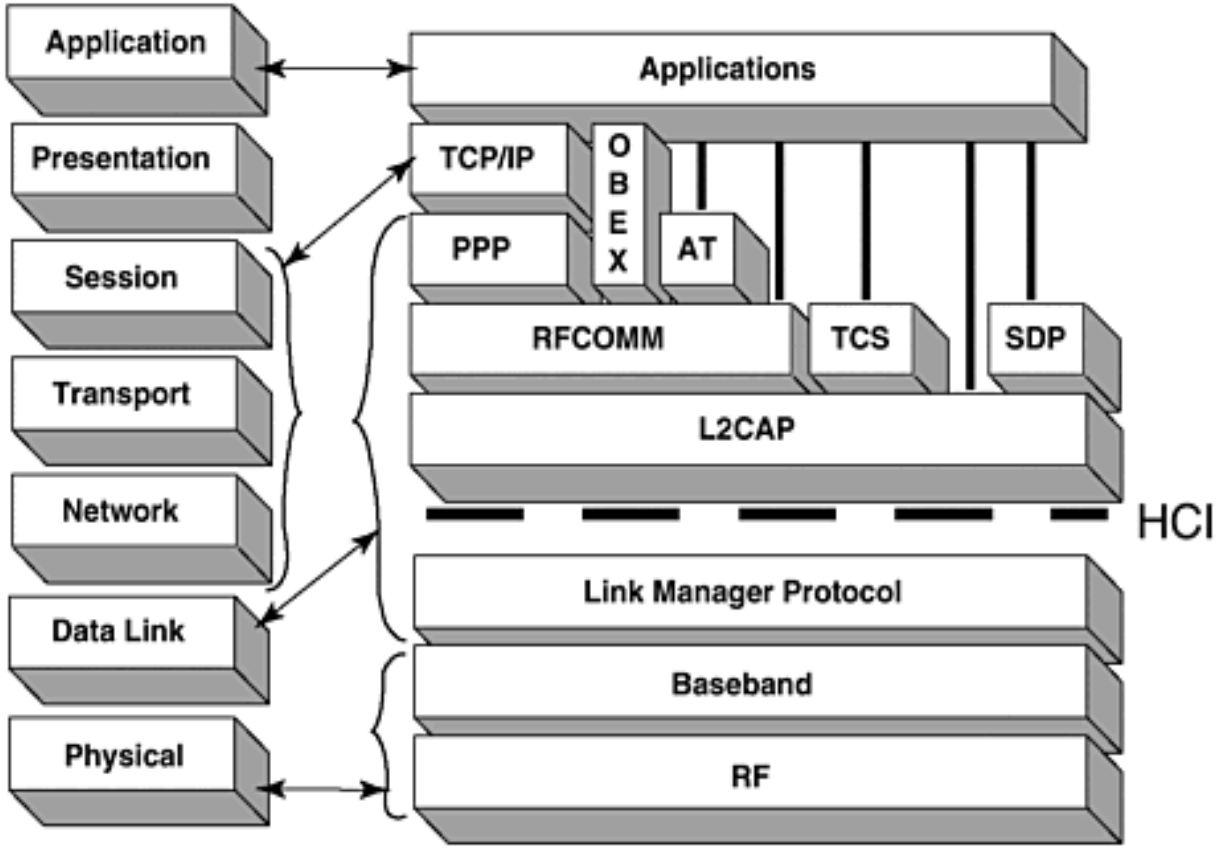
Bluetooth

- Bluetooth is a WPAN (Wireless Personal Area Network) communications protocol designed by the Bluetooth SIG (Special Interest Group)

- Replaces cables connecting many different types of devices
  - Mobile Phones & Headsets
  - Heart Monitors & Medical Equipment

Bluetooth

Bluetooth Protocol Stack



Bluetooth

Bluetooth Protocol Stack

- LMP: Link Management Protocol
  - Set-up and control of the link between two devices
- L2CAP: Logical Link Control and Adaptation Protocol
  - Multiplex multiple logical connections between two devices
  - Segmentation and reassembly
  - Payload
    - Default MTU: 672 bytes
    - Max: Up to 62KB
    - Min: 48 bytes
  - Retransmission and CRC check

Bluetooth

Bluetooth Protocol Stack

- SDP: Service Discovery Protocol
  - To determine which Bluetooth profiles can be used (ex) A2DP, …

Bluetooth

A2DP (Advanced Audio Distribution Profile)

- A2DP enables wireless transmission of stereo audio from an A2DP smartphone (or computer) to A2DP headphones (or stereo system)

Bluetooth

aptX

- Supports wireless real-time streaming of high quality stereo audio over the Bluetooth A2DP
- Includes proprietary audio codec compression algorithms
- Used in various consumer and automotive wireless audio applications

Bluetooth

Enhanced Data Rate (EDR)

- Introduced in Bluetooth v2.0 to support faster data transfer
- Supports a data rate up to 3 Mbps
- Using reduced duty cycle control, EDR can provide lower power consumption

Bluetooth

Bluetooth High Speed (HS)

- Bluetooth high speed technology was released in April 2009 (in Bluetooth version 3.0+HS)
- Bluetooth 3.0+HS provides data transfer speeds of up to 24 Mbps, though not over the Bluetooth link itself
- Bluetooth link is used for negotiation and establishment, and the high data rate traffic is carried over a collocated 802.11 link

Bluetooth

Bluetooth High Speed (HS)

- +HS part of the specification is not mandatory in Bluetooth version 3.0

- Only devices that display the "+HS" logo actually support Bluetooth over 802.11 high-speed data transfer

Bluetooth

Bluetooth Spec. Evolution

Specifications	1.1	1.2	2.0 + EDR	2.1 + EDR	3.0 +HS	4.0
Adopted	2002	2005	2004	2007	2009	2010
Transmission Rate	723.1 kbps	723.1 kbps	2.1 Mbps	3 Mbps	24 Mbps	25 Mbps
Standard PAN Range	10 m	10 m	10 m	10 m	10 m	50 m
Improved Pairing (without a PIN)				Yes	Yes	Yes
Improved Security		Yes	Yes	Yes	Yes	Yes
NFC Support			Yes	Yes	Yes	Yes

Bluetooth

Bluetooth Feature Evolution

Specifications	1.1	1.2	2.0 + EDR	2.1 + EDR	3.0 + HS	4.0
Voice Dialing	Yes	Yes	Yes	Yes	Yes	Yes
Call Mute	Yes	Yes	Yes	Yes	Yes	Yes
Last-Number Redial	Yes	Yes	Yes	Yes	Yes	Yes
Fast Transmission Speeds			Yes	Yes	Yes	Yes
Lower Power Consumption			Yes	Yes	Yes	Yes
Bluetooth Low Energy						Yes

Bluetooth

Bluetooth 4.0

- Bluetooth Specification 4.0 (called Bluetooth Smart) was adopted in June 2010
- Bluetooth 4.0 includes
  - Former Bluetooth standards
  - BLE (Bluetooth Low Energy)

Bluetooth

BLE (Bluetooth Low Energy)

- **Provide reduced power consumption and cost while maintaining a similar communication range**
  - **1–2 years with a 1,000mAh coin cell battery**
  - Smart protocol which **only transmits small packets** as compared to Bluetooth Classic
  - depending on **type of scans** and **number of Bluetooth Smart devices** in the vicinity

Bluetooth

BLE (Bluetooth Low Energy)

- Defines several profiles (specifications) on how a device can consume very low energy consumption while servicing a particular application

Bluetooth

Profiles

- The profiles provide standards which manufacturers follow to allow devices to use Bluetooth in the intended manner.
- Each profile specification contains information on the following topics at a minimum:
  - Dependencies on other formats
  - Suggested user interface formats
  - Specific parts of the Bluetooth protocol stack used by the profile. To perform its task, each profile uses particular options and parameters at each layer of the stack. This may include an outline of the required service record, if appropriate

Bluetooth

BLE (Bluetooth Low Energy)

- A manufacturer can implement customize specifications for their product
- A device can have multiple BLE profiles
  - Health Care Profiles
  - Sports and fitness profiles
  - IPSP (Internet Protocol Support Profile)
  - ESP (Environmental Sensing Profile)
  - etc.

Bluetooth

Applications of BLE

Health care profiles

- BLP (Blood Pressure Profile) — for blood pressure measurement.
- HTP (Health Thermometer Profile) — for medical temperature measurement devices.
- GLP (Glucose Profile) — for blood glucose monitors.
- CGMP (Continuous Glucose Monitor Profile)

Internet Connectivity

- IPSP (Internet Protocol Support Profile)

Generic Sensors

- ESP (Environmental Sensing Profile)
- UDS (User Data Service)

HID Connectivity

- HOGP (HID over GATT Profile)...

Sports and fitness profiles

- Profiles for sporting and fitness accessories include:
- BCS (Body Composition Service)
- CSCP (Cycling Speed and Cadence Profile) — for sensors attached to a bicycle or exercise bike to measure cadence and wheel speed.
- CPP (Cycling Power Profile)
- HRP (Heart Rate Profile) — for devices which measure heart rate
- LNP (Location and Navigation Profile)
- RSCP (Running Speed and Cadence Profile)
- WSP (Weight Scale Profile)

Bluetooth

Bluetooth Beacons

- Bluetooth beacon devices transmit a unique ID number that can be read by a Bluetooth receiver, which can be used by an Application on ones smartphone
- Bluetooth beacons are now commonly deployed as small devices (many are battery-powered) that broadcasts signals through BLE technology using a Bluetooth low energy antenna

Bluetooth

Bluetooth Beacons

- Smartphone Apps identify the location of the Beacon device and activate location specific information on the smartphone

- Beacons are used in many location based applications
  - Advertisement & Coupon distribution
  - Home Automation Systems
  - Transportation Systems
  - Sport Stadiums, Stores, etc.

Bluetooth

iBeacon

- Protocol developed by Apple and introduced at the Apple Worldwide Developers Conference in 2013
- BLE devices that broadcast their identifier to nearby portable electronic devices
- UUID (Universally Unique Identifier)
- Application is distributing messages at a specific Point of Interest, such as a store, a bus stop, a room, a piece of furniture, or a vending machine.
  - similar to previously used geopush technology based on GPS, but with a much reduced impact on battery life and better precision.

Bluetooth

Bluetooth 4.1

- Bluetooth Specification 4.1 was adopted in December 2013
- Incremental software update to Bluetooth Specification v4.0 (no hardware updates)
  - Increased co-existence support for LTE
  - Bulk data exchange rate support
  - Device multiple role simultaneous support

References

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