Wi-Fi & Bluetooth

Bluetooth

Bluetooth

❖ Bluetooth

- WPAN (Wireless Personal Area Network) protocol designed by the Bluetooth SIG (Special Interest Group)
- Used to replace cables connecting many different types of devices
  - Mobile Phones & Headsets
  - Heart Monitors & Medical Equipment

Bluetooth

❖ Bluetooth SIG Standardization

- Bluetooth SIG was formed in 1998
- First specification Bluetooth 1.0 was released in 1999
- Bluetooth 5 was released in Dec. 2016
- Earlier standards (Bluetooth 1.1 and 1.2) were ratified as the IEEE 802.15.1 standard
  - No longer maintain as an IEEE standard

Bluetooth

❖ Bluetooth Characteristics

- Operates in the 2.4 GHz unlicensed ISM band
- Uses adaptive Frequency Hopping scheme
  - FHSS (Frequency Hoping Spread Spectrum)
  - Avoids interference with other non-hopping (i.e., Wi-Fi, ZigBee) ISM wireless networks
  - Improves co-existence within the ISM band
- Forms a Piconet in a Star topology
  - One Master node and multiple Slave nodes

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❖ Bluetooth Characteristics

- Components of a Piconet
  - Master node
    - Maximum 1 node in a piconet
    - Provides packet exchange, reference clock time, and frequency hopping pattern
  - Slave node
    - Connected to the Master node
    - Synchronizes to the Master's clock and frequency hopping pattern

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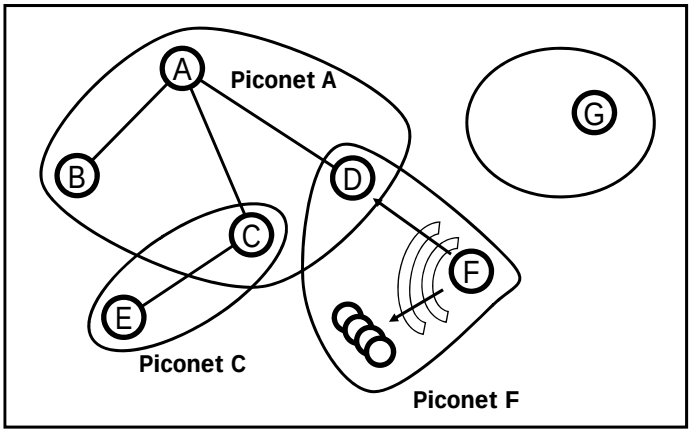
❖ Bluetooth Characteristics

- Example of Bluetooth piconet



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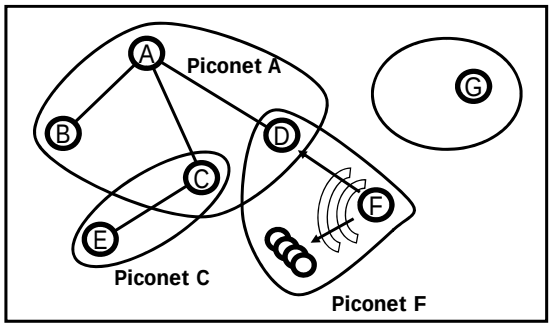
❖ Bluetooth Characteristics

- Example of Bluetooth piconet



- A is the Master of Piconet A
- B, C, and D are Slaves of Piconet A

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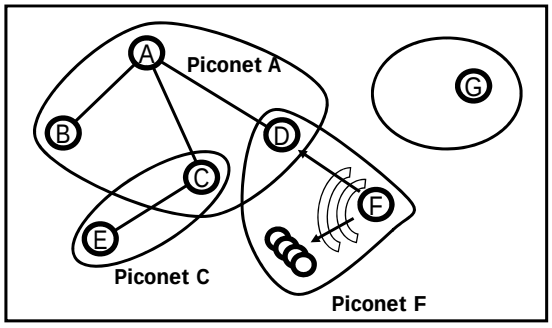
❖ Bluetooth Characteristics

- Example of Bluetooth piconet



- C serves as a Master in Piconet C although it is a Slave in Piconet A

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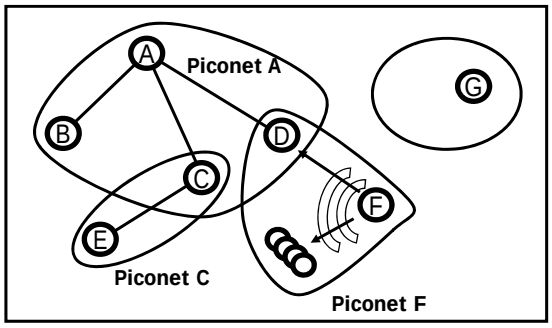
❖ Bluetooth Characteristics

- Example of Bluetooth piconet



  - As a Master, F broadcasts information to D and other Slaves in Piconet F

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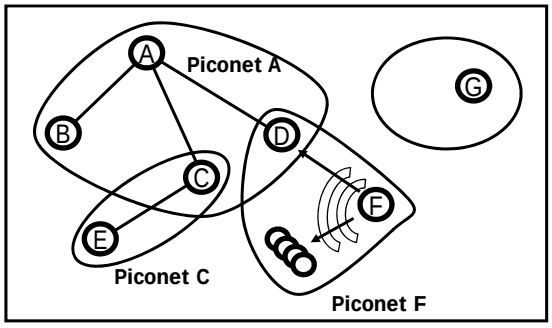
❖ Bluetooth Characteristics

- Example of Bluetooth piconet



  - No nodes are in the range of G, so G keeps scanning for other devices to form a piconet

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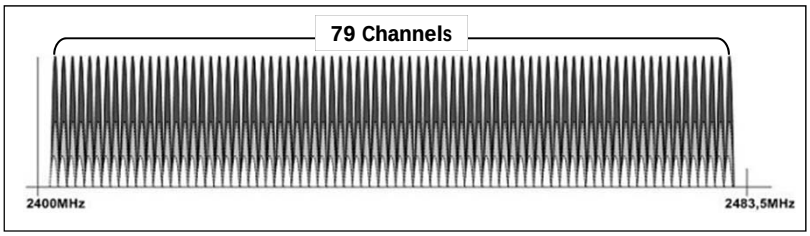
❖ Bluetooth Operations

- Bluetooth specification includes 2 major types of operation
  - **Classic Bluetooth**
    - Before Bluetooth 4.0
    - BR: Basic Rate
    - EDR: Enhanced Data Rate
  - **LE (Low Energy)**
    - Newly introduced technology in Bluetooth v4.0
    - BLE (Bluetooth Low Energy)

Bluetooth

❖ BR/EDR Channel Specifications

- Total 79 channels, each channel is 1 MHz
- Total Bandwidth 2.4 ~ 2.4835 GHz
- TDD (Time Division Duplex) scheme



BR system channel bandwidth

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❖ BR/EDR operation

- Modulation mode
  - BR: GFSK
  - EDR: $\pi/4$-DPSK or 8DPSK
- Data rate
  - BR: 1 Mbps
  - EDR: 2~3 Mbps
- One Master node can interconnect up to 7 slave nodes

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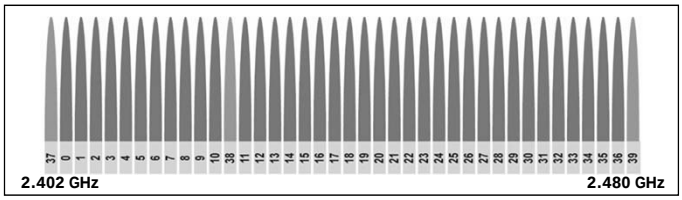
❖ BLE Operations

- Each channel uses a 2 MHz bandwidth between 2.402 ~ 2.480 GHz ➔ Total 40 channels
  - 3 channels for primary advertising channels: 37, 38, 39
  - 37 channels for data channels
    - Used as secondary advertising channels in Bluetooth 5



Bluetooth LE system channel bandwidth

Bluetooth

❖ BLE Operations

- TDMA and FDMA multiple access scheme
- Modulation mode: GFSK
- Data Rate
  - Before Bluetooth 5: 1 Mbps
  - After Bluetooth 5: 125 kbps ~ 2 Mbps
  - Differs in PHY coding method
    - Bluetooth 5 supports error correction coding resulting in lowered data rate but more secure data transmission

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❖ BLE Operations

- Data is transmitted being positioned on a time duration called an 'Event'
- Two types of Events
  - Advertising
    - Advertise messages without connection
  - Connection
    - Build a connection to send data between the Master and Slave devices

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❖ BLE Advertising Event

- Purpose of Advertising channels
  1. Set up connection between devices
  2. Communicate information between unconnected devices

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❖ BLE Advertising Event

- Device Types
  - Advertiser
    - Device that transmits an advertising packet
  - Scanner
    - Receiver without intention to connect
  - Initiator
    - Listens for 'Connectable Advertising Packet' to initiate connection

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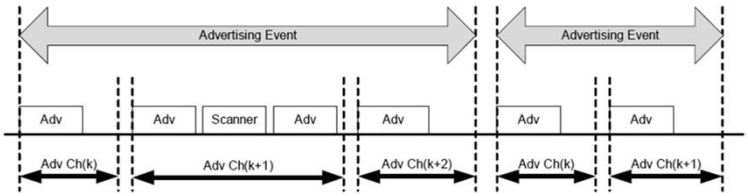
❖ BLE Advertising Event



- Advertising event occurs in Advertising Channels
  - Advertising Channels 37, 38, and 39
- Either can Broadcast or conduct
  Unidirectional Communication

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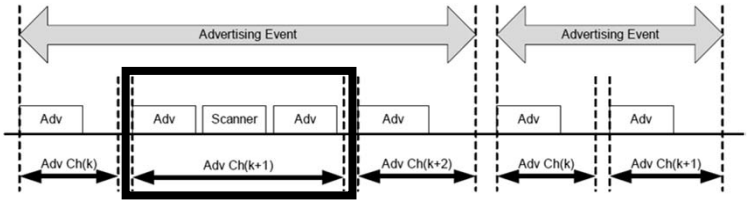
❖ BLE Advertising Event



- Scanner node may send back a response message

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❖ BLE Connection Event

- A series of one or more pairs of interleaving data packets sent between a Master and a Slave on the same physical channel
- Initiator listens for a 'connectable advertising packet' from an Advertiser, and requests for connection initiation
- Initiator becomes the Master device, and Advertiser becomes the slave device

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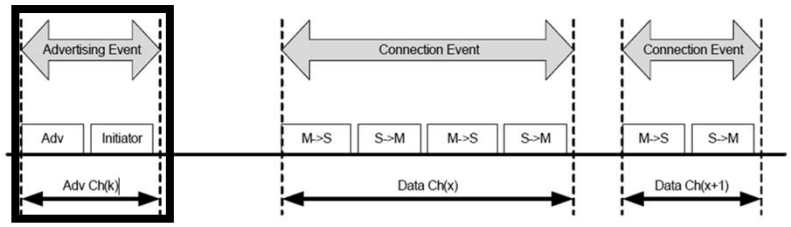
❖ BLE Connection Event



- An Initiator detects a connectable message from an Advertiser during the Advertising Event on the Advertising Channel

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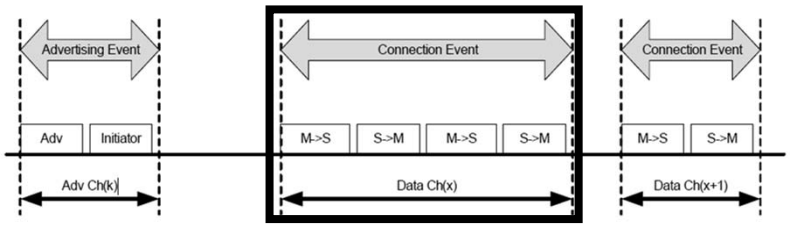
❖ BLE Connection Event



- Advertiser (Slave) and the Initiator (Master) operate during the Connection Event
- Connection Event occurs within the data channel

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References

References

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Image sources

- Bluetooth Logo, By Bluetooth Special Interest Group. (SVG rendering drawn by me, =Nichalp «Talk»=) [Public domain], via Wikimedia Commons