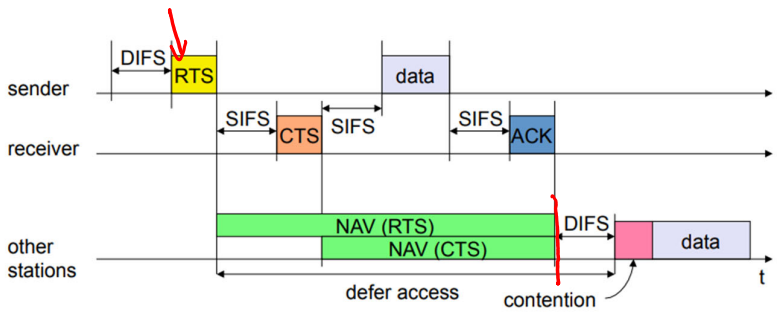
Virtual Channel Sensing in CSMA/CA

- Virtual channel sense or virtual carrier sense is a mechanism to predict future traffic in wireless networks that uses carrier sense multiple access with collision avoidance (CSMA/CA).
  - saves power since no need to do physical carrier sensing
- It is implemented in wireless network protocols, IEEE 802.11 and IEEE 802.16, and operates in the medium access control (MAC) layer.

- In virtual channel sensing, a timer mechanism is used that is based on information of durations of previous frame transmissions in order to predict future traffic in the channel.
- It uses network allocation vector (NAV), which can be considered as a counter that counts down to zero.

Virtual Channel Sensing in CSMA/CA



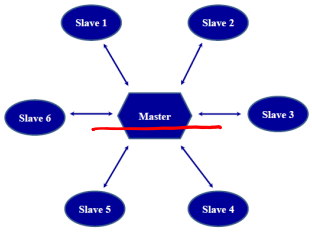
- The steps are:
  - The transmitting station waits for a time equal to DIFS and issues a request to send (RTS) if the channel is clear.
  - After sending RTS, the *Duration* field is read and a NAV (RTS) is initialized at other stations, so they do not attempt to transmit until the end of the NAV.
  - The receiving station waits for SIFS time and issues a clear to send (CTS).
  - With the CTS, the *Duration* field is read and a NAV (CTS) is initialized at other stations.
  - The sender waits for SIFS time and transmits its data frame.
  - On receiving the data frame, the receiver waits for SIFS time and sends an acknowledgement frame (ACK).
  - Both the NAV values decrement to 0 during this time period.
  - The other stations wait for a DIFS before contending for the channel.

Wireless Personal Area Network

- IEEE 802.15.x protocols address needs of WPANs with various data rates
- Bluetooth adopted as IEEE 802.15.1 (medium rate), while the IEEE 802.15.3 (high rate) and 802.15.4 (low rate) are also available
- Bluetooth initially conceived to replace RS232 cables
- Since 2002, its presence has become visible in devices ranging from laptops to wireless mouse to cameras, to headsets, to printers and cell phones.

- Currently, most devices are on Bluetooth version 5
- - supports BT Classic (BR/EDR) and BT Low Energy (LE)
- The Bluetooth Special Interest Group (SIG) officially adopted v5 as the latest version in December 2016. (not maintained by IEEE)
- Bluetooth 5 is backward-compatible with previous versions, but new hardware is required.
- Ubiquitous! wireless ear-buds, Covid-19 contact tracing, *TraceTogether* app and token etc.

Bluetooth Classic Features



- Fast frequency hopping to reduce interference.
- Adaptive output power to minimize interference.
- Short data packets to maximize capacity.
- Fast acks allowing for low coding overhead for links.
- Flexible packet types that support a wide application range.
- CVSD (Continuous Variable Slope Delta Modulation) voice coding that can withstand high bit error rates.
- Transmission/reception interface tailored to minimize power consumption.
- Bluetooth devices can interact with other Bluetooth devices.
- One of the devices acts as a **master** and others as **slaves**.
- This network is called a “piconet”. (BT LE adopts client(P)-server(C) model)
- A single channel is shared among all devices in a piconet.
- There can be up to seven active slaves in the piconet.

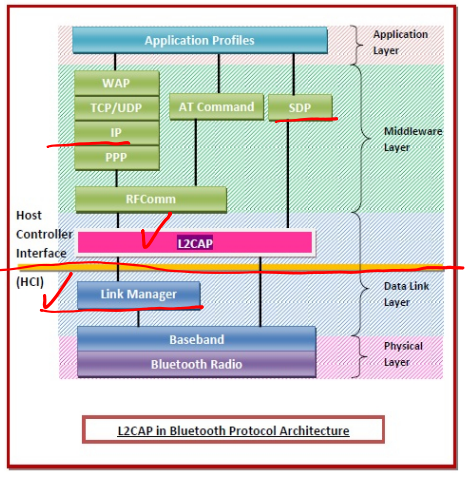
Bluetooth Classic Technical Characteristics

Frequency band	2.4 GHz (unlicensed ISM band)
Technology	Spread spectrum (send signal over a wide bandwidth)
Transmission method	Hybrid direct sequence and Frequency Hopping Spread Spectrum
Transmission power	1 milli-watt (0 dBm)
Range	10 meters (40 feet)
Number of devices	8 per piconet, 10 piconets per coverage area
Data speed	Asymmetric link: 721+57.6 kbps
	Symmetric link: 432.6 kbps
Maximum voice channels	3 per piconet
Maximum data channels	7 per piconet
Security	Link layer w/s fast frequency hopping (1600 /sec)
Power consumption	30 µA sleep, 60 µA hold, 300 µA standby, 800 µA max transmit
Module size	3 square cm (0.5 square inches)
Price	Expected to fall to $5 in the next few years
C/I co-channel	11 dB (0.1% BER)
C/I 1 MHz	-8 dB (0.1% BER)
C/I 2 MHz	-40 dB (0.1% BER)
Channel switching time	220 µs

Bluetooth MAC (Classic and LE)

- **Bluetooth MAC layer** consists of Link Manager Protocol (LMP) and Logical Link Control and Adaptation Protocol (L2CAP).
- **Link Manager Protocol (LMP)**
- LMP is used to establish the link and to control the link.
- Provides a reliable link using flow control and error control.
- **Logical Link Control and Adaptation Protocol (L2CAP)**
- Multiplexing of higher layer protocols, which allows them to use the links provided by the lower layers.
- Adaptation between higher-layer frames and lower layer frames of the Bluetooth protocol stack.
- Segmentation and reassembly of data packets of the upper layer that are larger than the capacity of the radio layer underneath.
- Supports connectionless (for control and data packets) and connection-oriented services (for voice).
- Provides Quality of Service (QoS) for upper-layer protocols.

BT Classic



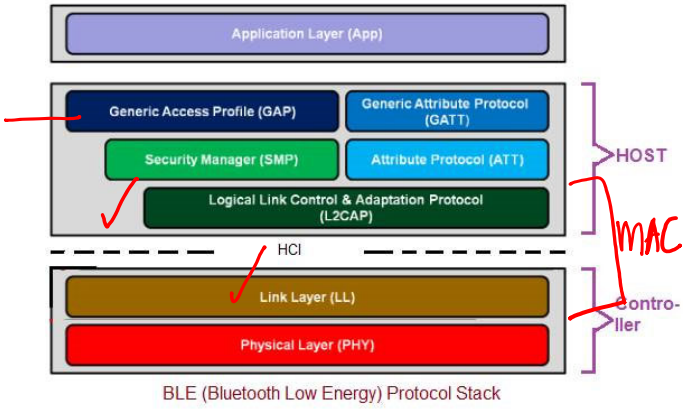
Baseband: Enables the physical RF link between Bluetooth units (e.g. in piconet)

(Classic) Service Discovery Protocol (SDP): Provides a means for applications to discover which services are provided by, or available through, a Bluetooth device.

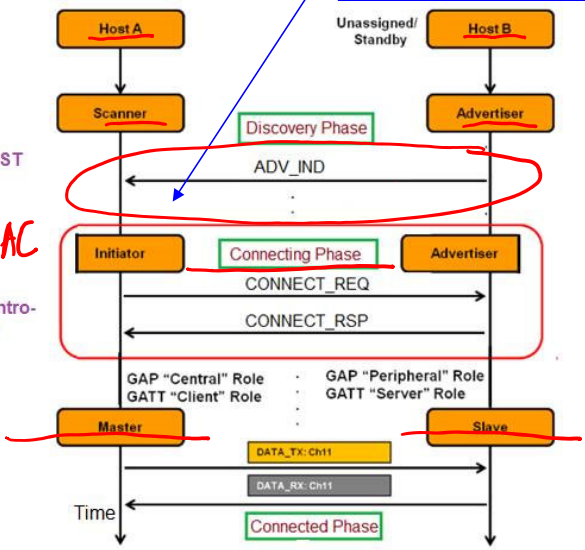
Bluetooth Low Energy (BLE)

- Bluetooth Low Energy still uses L2CAP
- Generic Attribute Profile (GAP) defines services

TraceTogether app and token: *BlueTrace* protocol: 'handshake' using Encounter messages



BLE (Bluetooth Low Energy) Protocol Stack



BLE Connection Establishment Procedure

The End

Questions?