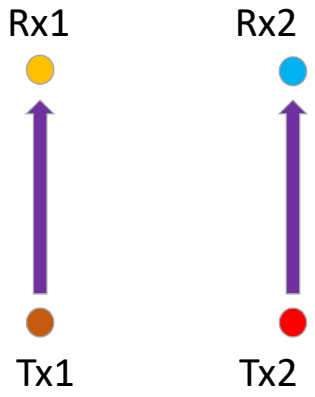
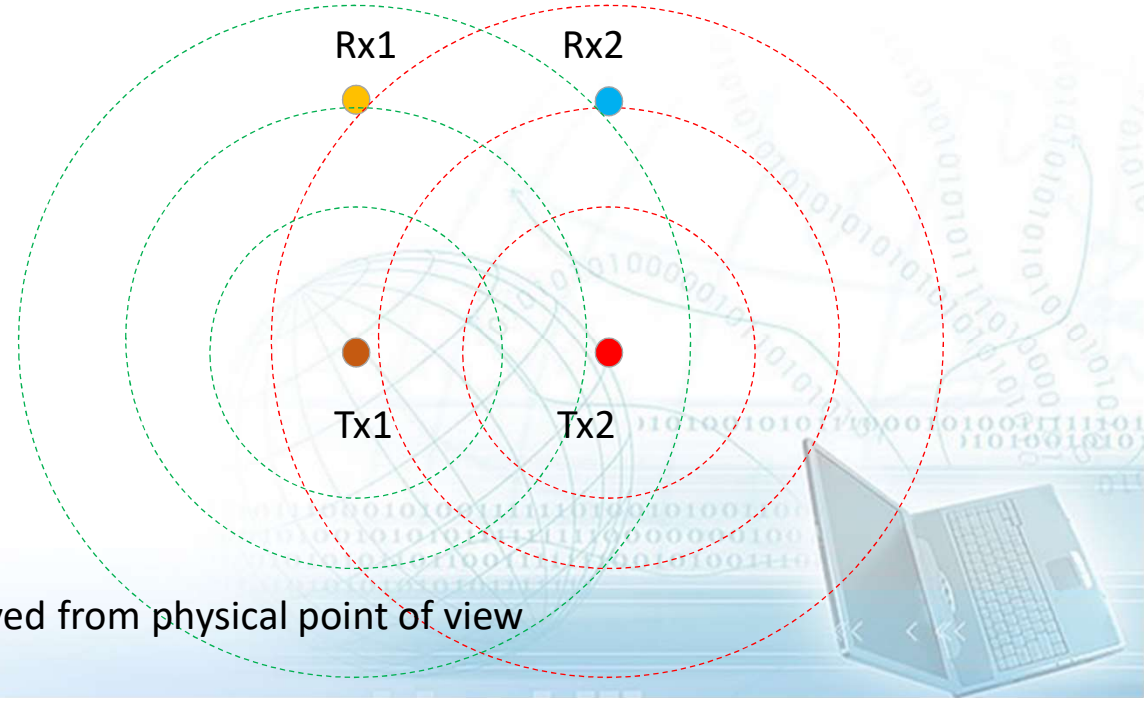
Fundamental : Medium Access Control

Medium Access Control (MAC)

- Sub layer of data link layer in OSI protocol architecture
- Medium Access Control Protocol
  - Provide the mechanism to access shared communication medium between multiple communication terminals
    - Wireless communication uses a shared medium



Logical link



Observed from physical point of view

MAC Protocol in General

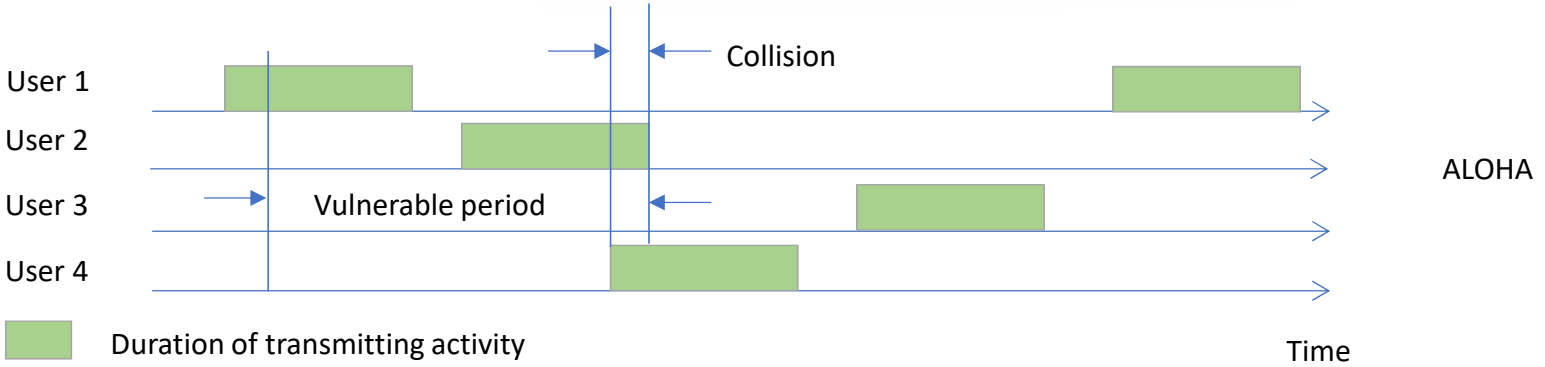
- Non contention-based
  - Frequency Division Multiple Access (FDMA)
  - Time Division Multiple Access (TDMA)
  - Code Division Multiple Access (CDMA)

- Contention-based
  - ALOHA
    - Pure Aloha
    - Slotted Aloha
  - Carrier sense medium access

Contention-Based : Aloha

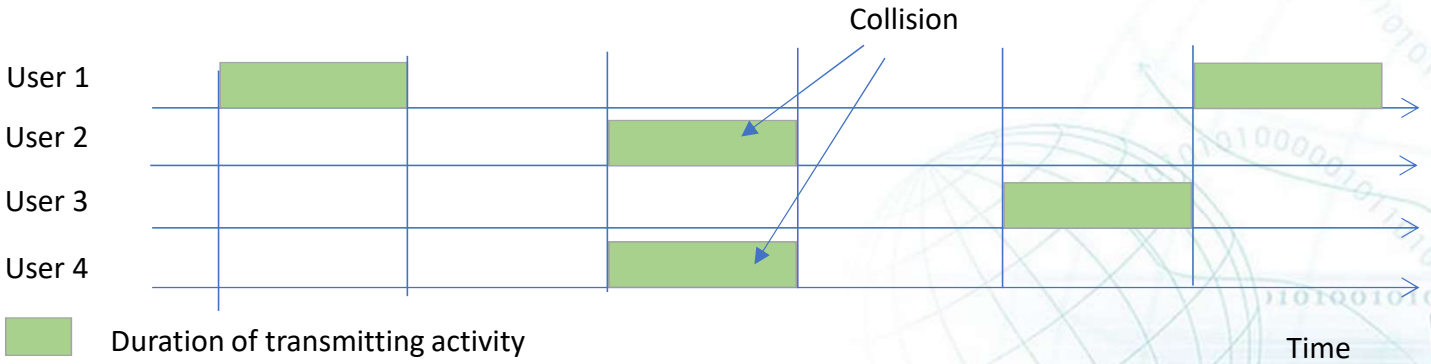
- User who has data to send can transmit it immediately
  - Collisions between transmissions commonly happen, which can impair the transmitted data.
  - More users impose more collisions
  - Hence, feedback mechanism is required
  - Channel maximum useful channel time in long run is only 18%
- To improve the performance of ALOHA, Slotted Aloha is proposed
  - Transmitting radio should send at the beginning of time slot whenever they have data.
  - Slot for transmission avoid vulnerable to collision duration
  - Doubles the performance of pure Aloha

Timing illustration fo Aloha and Slotted Aloha



Duration of transmitting activity

Receiver of user 2 and user 3 might drop the packet entirely because collision may damage the incoming packet



Duration of transmitting activity

Vulnerable period is only T, since each user only transmit at the beginning of slot

Contention-Based : Carrier Sense

- CSMA (Carrier-Sense Multiple Access)
  - In most wireless networks, whereby internode distance is relatively close, the propagation time of signal is very small compared to frame transmission time
  - A stations can “immediately” sense a nearby stations having transmission underway
    - Non-persistent CSMA
      - Before transmitting the data, a transmitting stations listen to medium. If medium is busy, the station will wait for an amount of time until it begins to sense the channel. If channel is not busy, then transmit the packet
    - 1-persistent CSMA
      - When medium is busy, the station will keep sensing the channel until its free. When channel is free, it transmit immediately
    - P-persistent CSMA
      - When the station senses idle medium, it will do transmission with probability of P. This also means that even in the case of idle medium, the station may not do transmission with probability of (1-P). If channel is busy, it keeps sensing the channel until it becomes idle

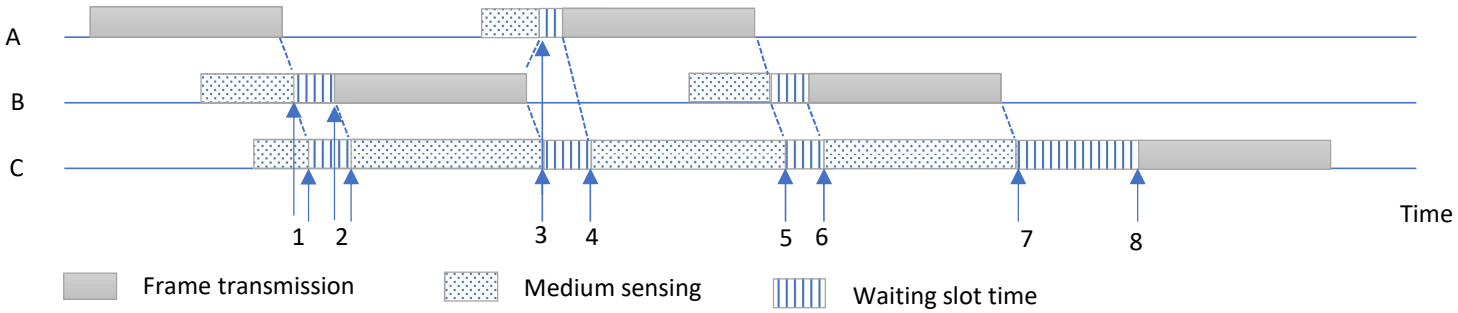
Contention-Based : Carrier Sense

- CSMA –CD (CSMA with Collision Detection)
  - Its use is actually more relevant in wired network
    - In wireless media, there is no way to detect collision
  - The algorithm is as follows:
    - If medium is idle, transmit
    - If the medium is busy, continue to listen until the channel is idle, then transmit immediately
    - If a collision is detected during transmission, transmit a brief jamming signal to assure that all stations know that there has been a collision and then cease transmission
    - After transmitting the jamming signal, wait a random amount of time, referred to as the back-off, then attempt to transmit again.
  - This is used in IEEE 802.3 standard
    - Now it becomes obsolete

Contention-Based : Carrier Sense

- CSMA-CA (CSMA with Collision Avoidance)
  - The mechanism is as follows:
    - When the station senses idle medium, it will wait for a random amount of time (implemented as counter of slots) before transmitting. If within this contention window the station sense busy channel, it stops the counter and resume the counter whenever the station sense idle channel (transmission for other station has already completed).
    - If the counter reaches zero and it senses idle channel, it can transmit immediately. If it senses busy channel, then the station will do back-off by setting another random amount of time (counter of slots) using binary exponential strategy
  - However, it does not solve hidden node problem
    - RTS/CTS exchange can be applied in order to mitigate hidden node problem (Illustration follows in later slide)

CSMA – CA : Illustration



- Initial condition : **A** transmit frame. While it transmits, **B** and **C** sense the medium

1. **B** and **C** sense the medium idle and waiting for random waiting slot time (note that **B** and **C** may have different number of slots).
2. **B** accomplishes its waiting time, sense the medium idle, and start transmitting. Meanwhile, **C** freeze waiting and start sensing medium
3. **C** and **A** sense medium idle. **A** start waiting for a certain amount of slot time, while **C** resumes waiting
4. **C** finishes waiting, however, it senses the medium busy, then it does back-off, and performs binary exponential back off for the next waiting time
5. **C** and **B** sense medium idle, and count their respective waiting slot
6. **C** freeze waiting and sense the medium
7. **C** senses medium idle and resume count down its waiting slot
8. **C** accomplishes waiting and start transmitting immediately because medium is idle

Hidden Node Problem

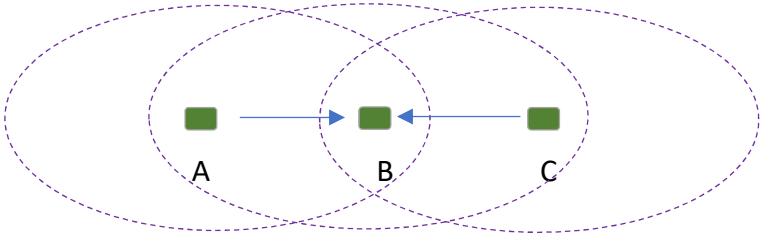


Figure 1

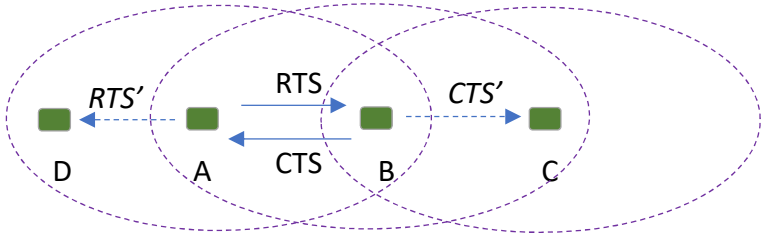
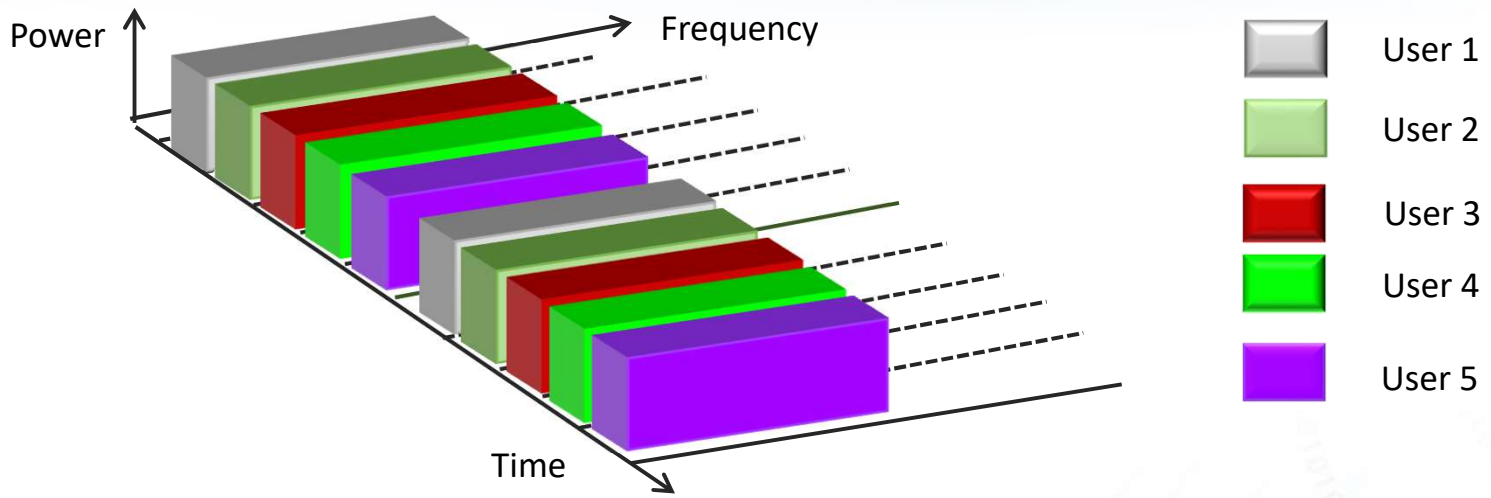


Figure 2

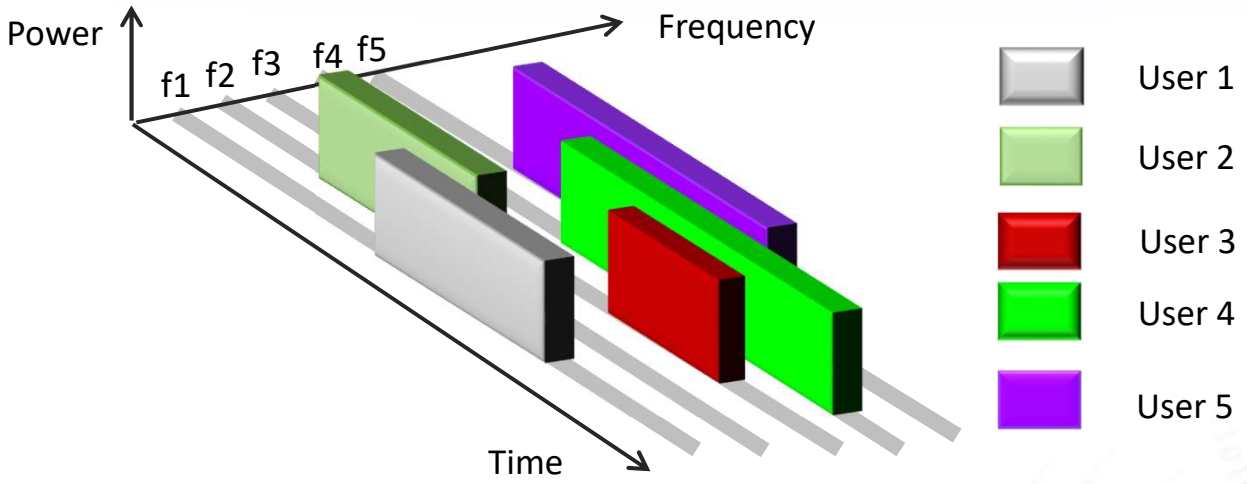
- (Figure 1) A can not sense the carrier emitted by C and vice versa. This means A does not aware the presence of C and vice versa. However, B can hear both
- A and C may need to send packet to B and collision could occur at B
- (Figure 2) To mitigate the problem, RTS (Request to Send)/CTS (Clear to Send) packet exchange is applied
  - A does CSMA and sends RTS to B when channel is idle. Meanwhile, D overhears RTS from A and defers to allow CTS
  - B replied with CTS back to A. Meanwhile C overhears CTS from B and defers to allow transmit packet
  - A sends to B

Non-Contention Based MAC



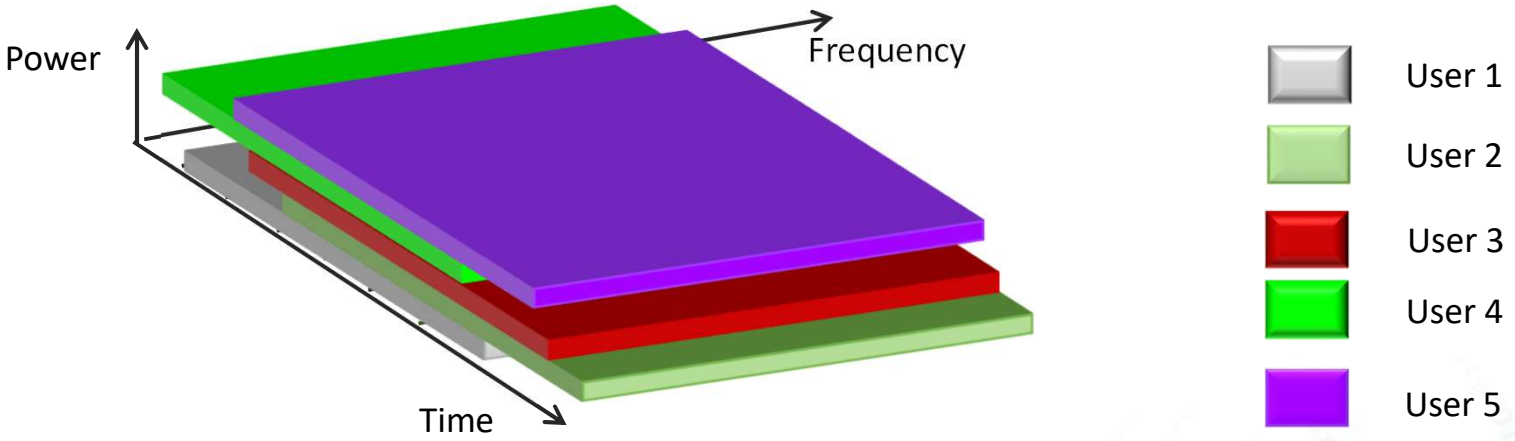
- Time Division Multiple Access (TDMA)
  - Transmission time is divided into slots.
  - Each user may be assigned a slot to transmit the frame
  - Similar idea to Time Division Multiplexing
    - In Time Division Multiplexing, a transmitter multiplex different channel into different time slot, while in TDMA, multi-transmitter will transmit within its respective time slot, either using single frequency or set of frequency (channel)

Non Contention Based MAC



- Frequency Division Multiple Access (FDMA)
  - Each user is assigned particular frequency or sub-channel (set of carriers) to transmit
  - Similar idea to FDM (Frequency Division Multiplexing)
    - In multiplexing, one user utilizes multi-frequencies to transmit, while in multiple access, multi-user use their assigned frequency
    - FDM is more relevant in physical layer (signal processing), while FDMA is more relevant to the context of data link layer

Non Contention Based MAC



- Code Division Multiple Access (CDMA)
  - Similar technique to Direct Sequence Spread Spectrum
  - While in Code Division Multiplexing, a user uses a set of PN (Pseudo-noise) code, while in CDMA, in which multi-transmitter are involved, each transmitter would have unique PN bit stream. Ideally, these PNs are orthogonal to each other
    - To decode the code, receiver should have the same PN as the transmitter