Random Access Mechanism in IEEE802.11

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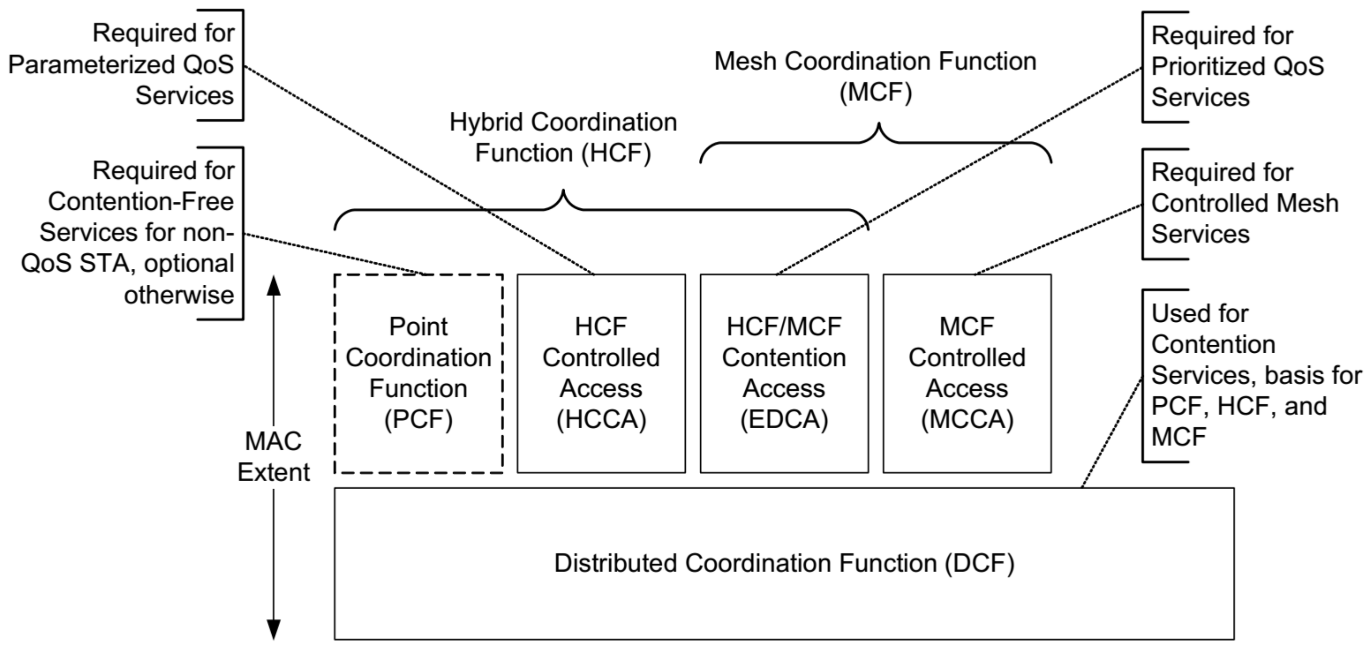
Random Access

- In the most popular infrastructure mode, how to coordinate the transmission from multiple STAs to AP?
- Random access: the need of data transmission is random and not predictable.
- Simultaneous wireless transmission will cause mutual interference.
- Methods: centralized, distributed and grant-free
  - Centralized: transmission grant is made by AP
  - Distributed: STAs compete for transmission right
  - Grant-free: resolve simultaneous transmissions via complex signal processing

How to coordinate the multiple access?

- **DCF** provide the basic access function
- **MCF, PCF** and **HCF** are build on top of DCF
- Infrastructure mode: PCF and HCF; Ad hoc mode: MCF
- PCF may be obsoleted in the later version



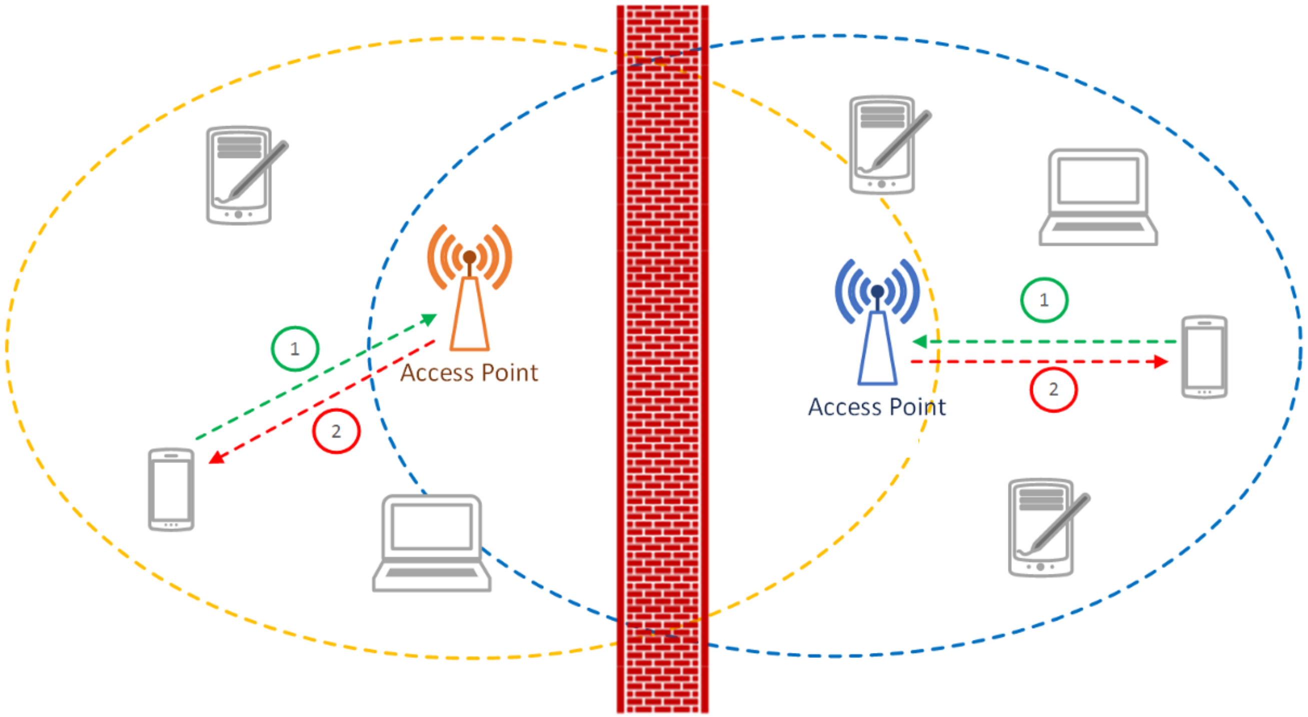
Distributed Coordination Function (DCF)

- DCF uses CSMA/CA for transmission coordination
  - **CSMA/CA:** Carrier sense multiple access with collision avoidance

- Procedure
  - **Carrier sensing:** a STA having a packet to transmit checks the state of the medium.
  - **Wait:** the STA waits if it senses a busy medium. Moreover, it determines a random back-off period by setting an internal timer to an integer number of slot times.
  - **Still wait:** the station defers until the medium is idle for one DIFS period.
  - **Countdown:** after DIFS, an internal timer is set. If the timer reaches zero, the station begins transmission.
  - **Suspension:** however, if the channel is seized by another station before the timer reaches zero, the timer setting is suspended at the decremented value for subsequent transmission.

Carrier Sensing

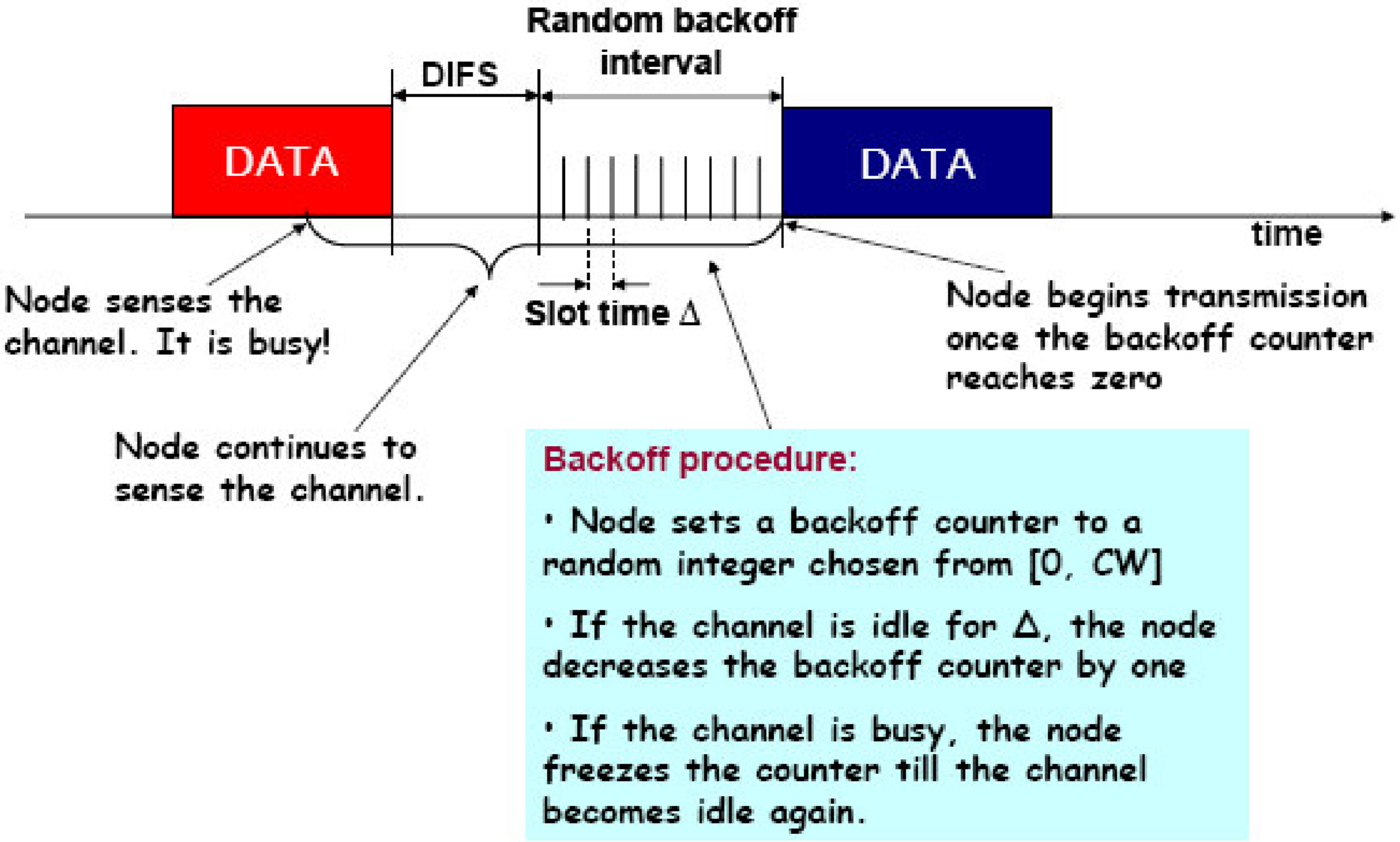
- Carrier sensing is to determine whether the channel is available or not
- How to determine the threshold of sensing?
- This is not mentioned in the specification



Larger threshold =>
Stronger interference & Lower data rate

Smaller threshold =>
Less transmission opportunity

Waiting



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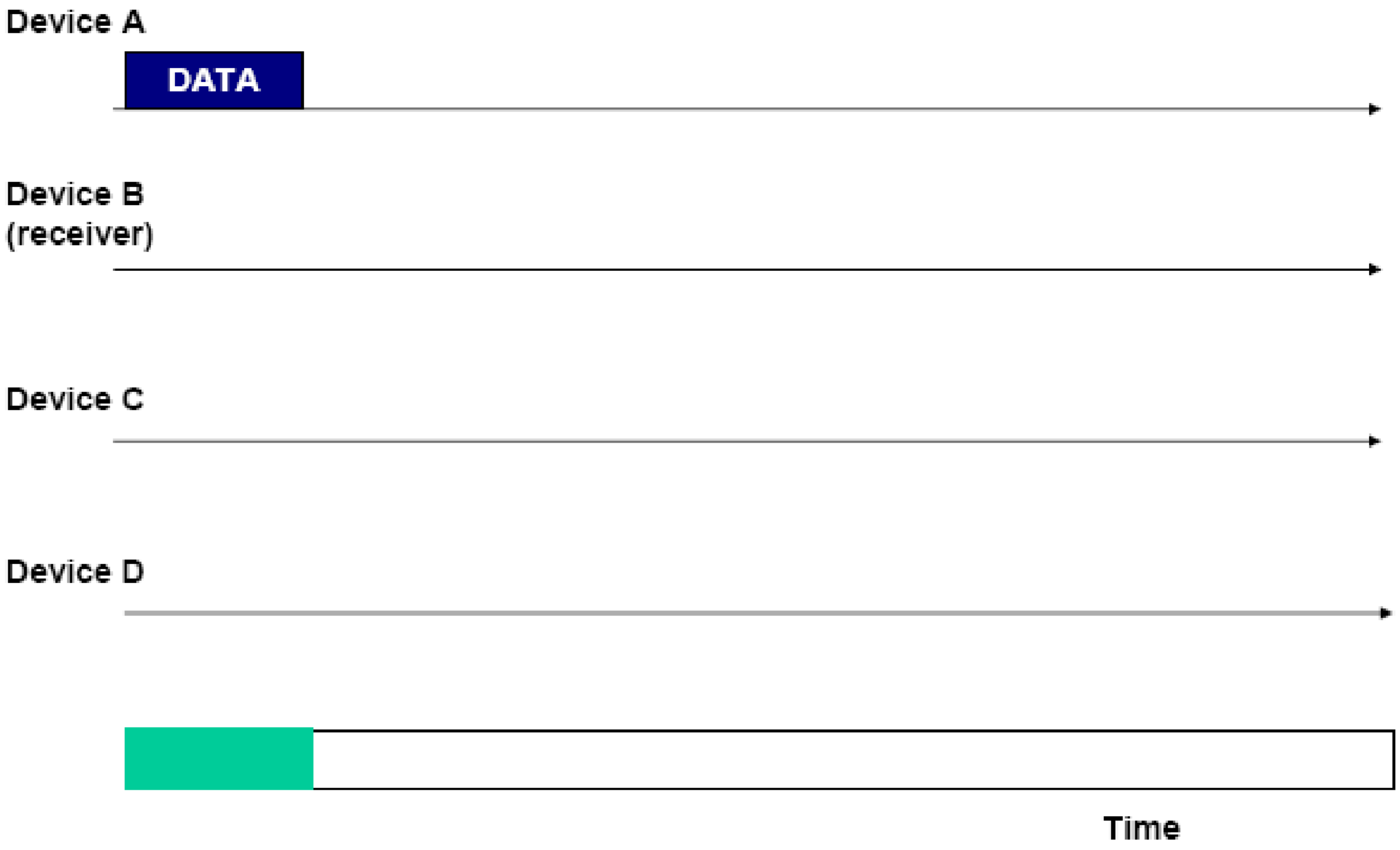
Interframe Space (IFS)

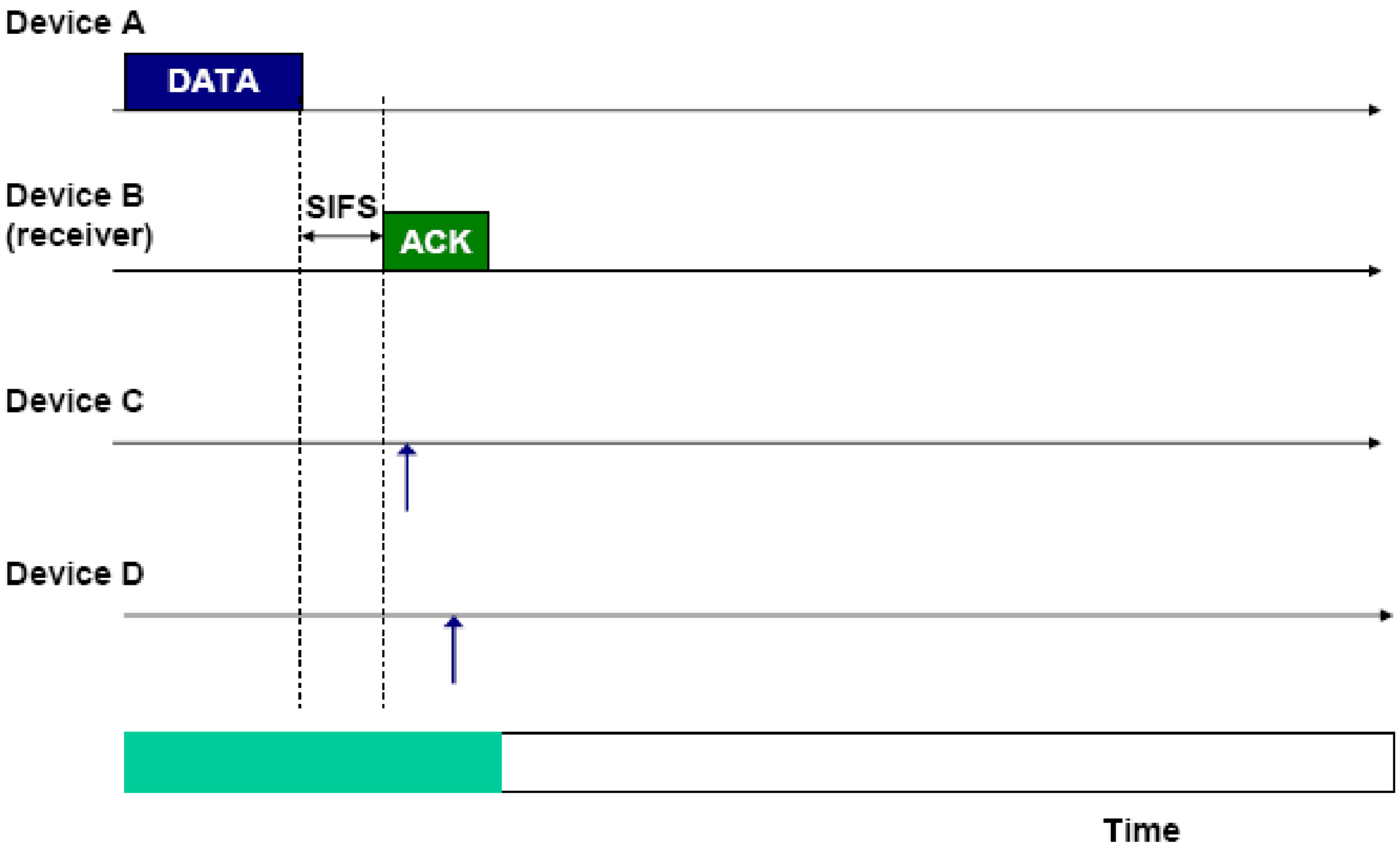
- The time interval between frames is called the IFS
- Ten different IFSs are defined to provide priority levels for access to the wireless medium
- Two most important ones: short interframe space (SIFS) & DCF interframe space (DIFS)
- SIFS is the space for ACK
- DIFS is the space for new transmission

Example of DCF CSMA/CA (1)



AirTight Networks

Example of DCF CSMA/CA (2)



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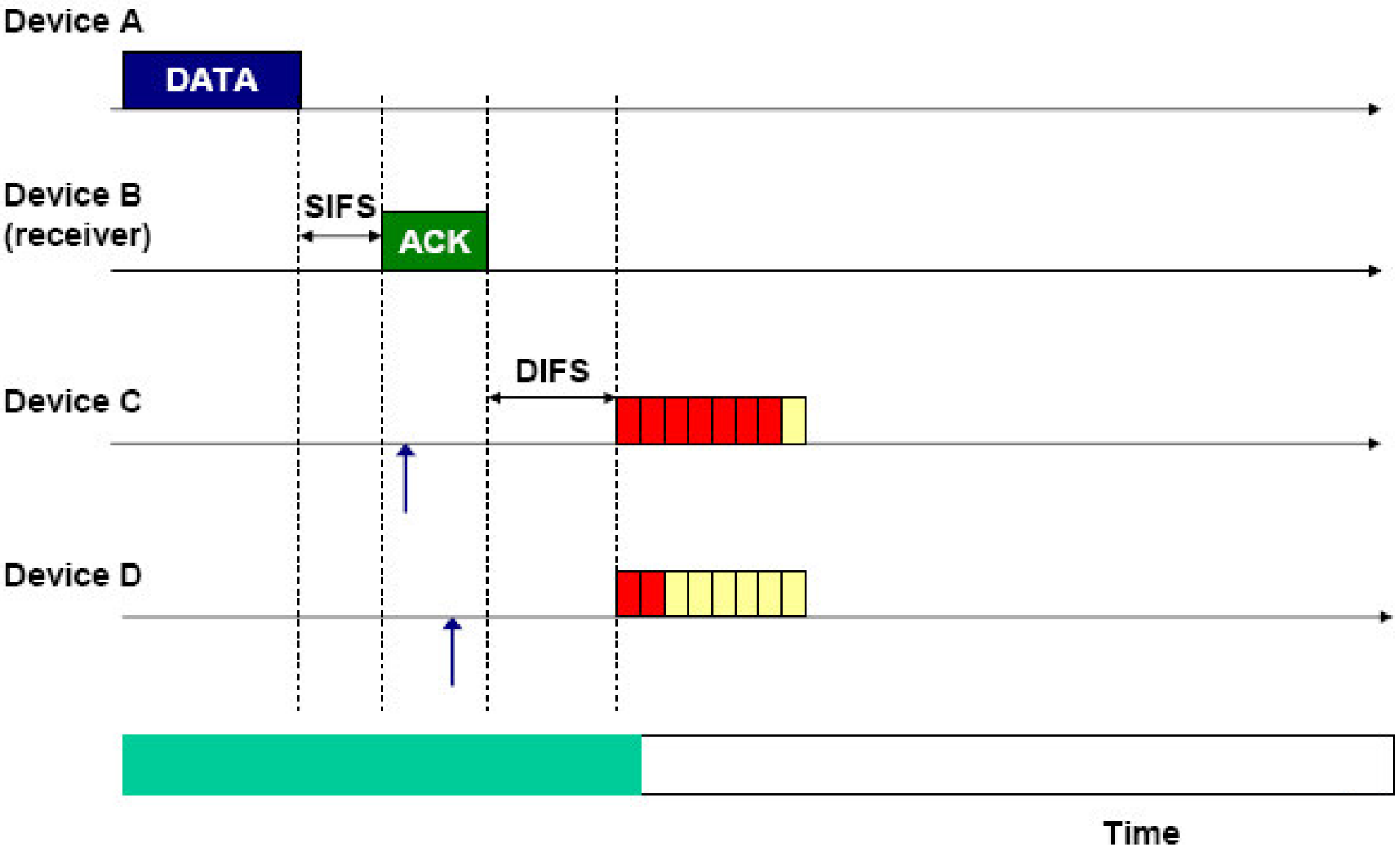
Example of DCF CSMA/CA (3)



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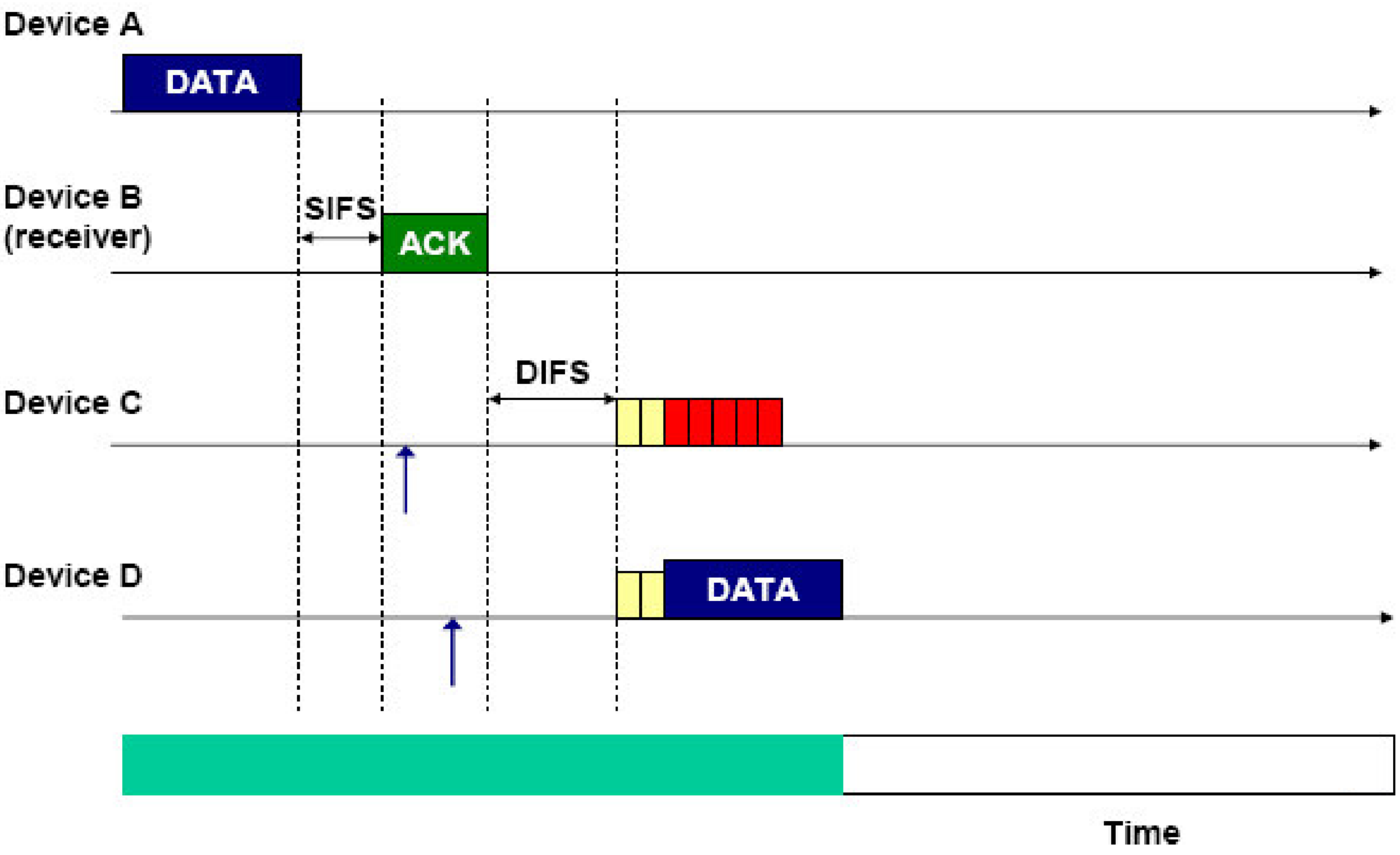
Example of DCF CSMA/CA (4)



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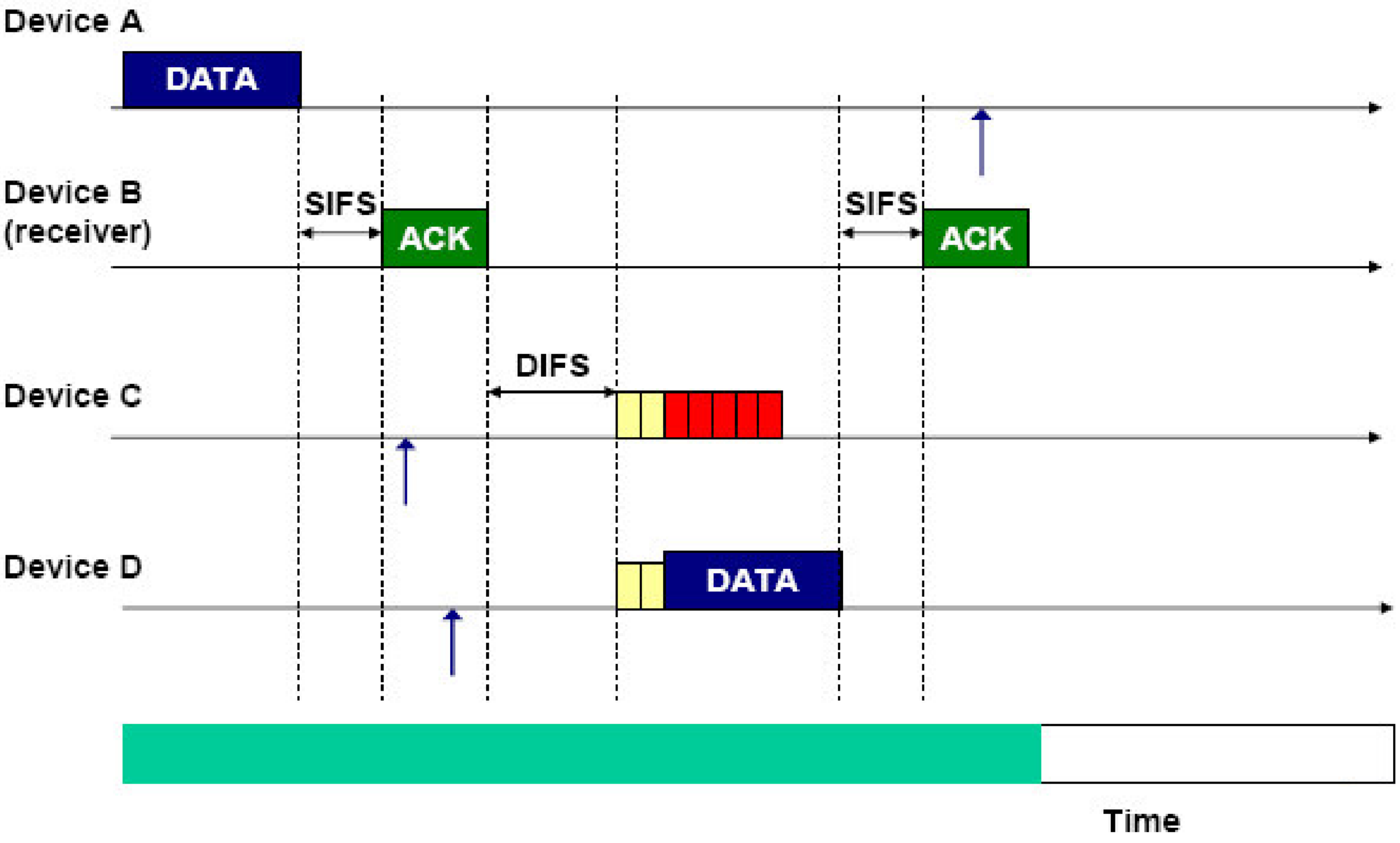
Example of DCF CSMA/CA (5)



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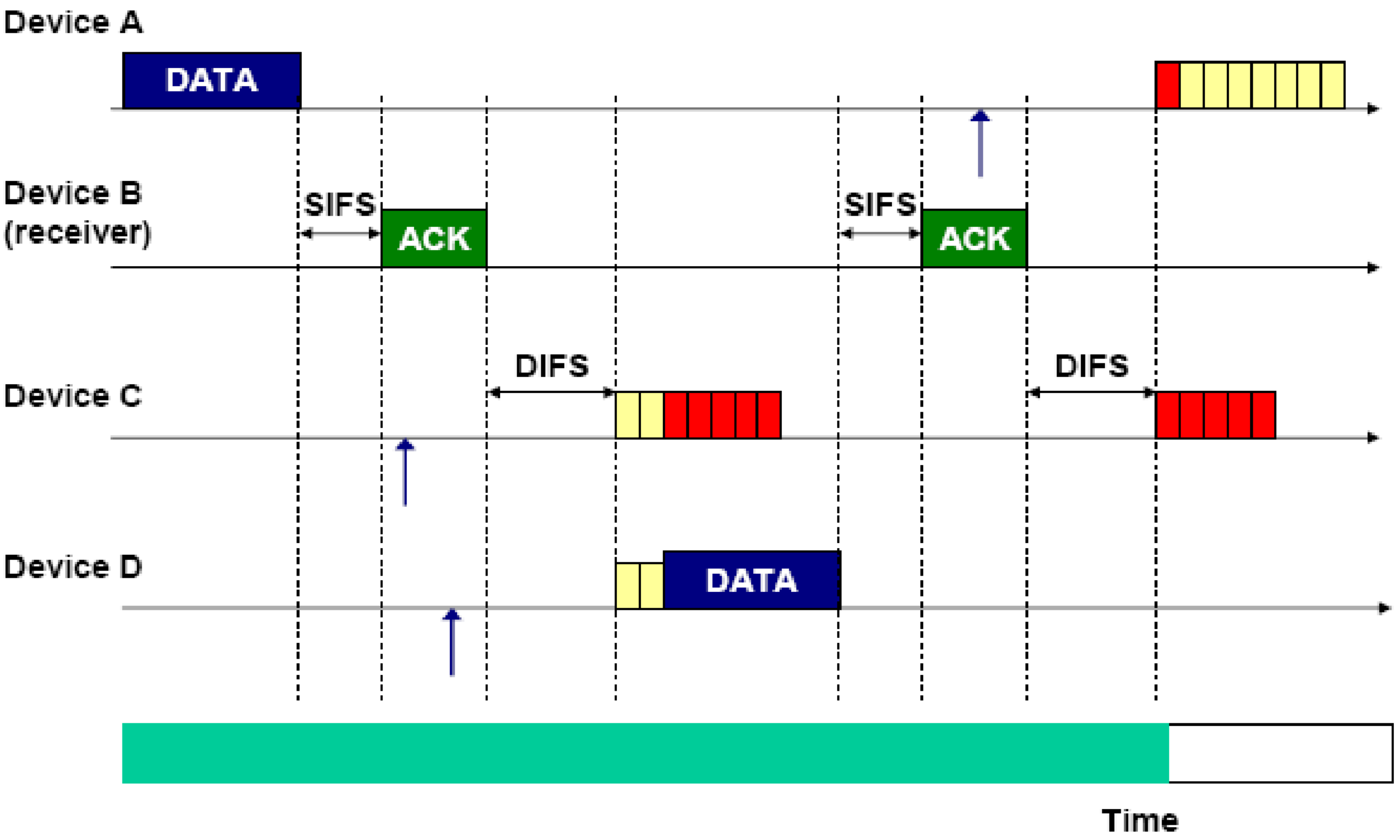
Example of DCF CSMA/CA (6)



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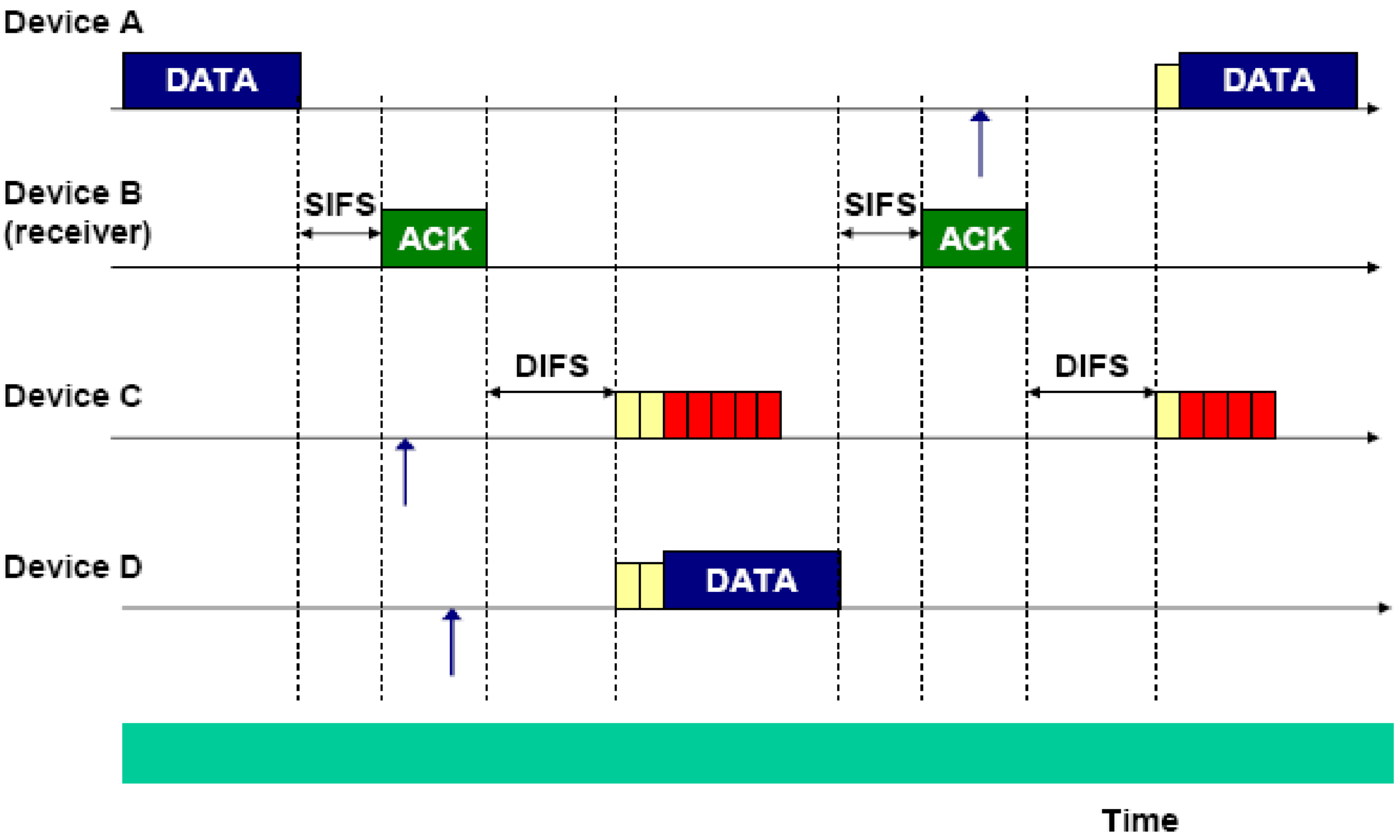
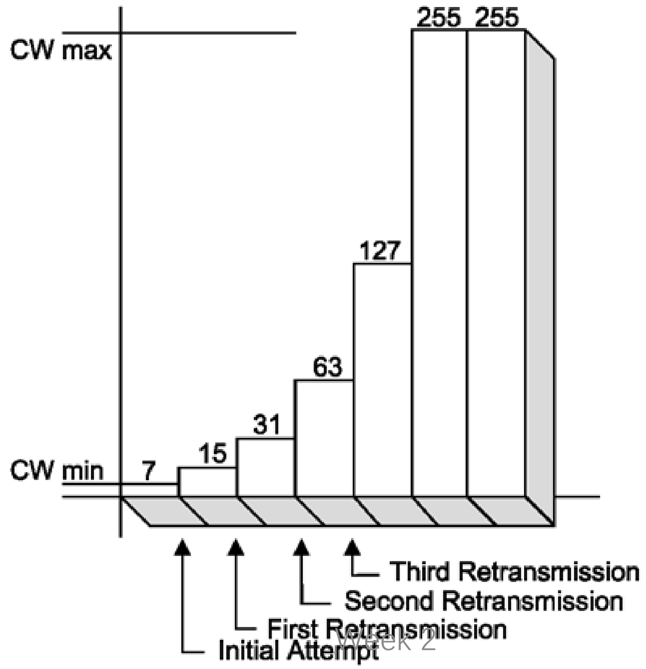
Example of DCF CSMA/CA (7)



AirTight Networks

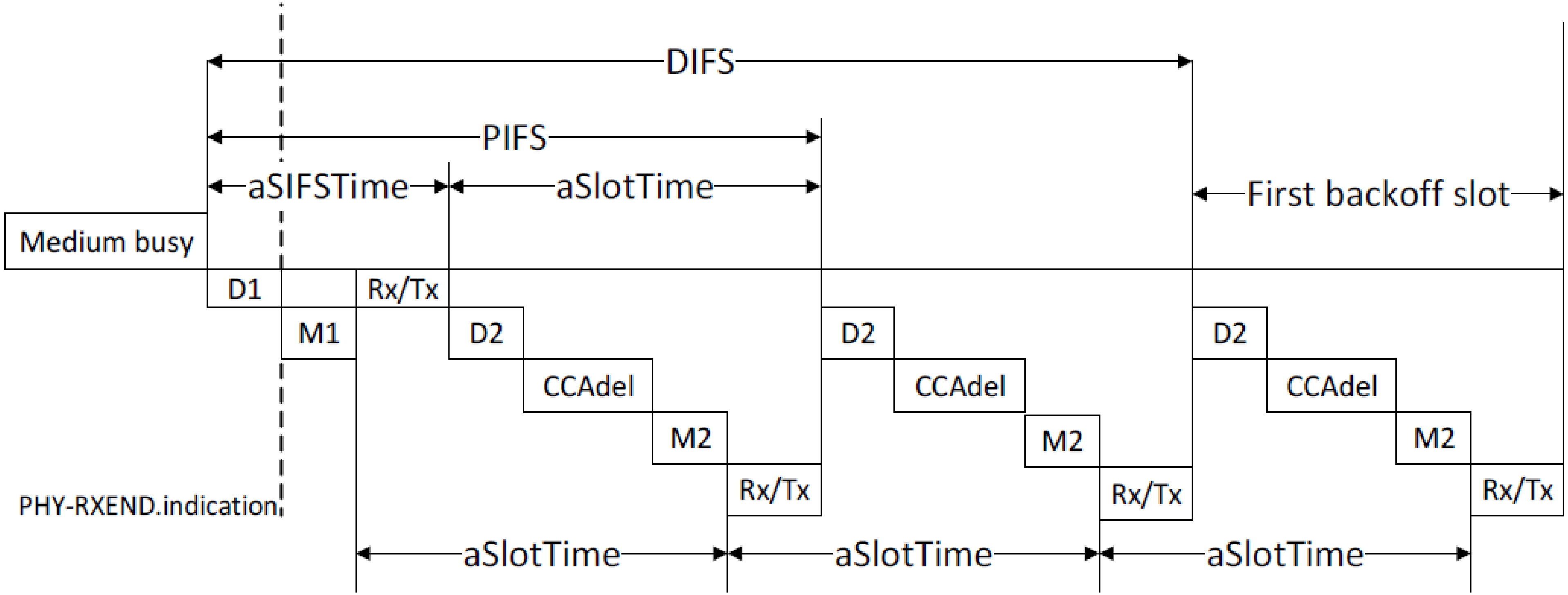
Random backoff

- Backoff Time = Random() × aSlotTime (Page 1323)
- Random(): "Pseudorandom integer drawn from a uniform distribution over the interval [0,CW], where CW is an integer within the range of values of the PHY characteristics aCWmin and aCWmax"



CW increases if transmission fails

DCF Timing



aSlotTime = D2 + CCAdel + M2 + Rx/Tx

D2: time for PHY-layer reception

CCAdel： time for channel sensing

M2: time for MAC-layer processing

Rx/Tx: switch from Rx mode to Tx mode

aSIFSTime = D1 + M1 + Rx/Tx

D1: ?

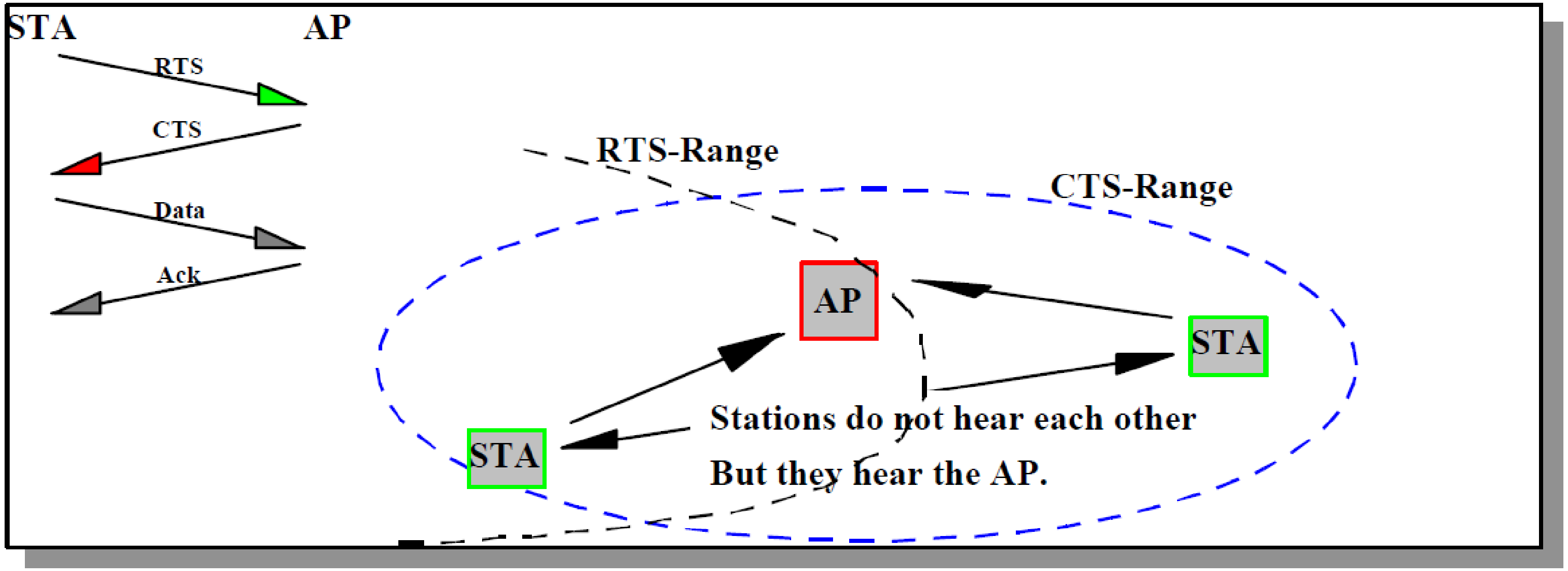
M1： ?

Discussion

- How much overhead is consumed for channel contention?
- Scenario of many users
- Dense WiFi network

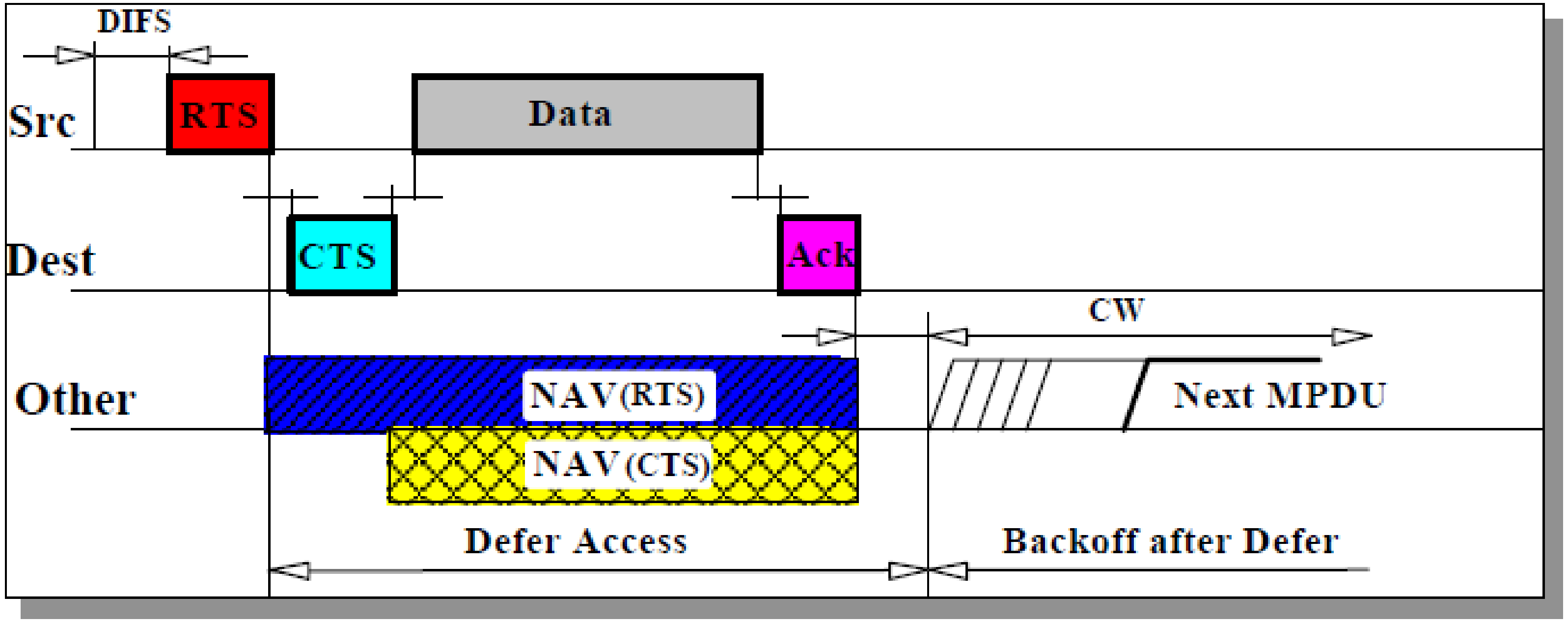
Hidden Node Problem

- Suppose both STAs want to deliver MPDU to AP. STAs cannot hear each other
- Transmission from both STAs will collide at AP
- **RTS-CTS:** make appointment before transmission



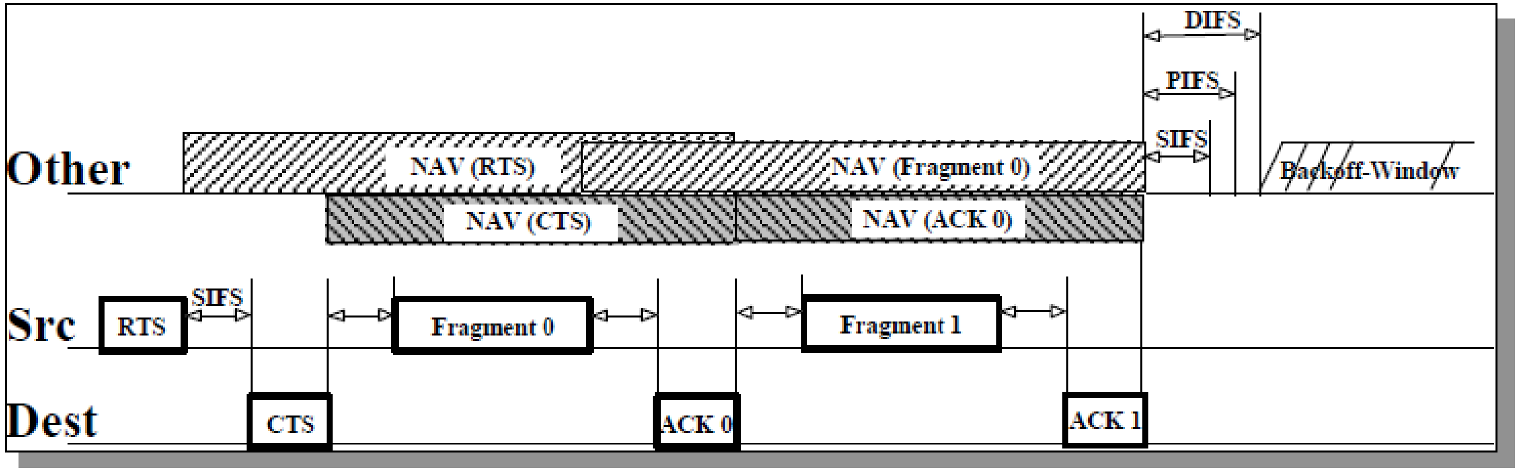
RTS-CTS-Transmission-ACK

- Duration field in RTS and CTS frames distribute Medium Reservation information which is stored in a **Net Allocation Vector (NAV)**
- Use of RTS / CTS is controlled by a RTS_Threshold parameter per station.
  - To limit overhead for short frames.



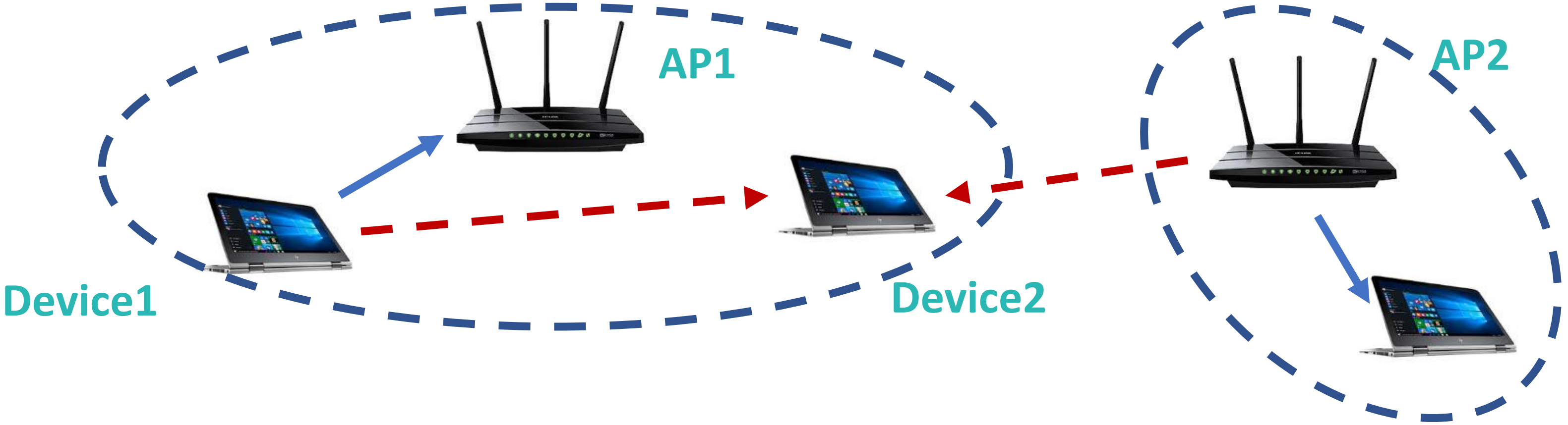
RTS-CTS with Fragmentation

- Long MSDU will be cut into fragments before transmission
- Burst of Fragments which are individually acknowledged
- Random back-off and retransmission of failing fragment when no ACK is returned.
- Duration information in data fragments and ACK frames causes NAV to be set, for medium reservation mechanism.



Issue of Dense WiFi

- When WiFi is deployed densely, the CS mechanism may block the transmission severely.
- **Example:** if Device 2 wants to send data to AP1, it will sense the channel. Interference from either Device 1 or AP 2 will block the its transmission.



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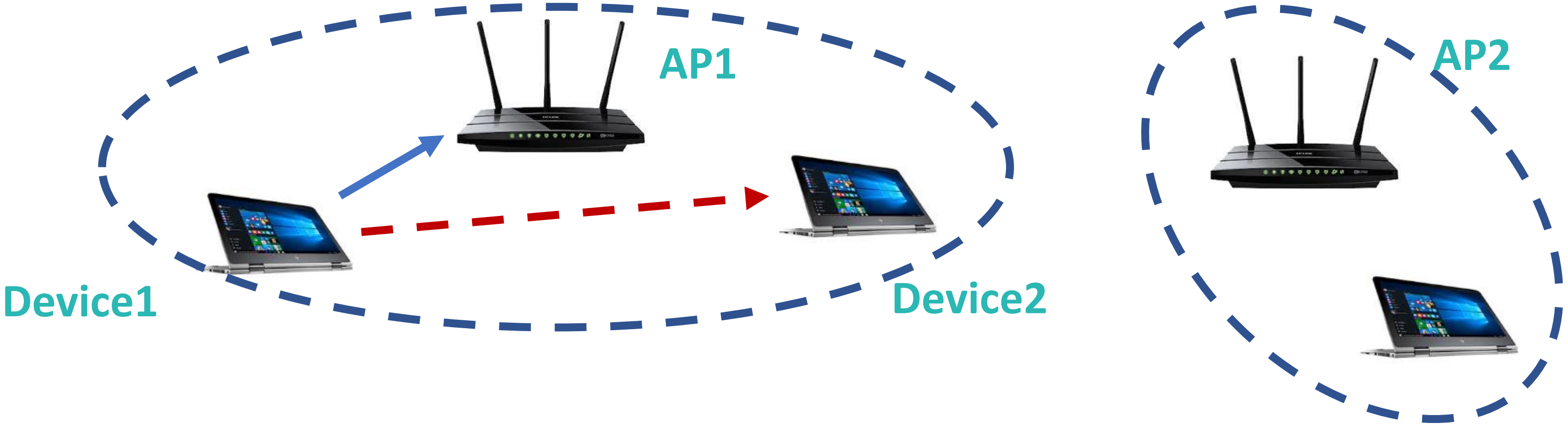

In fact, Device 1 & 2 cannot transmit simultaneously.
This is because both of them deliver data to AP1.
It is reasonable to block Device 2, if Device 1 is transmitting.

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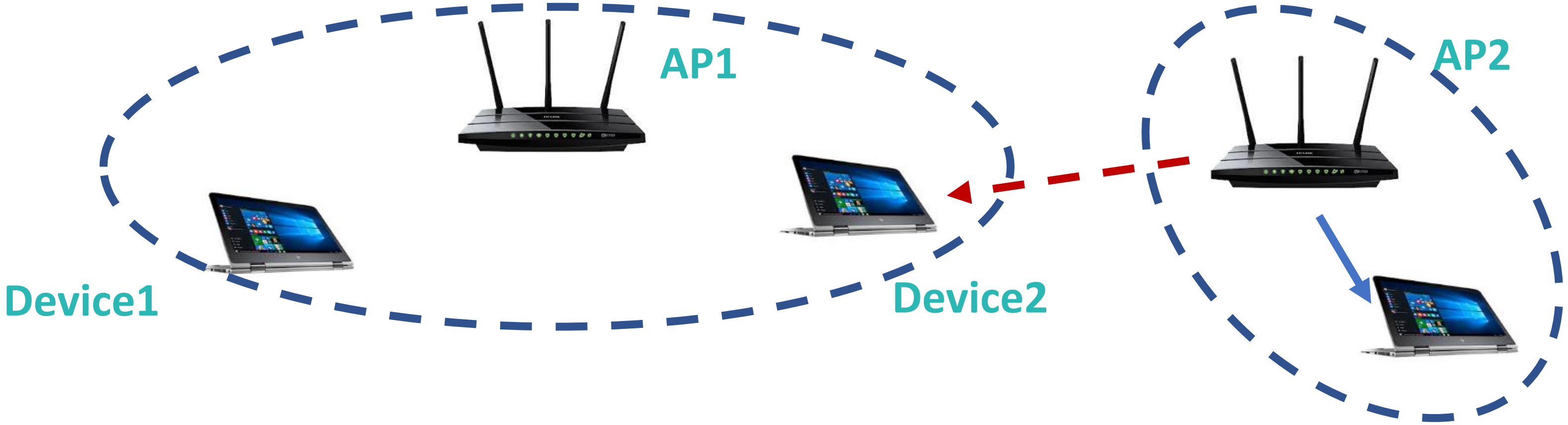

On the other hand, it is not necessary to block Device 2 when AP2 is transmitting.

1. AP2 may not be close to AP1.
2. Even AP2 may cause interference to AP1, Device 2 can transmit with sufficient SINR.

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SINR = Signal Strength of Path 1 / (Signal Strength Path 2+ Noise)

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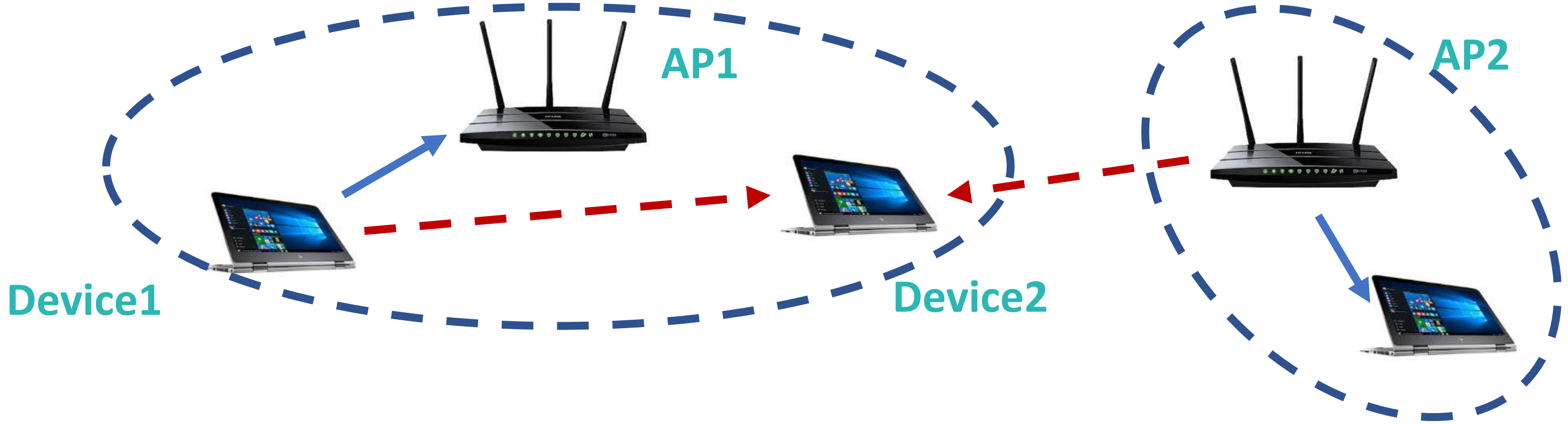
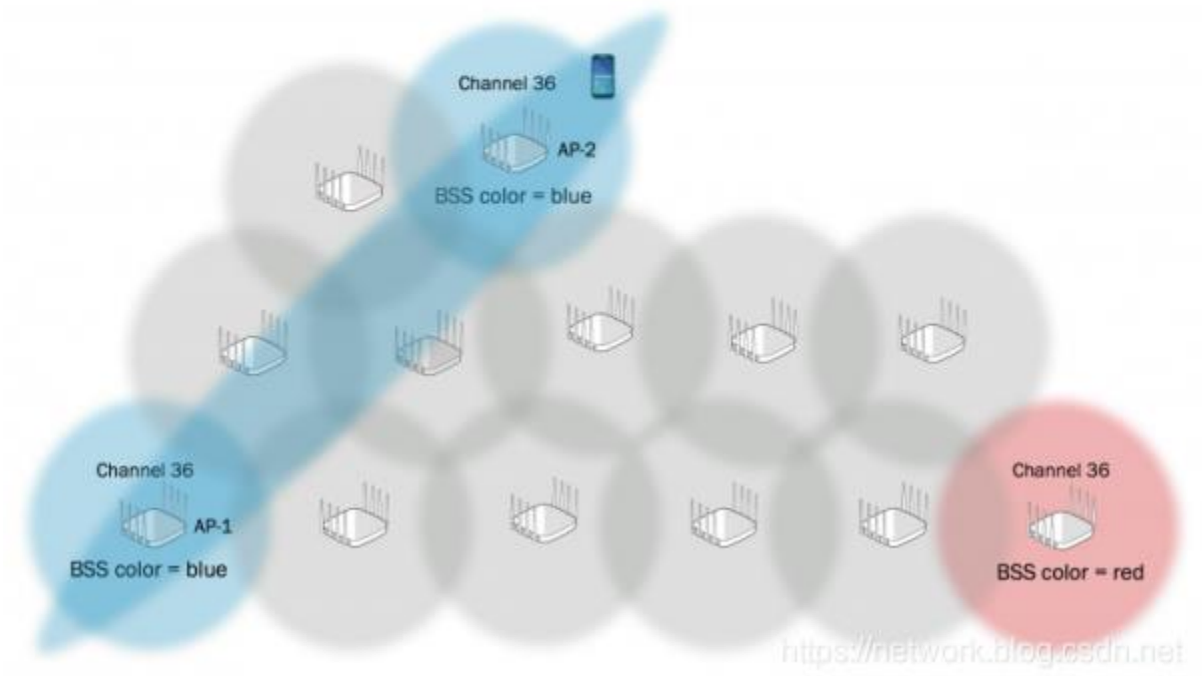


We can treat intra-BSS interference and inter-BSS interference separately.
One coloring mechanism is introduced in 11ax for the STAs to tell the interference.

11ax Improvement - BSS Color Code

- To address the issue of dense deployment, 802.11ax introduce a mechanism of BSS coloring
- **BSS color code:** Each BSS has a code to represent its "color". This color code can be easily detected in the phase of CS.



Within the same channel, BSSs interfering each other are call as Overlapping BSS (OBSS).

BSS's within OBSS are assigned with different color codes.

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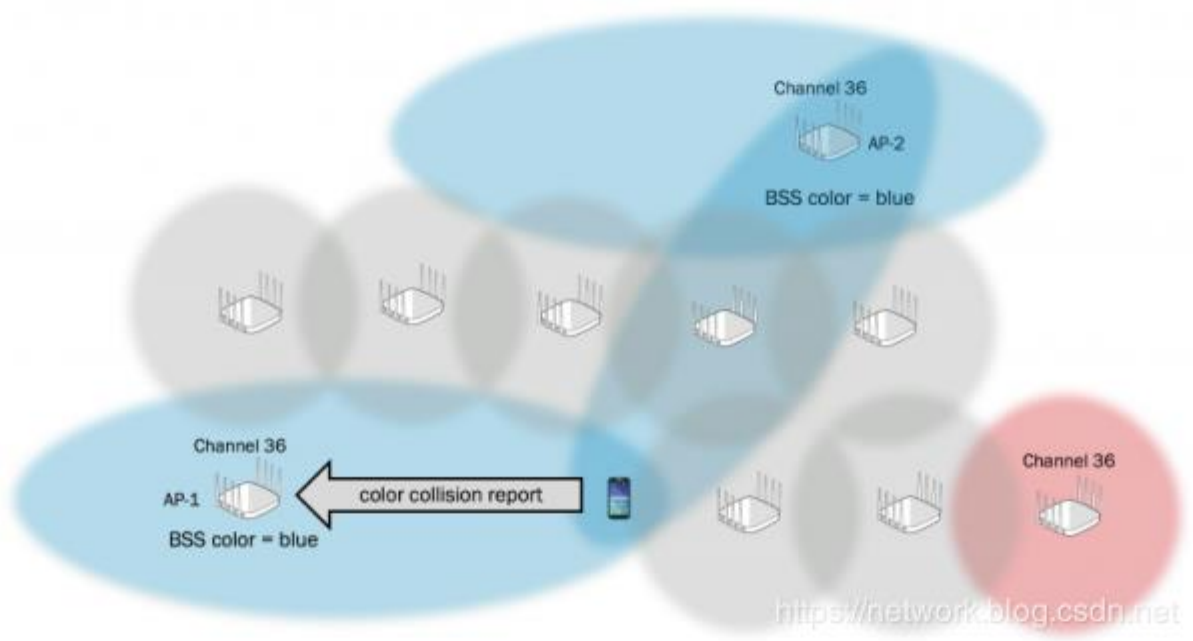

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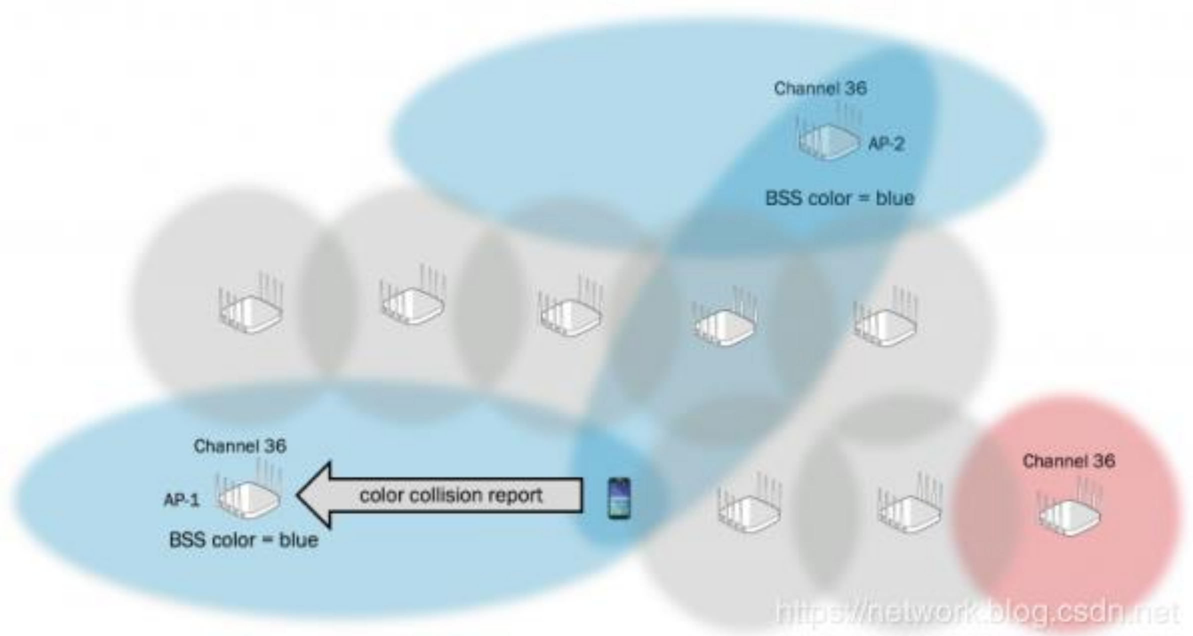

Color collision detection: AP and other STAs will detect the color collision and change their color.
CS with color: One STA uses low threshold to sense the signals from its BSS, and relatively high threshold to sense the signals from other color code.
Frequency reuse: BSSs with different colors and strong interference may choose different channels

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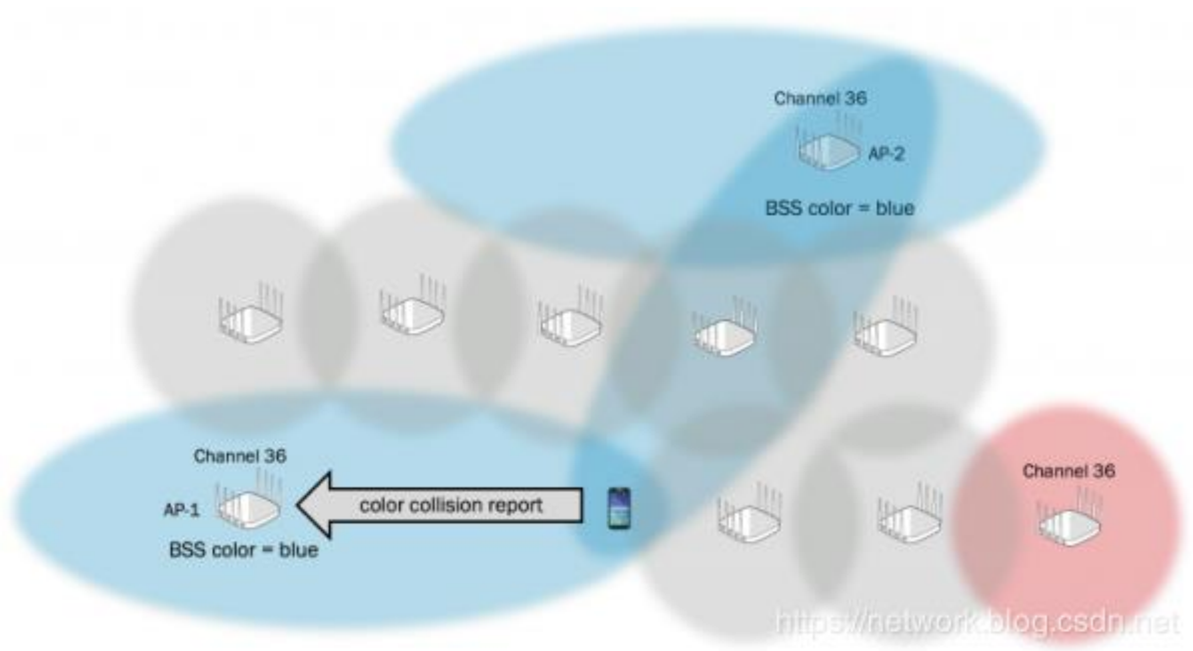

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Reading requirement

IEEE Std 802.11™-2020

- Section 10.1, 10.3.1-10.3.7