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IEEE 802.11 MAC layer operation

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Medium Access Control (MAC)

Medium access control: Different nodes must gain access to the shared medium (for instance a wireless channel) in a controlled fashion (otherwise there will be collisions).

Access methods:

FDMA	Assigning channels in frequency domain
TDMA	Assigning time slots in time domain
CDMA	Assigning code sequences in code domain
CSMA	Assigning transmission opportunities in time domain on a statistical basis

:
LLC
MAC
PHY

CSMA/CD vs. CSMA/CA (1)

CSMA/CD (Collision Detection) is the MAC method used in a wired LAN (Ethernet). Wired LAN stations can (whereas wireless stations cannot) detect collisions.

Basic CSMA/CD operation:

1) Wait for free medium
2) Transmit frame
3) If collision, stop transmission immediately
4) Retransmit after random time (backoff)

CSMA/CD rule:
Backoff after collision

CSMA/CD vs. CSMA/CA (2)

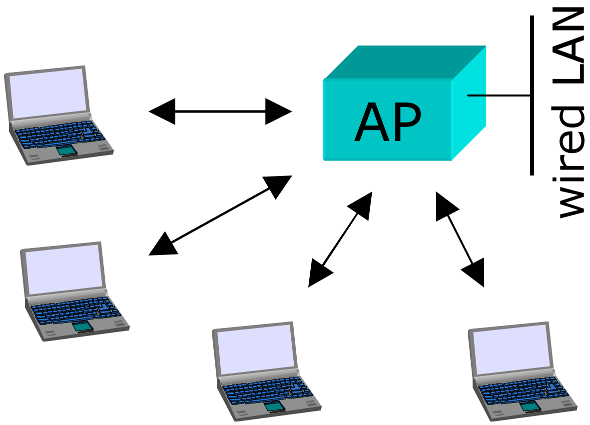
CSMA/CA (Collision Avoidance) is the MAC method used in a wireless LAN. Wireless stations cannot detect collisions (i.e. the whole packets will be transmitted anyway).

Basic CSMA/CA operation:

1) Wait for free medium
2) Wait a random time (backoff)
3) Transmit frame
4) If collision, the stations do not notice it
5) Collision => erroneous frame => no ACK returned

CSMA/CA rule: Backoff before collision

Basic wireless medium access



CSMA:
One packet at a time

We shall next investigate Infrastructure BSS only.

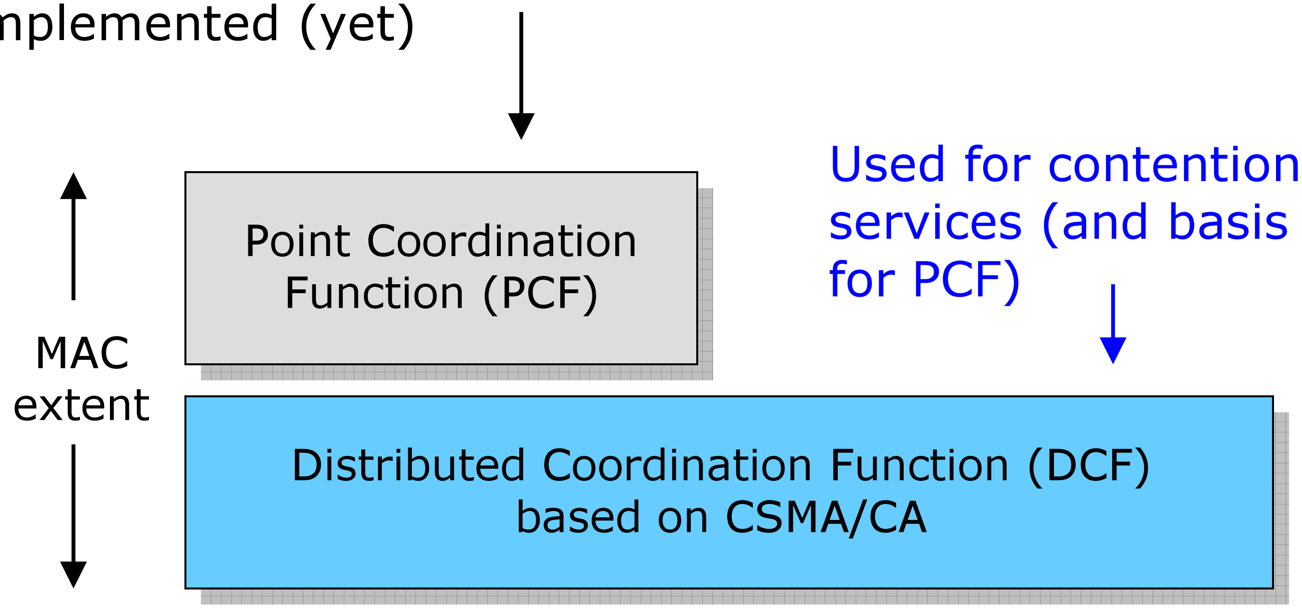
As far as medium access is concerned, all stations and AP have equal priority

⇔

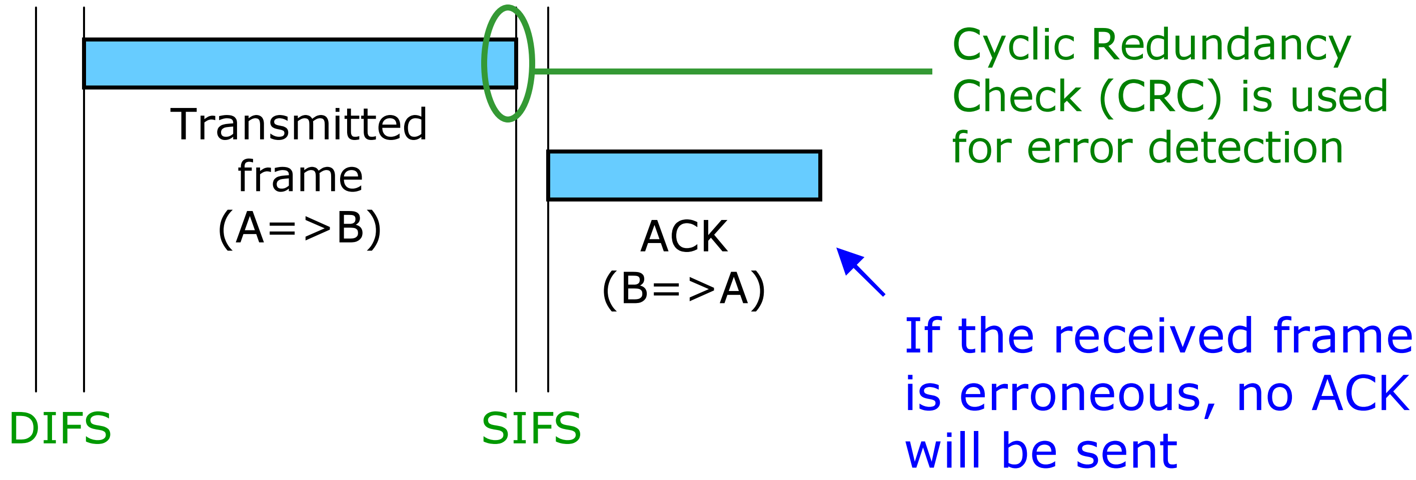
transmission in downlink (from the AP) and uplink (from a station) is similar.

DCF (CSMA/CA) vs. PCF

Designed for contention-free services (delay-sensitive real-time services such as voice transmission), but has not been implemented (yet)

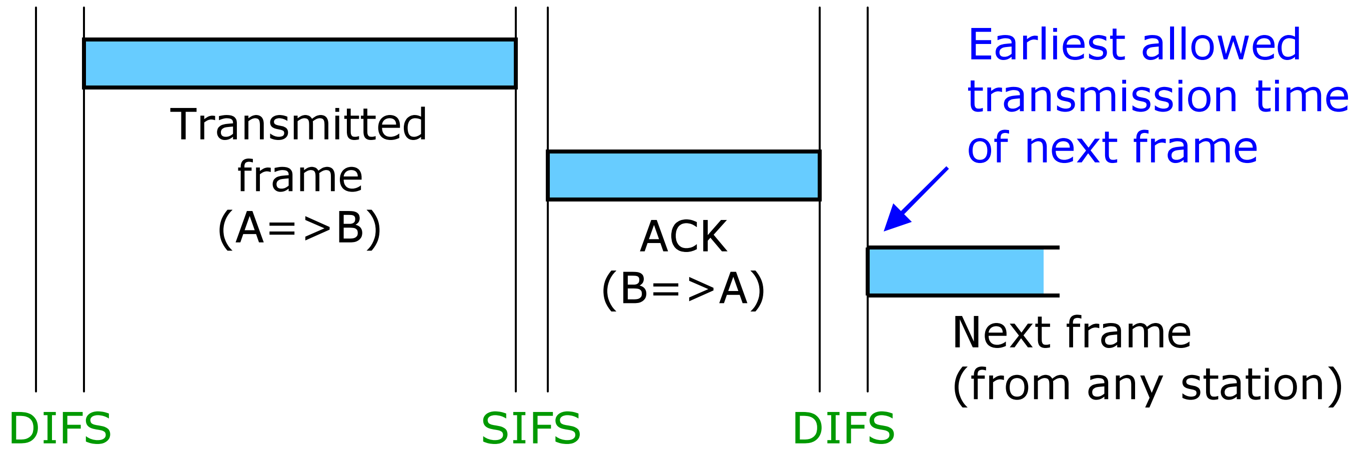


Wireless medium access (1)



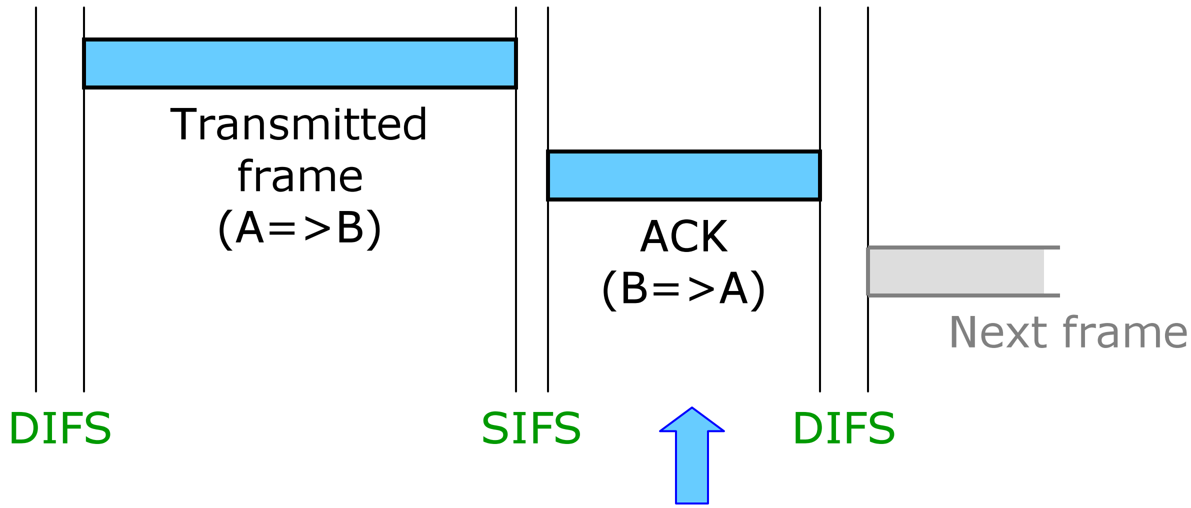
When a frame is received without bit errors, the receiving station (B) sends an Acknowledgement (ACK) frame back to the transmitting station (A).

Wireless medium access (2)



During the transmission sequence (Frame + SIFS + ACK) the medium (radio channel) is reserved. The next frame can be transmitted at earliest after the next DIFS period.

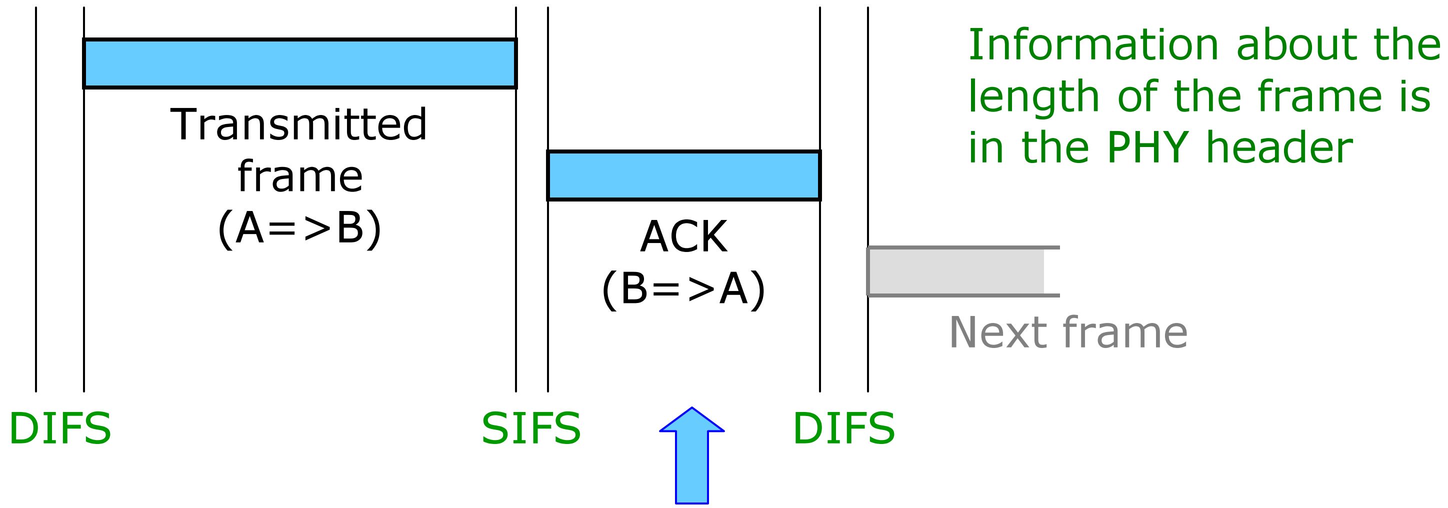
Wireless medium access (3)



There are two mechanisms for reserving the channel:

Physical carrier sensing and Virtual carrier sensing using the so-called Network Allocation Vector (NAV).

Wireless medium access (4)



Physical carrier sensing means that the physical layer (PHY) informs the MAC layer when a frame has been detected. Access priorities are achieved through interframe spacing.

Wireless medium access (5)

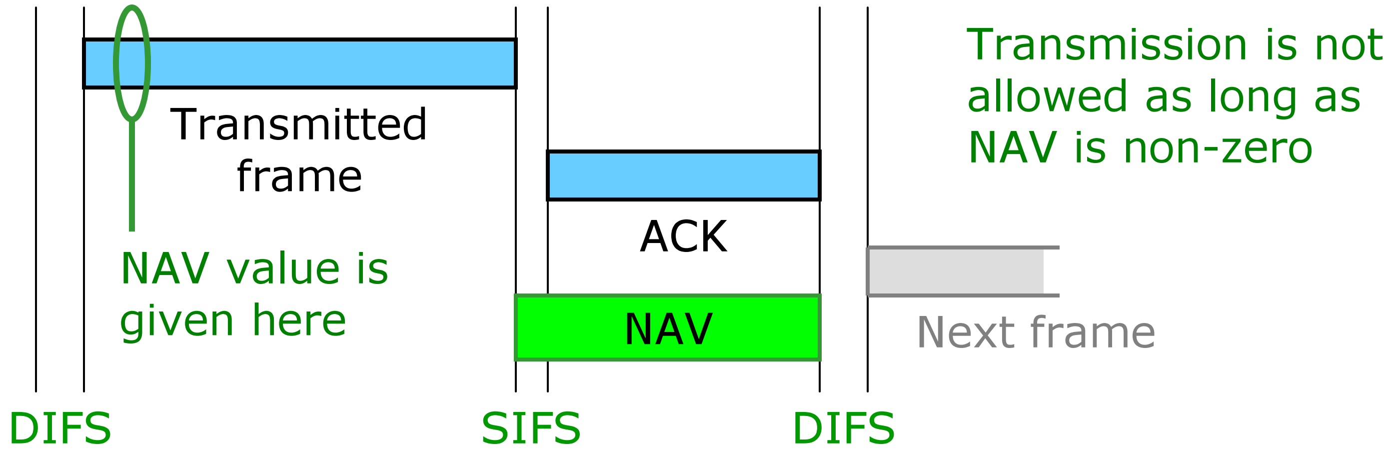
The two most important interframe spacing times are SIFS and DIFS. In 802.11b networks, the times are:

SIFS (Short Interframe Space) = 10 μs

DIFS (DCF Interframe Space) = 50 μs

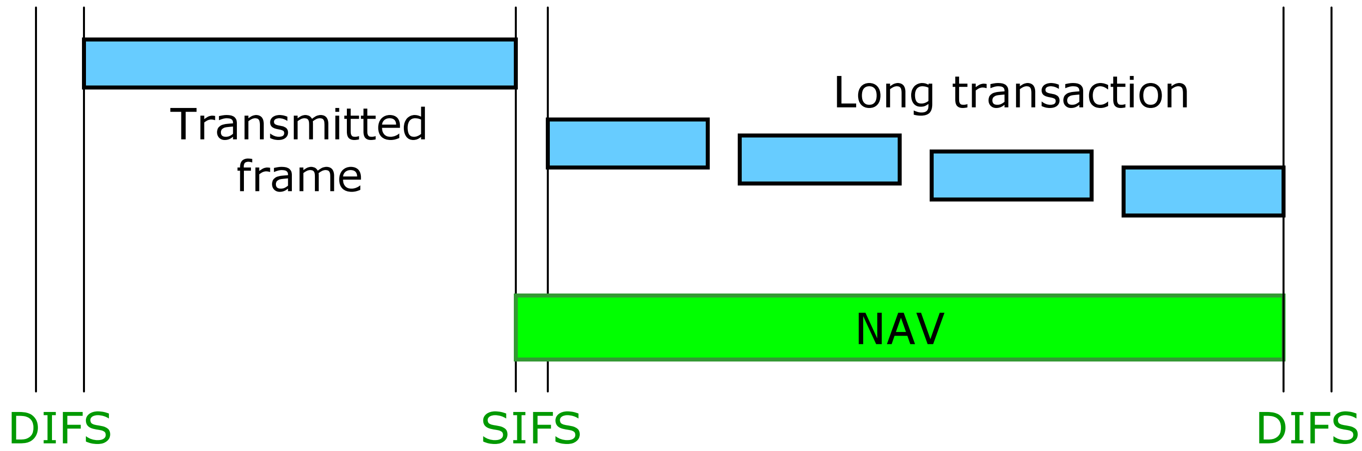
When two stations try to access the medium at the same time, the one that has to wait for the time SIFS wins over the one that has to wait for the time DIFS. In other words, SIFS has higher priority over DIFS.

Wireless medium access (6)



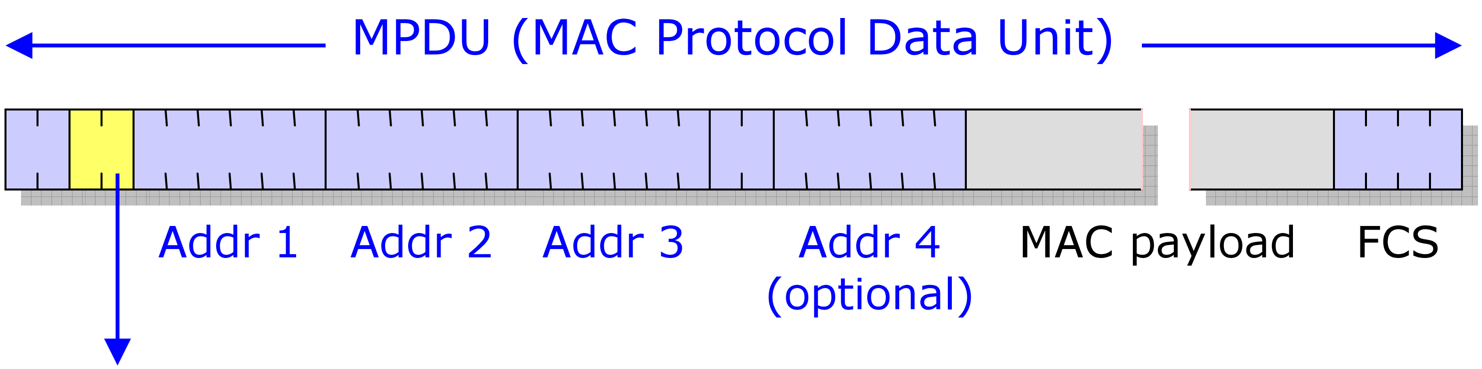
Virtual carrier sensing means that a NAV value is set in all stations that were able to receive a transmitted frame and were able to read the NAV value in this frame.

Wireless medium access (7)



Virtual carrier sensing using NAV is important in situations where the channel should be reserved for a ”longer time” (RTS/CTS usage, fragmentation, etc.).

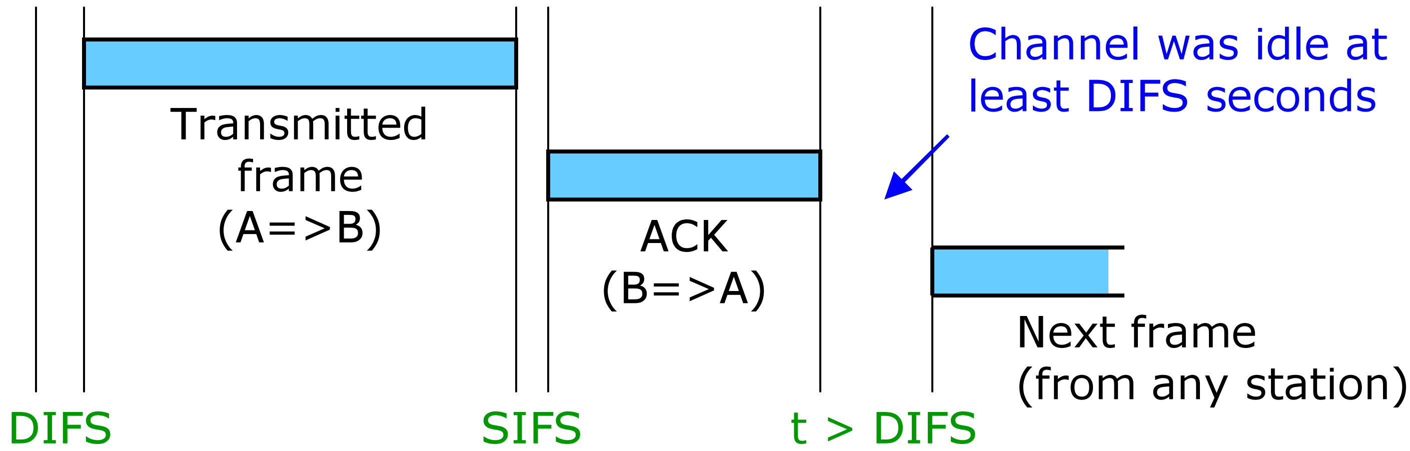
NAV value is carried in MAC header



Duration field: 15 bits contain the NAV value in number of microseconds. The last (sixteenth) bit is zero.

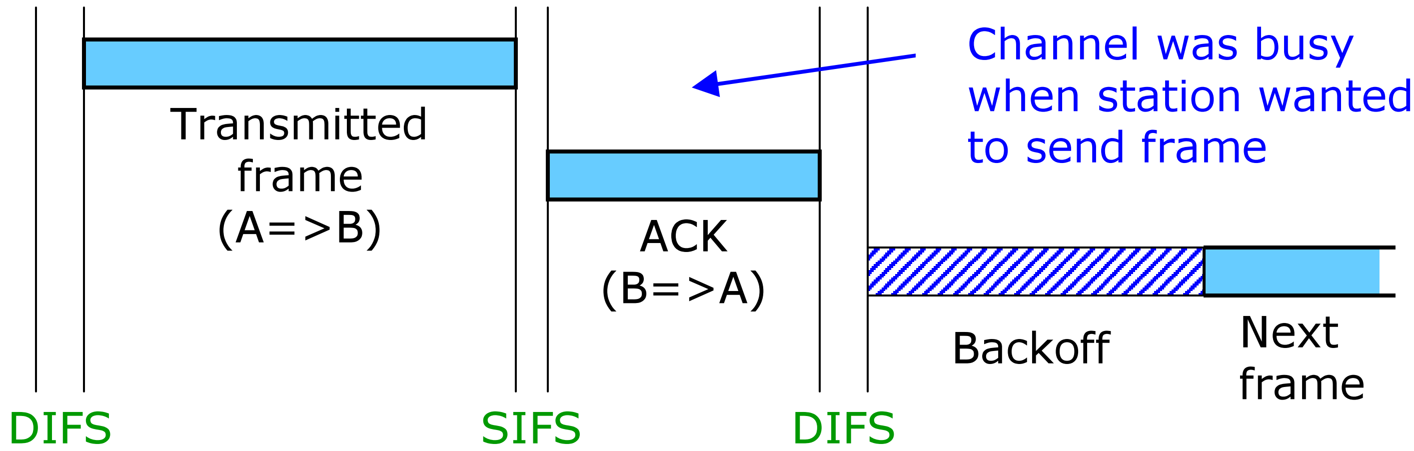
All stations must monitor the headers of all frames they receive and store the NAV value in a counter. The counter decrements in steps of one microsecond. When the counter reaches zero, the channel is available again.

Wireless medium access (8)



When a station wants to send a frame and the channel has been idle for a time > DIFS (counted from the moment the station first probed the channel) => can send immediately.

Wireless medium access (9)

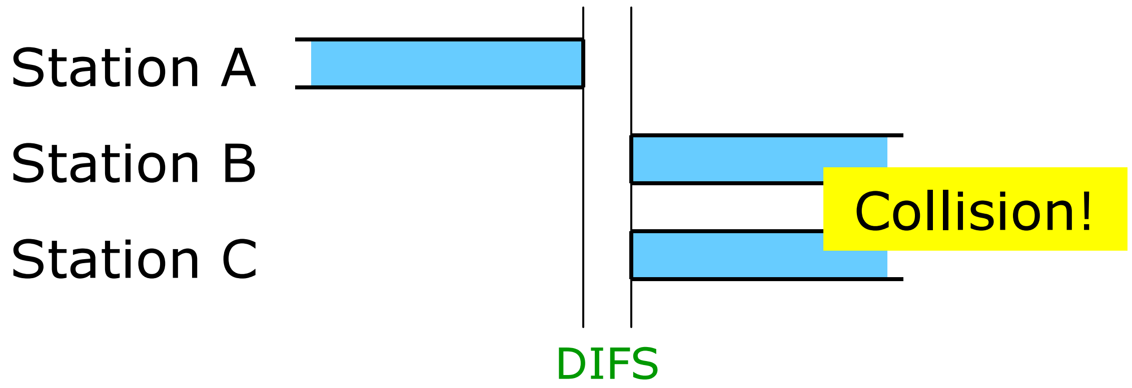


When a station wants to send a frame and the channel is busy => the station must wait a backoff time before it is allowed to transmit the frame. Reason? Next two slides…

No backoff => collision is certain

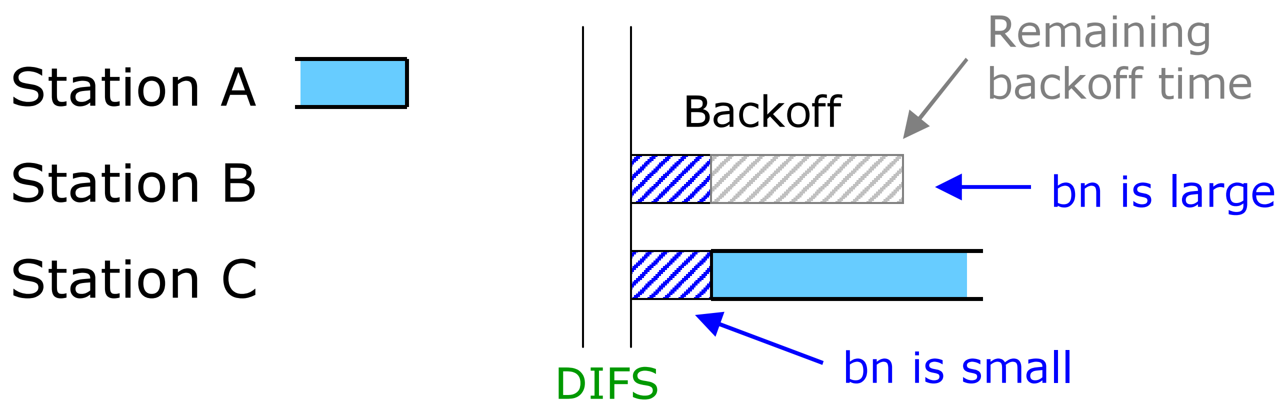
Suppose that several stations (B and C in the figure) are waiting to access the wireless medium.

When the channel becomes idle, these stations start sending their packets at the same time => collision!



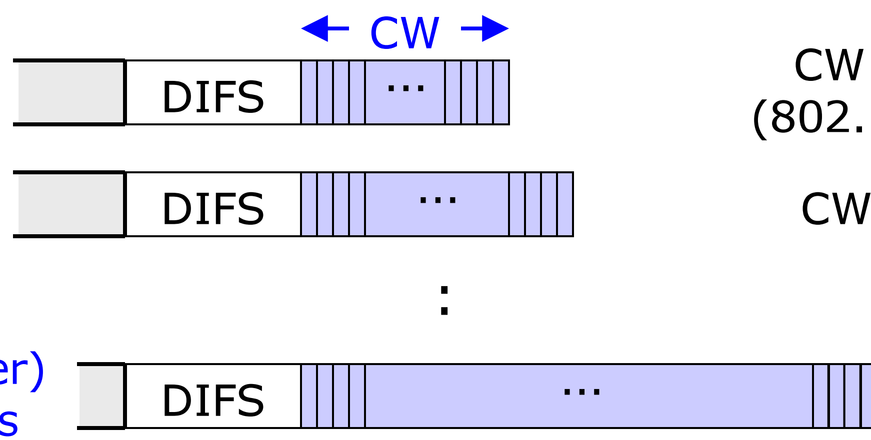
Backoff => collision probability is reduced

Contending stations generate random backoff values bn. Backoff counters count downwards, starting from bn. When a counter reaches zero, the station is allowed to send its frame. All other counters stop counting until the channel becomes idle again.



Contention window (CW)

If transmission of a frame was unsuccessful and the frame is allowed to be retransmitted, before each retransmission the Contention Window (CW) from which bn is chosen is increased.



Initial attempt — $CW = 2^5-1 = 31$ slots (802.11b: slot = 20 μs)

1st retransm. — $CW = 2^6-1 = 63$ slots

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5th (and further) retransmissions — $CW = 2^{10}-1 = 1023$ slots

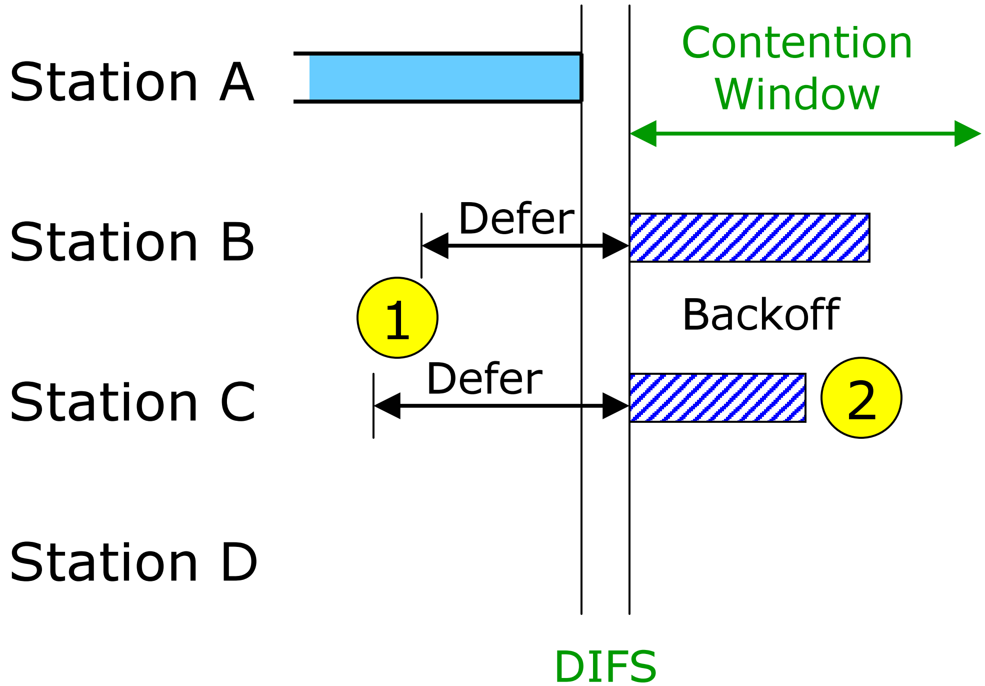
Selection of random backoff

From the number CW (= 31 … 1023 slots) the random backoff bn (in terms of slots) is chosen in such a way that bn is uniformly distributed between 0 … CW.

Since it is unlikely that several stations will choose the same value of bn, collisions are avoided.

The next slides show wireless medium access in action. The example involves four stations: A, B, C and D. ”Sending a packet” means ”Data+SIFS+ACK” sequence. Note how the backoff time can be split into several parts.

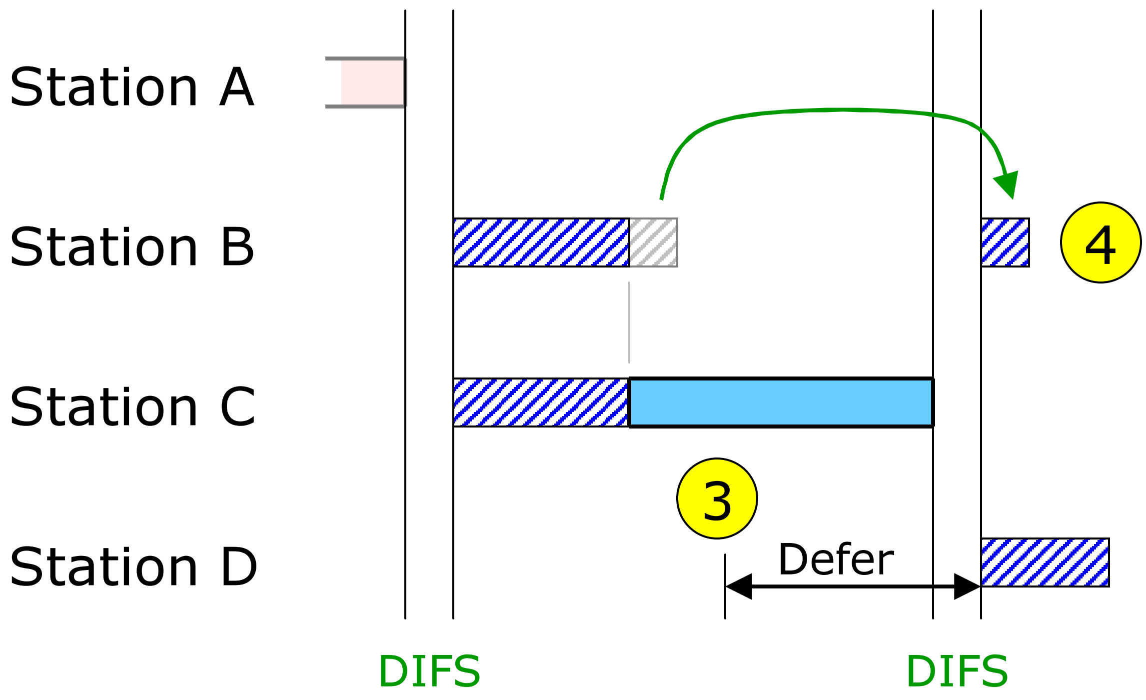
Wireless medium access (1)



1) While station A is sending a packet, stations B and C also wish to send packets, but have to wait (defer + backoff)

2) Station C is ”winner” (backoff time expires first) and starts sending packet

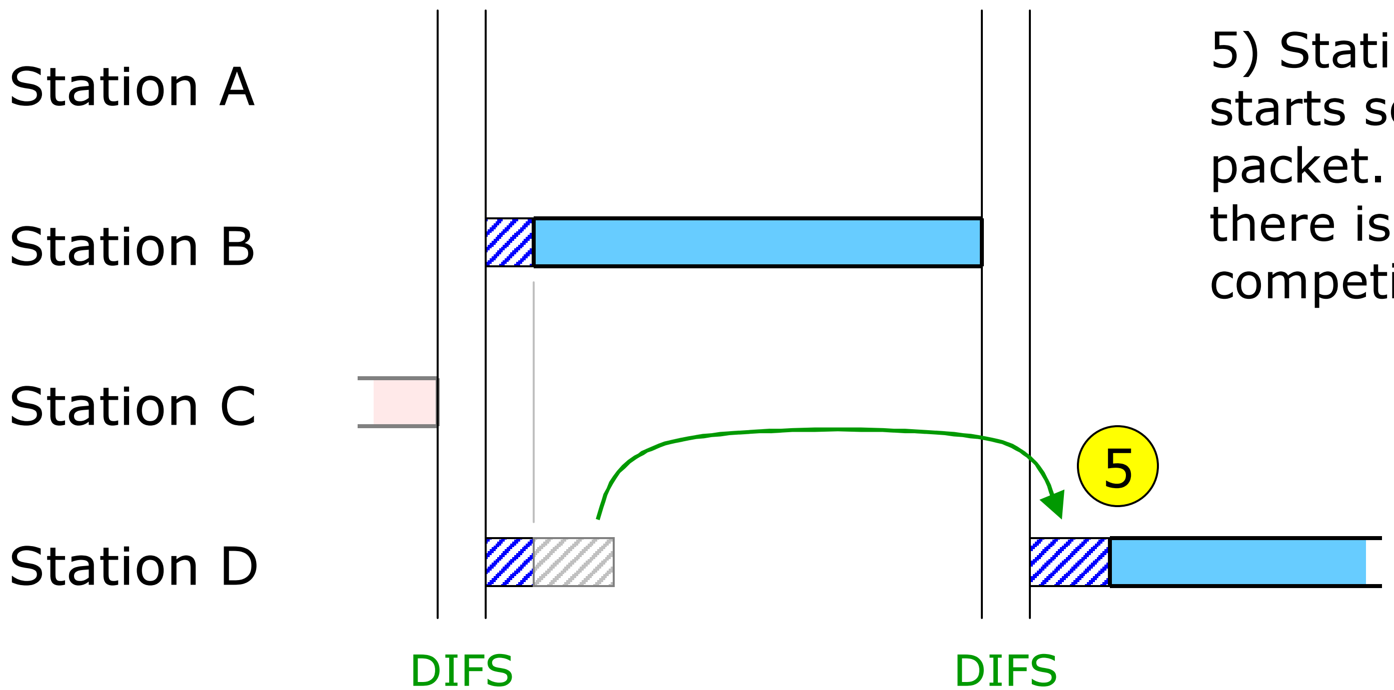
Wireless medium access (2)



3) Station D also wishes to send a packet

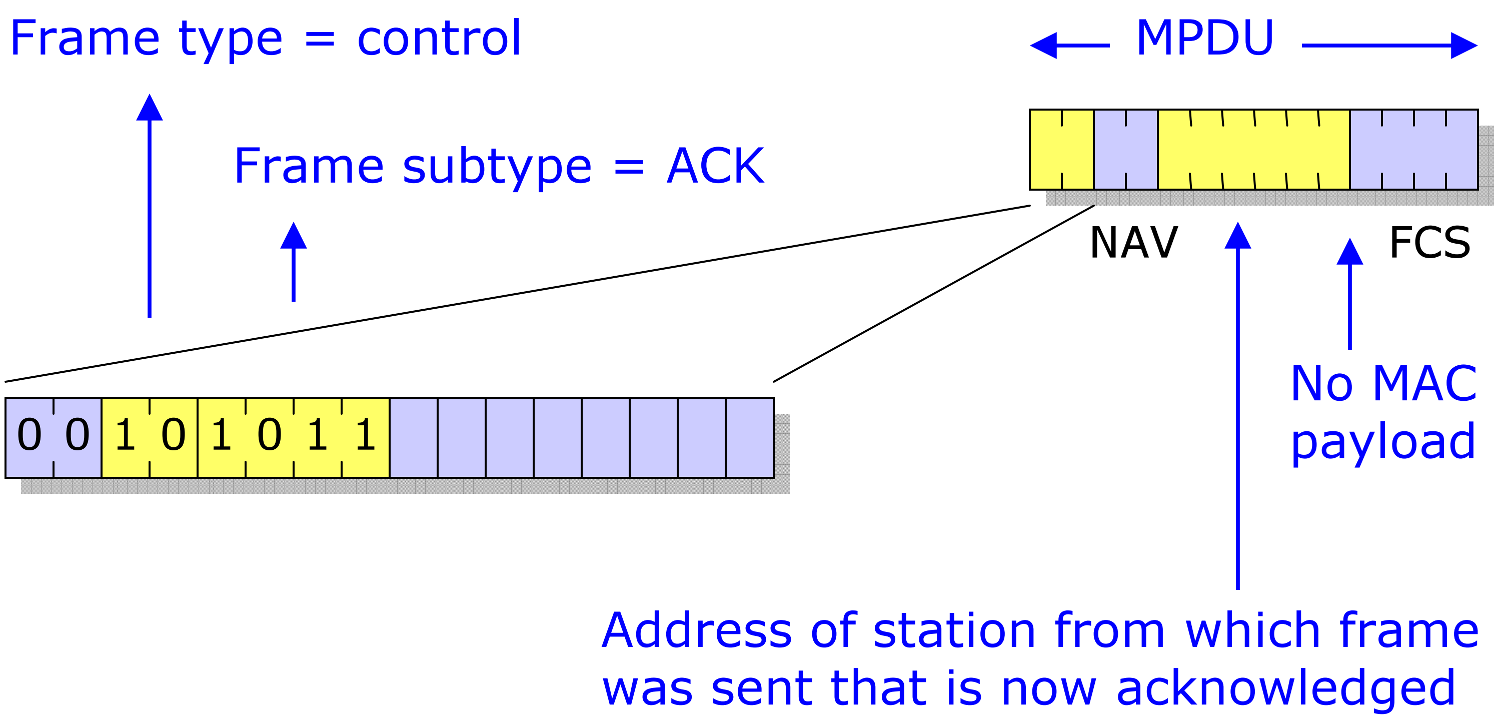
4) However, station B is ”winner” and starts sending packet

Wireless medium access (3)



5) Station D starts sending packet. Now there is no competition.

ACK frame structure



Usage of RTS & CTS

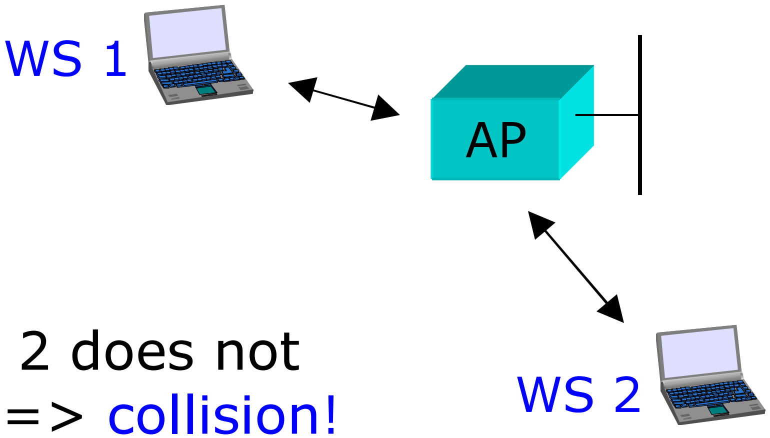
The RTS/CTS (Request/Clear To Send) scheme is used as a countermeasure against the "hidden node" problem:

Hidden node problem:

WS 1 and WS 2 can hear the AP but not each other

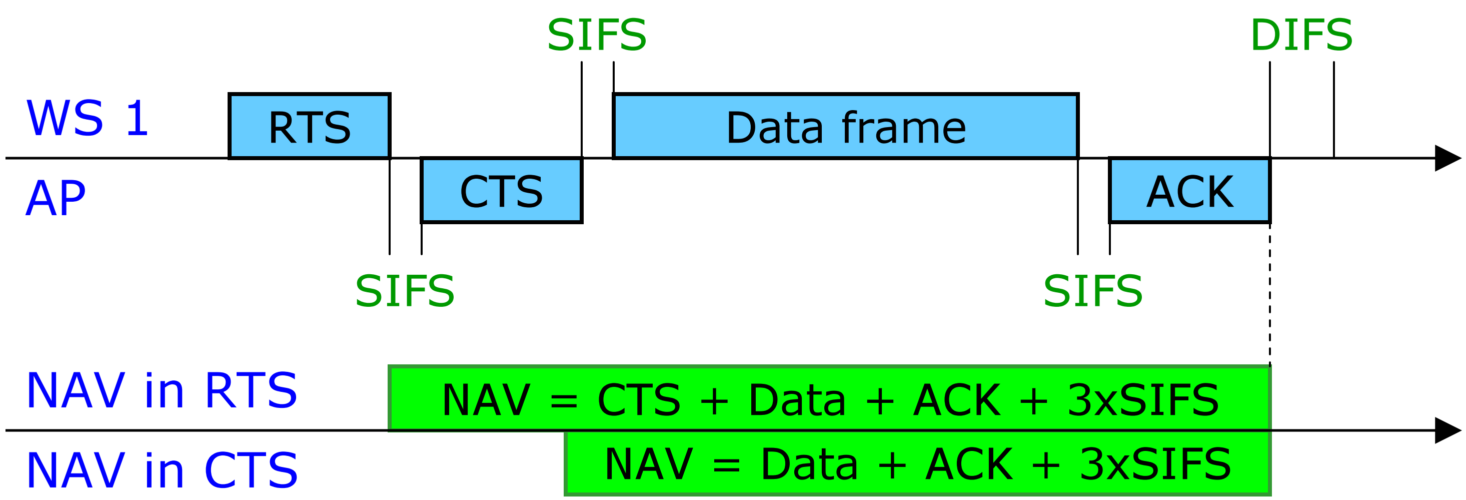
=>

If WS 1 sends a packet, WS 2 does not notice this (and vice versa) => collision!



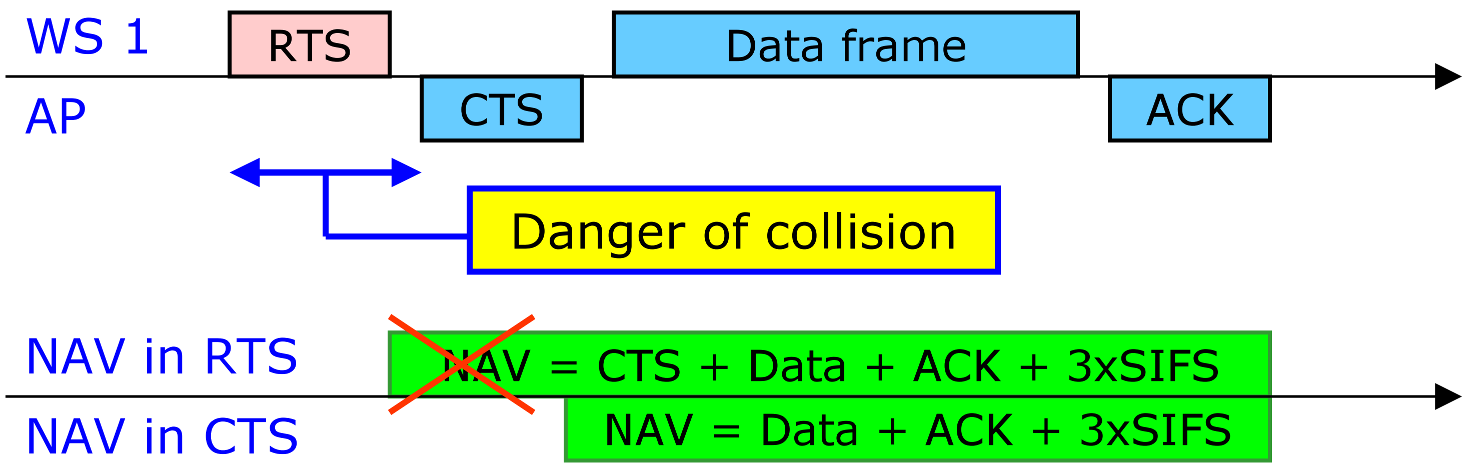
Reservation of medium using NAV

The RTS/CTS scheme makes use of “SIFS-only” and the NAV (Network Allocation Vector) to reserve the medium:



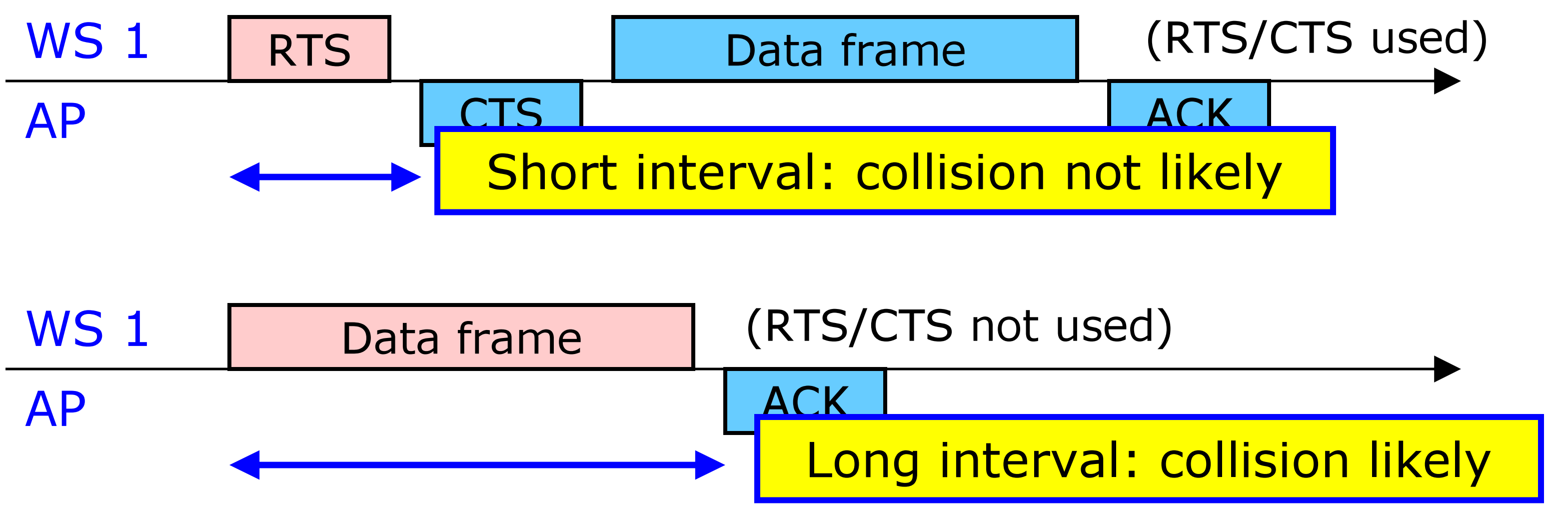
Danger of collision only during RTS

WS 2 does not hear the RTS frame (and associated NAV), but can hear the CTS frame (and associated NAV).



Advantage of RTS & CTS (1)

Usage of RTS/CTS offers an advantage if the data frame is very long compared to the RTS frame:



Advantage of RTS & CTS (2)

A long collision danger interval (previous slide) should be avoided for the following reasons:

- Larger probability of collision
- Greater waste of capacity if a collision occurs and the frame has to be retransmitted.

A threshold parameter (dot11RTSThreshold) can be set in the mobile station. Frames shorter than this threshold value will be transmitted without using RTS/CTS.