EC 553
Communication Networks

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Syllabus

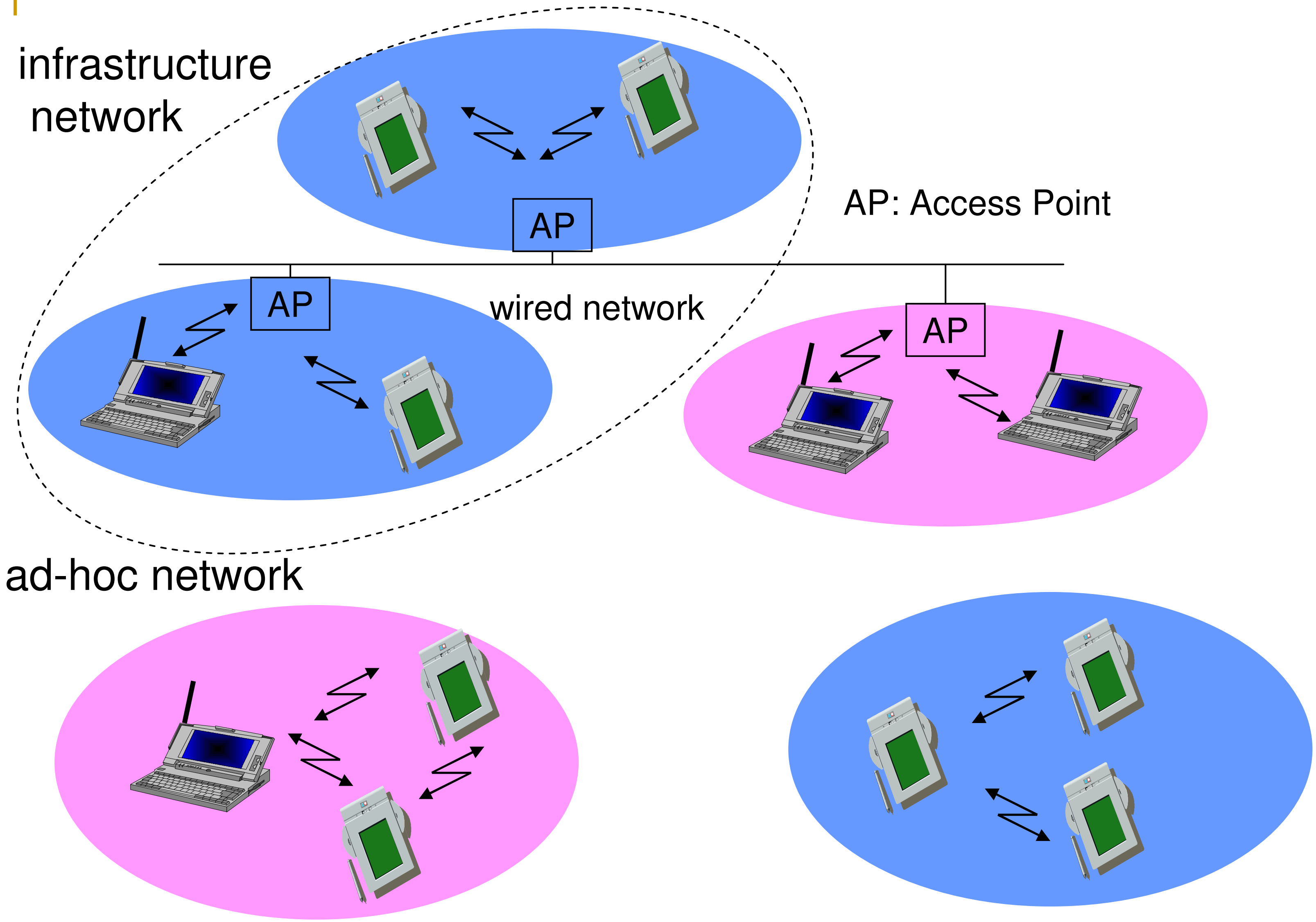
- Tentatively

Week 1	Overview
Week 2	Packet Switching
Week 3	IP addressing and subnetting
Week 4	IP addressing and subnetting
Week 5	Introduction to Routing concept, Routing algorithms
Week 6	Routing protocols
Week 7	Multiple Access I
Week 8	Multiple access II
Week 9	LAN networks
Week 10	Token ring networks
Week 11	VOIP
Week 12	WLAN
Week 13	TCP
Week 14	Congestion control
Week 15	QOS

Requirements

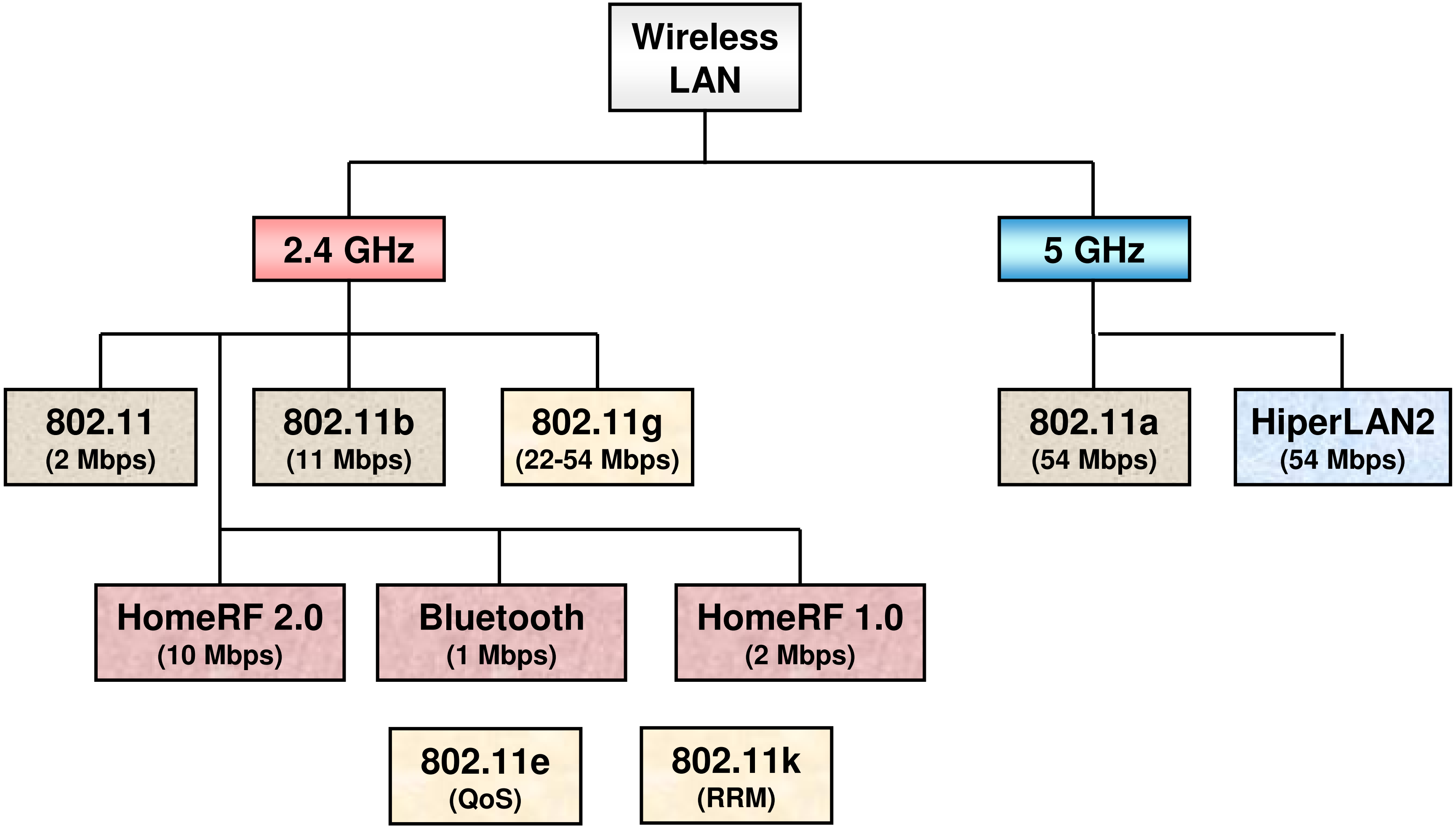
- Collision avoidance
  - Basic task — medium access control
- Energy efficiency
- Scalability and adaptivity
  - Number of nodes changes overtime
- Latency
- Fairness
- Throughput
- Bandwidth utilization

Infrastructure and Adhoc Networks



Source: Schiller

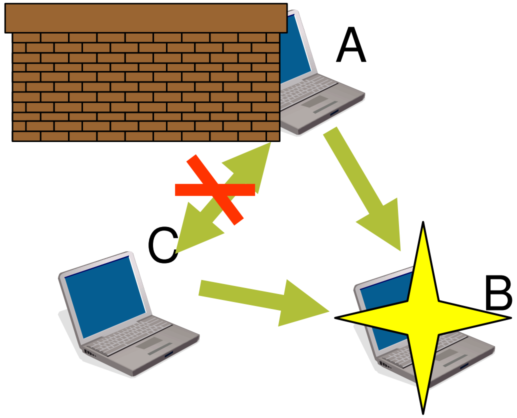
WLAN: Standards



Cotention-based Protocols

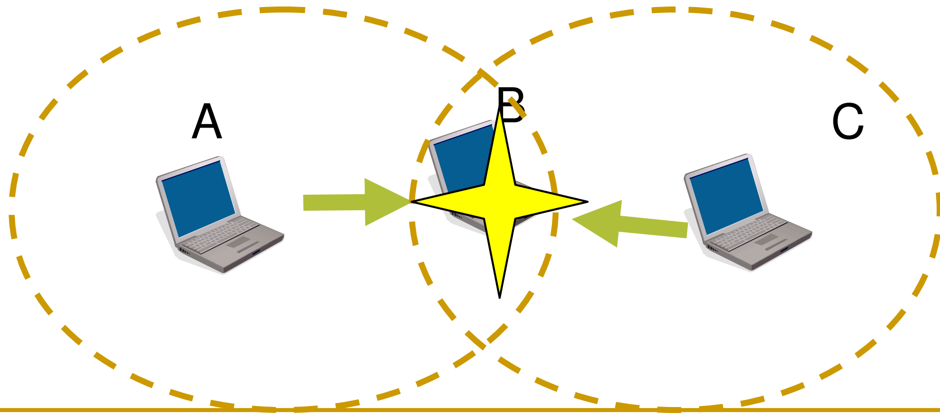
- Random assignment approaches
  - Dynamic number of transceivers contend for medium
  - Distributed (peer-to-peer) algorithms for contention
  - Great for dynamic / unplanned or distributed networks
  - Problem: Hidden and Exposed Terminal Problems

Hidden Terminal Problem

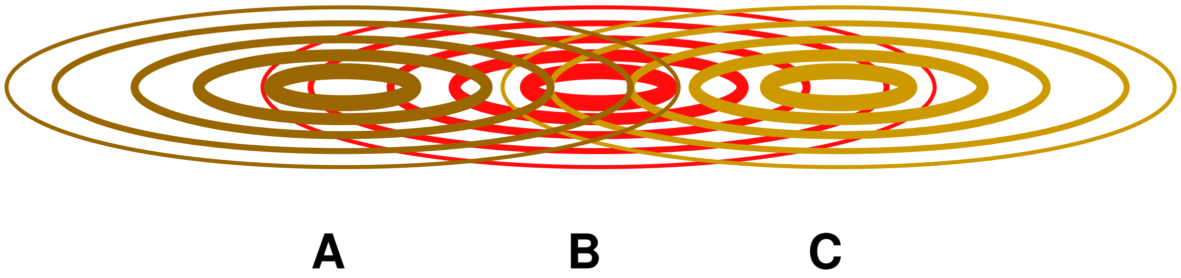


Senders A and C separated by obstacle. Each thinks the medium is free.

Senders A and C out of range of each other. Each thinks medium is free.

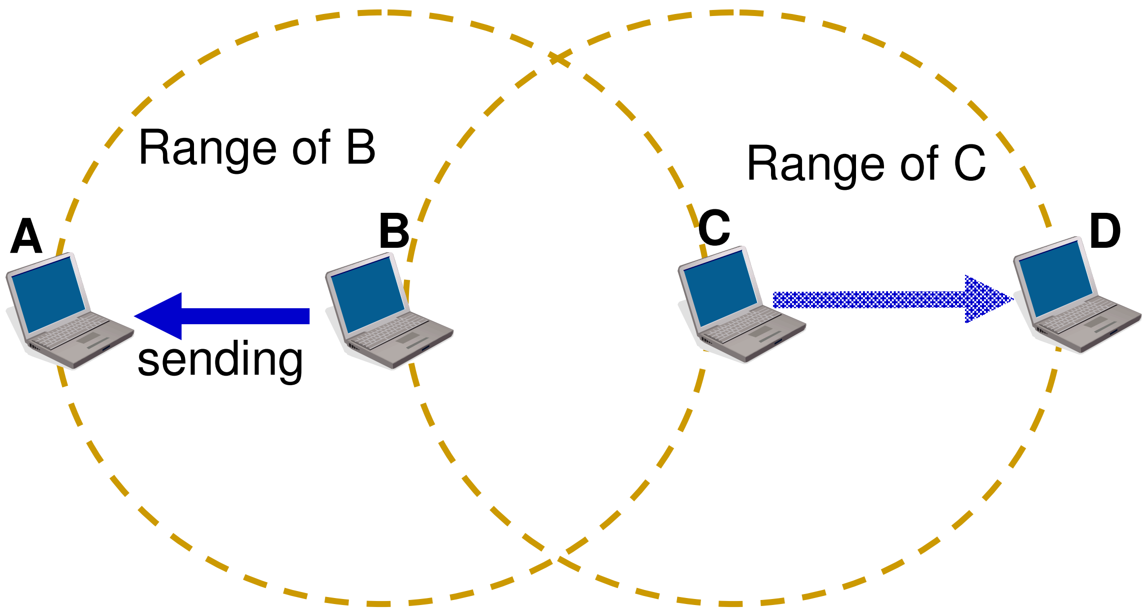


Hidden Terminal Problem

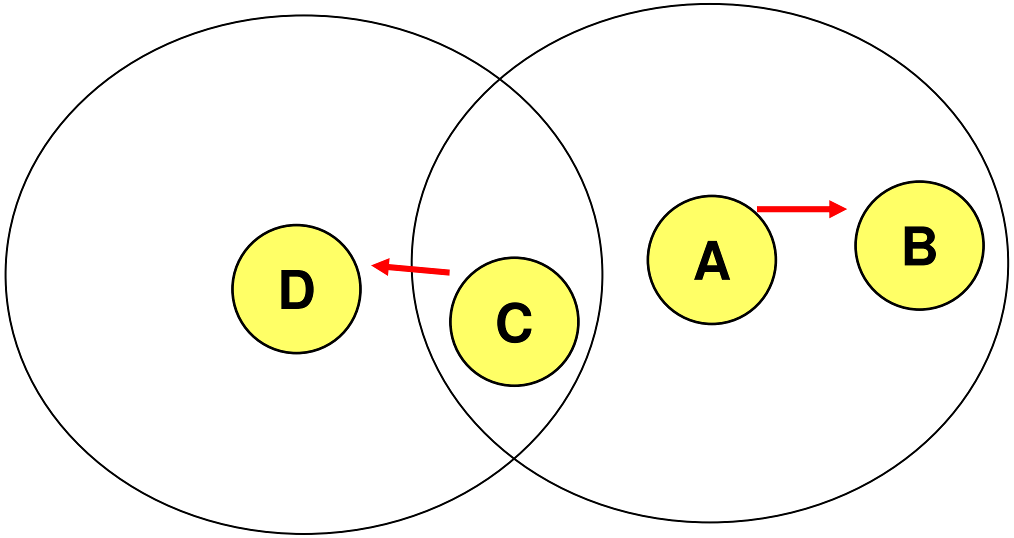


- A and C cannot hear each other.
- A sends to B, C cannot receive A.
- C wants to send to B, C senses a “free” medium (CS fails)
- Collision occurs at B.
- A cannot receive the collision (CD fails).
- A is “hidden” for C.

Exposed Terminal Problem



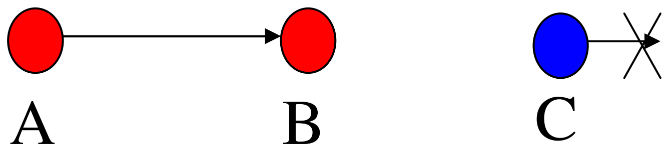
Exposed Terminal Problem



- A starts sending to B.
- C senses carrier, finds medium in use and has to wait for A->B to end.
- D is outside the range of A, therefore waiting is not necessary.

Contention-based Protocols -Examples

- CSMA — Carrier Sense Multiple Access
  - Ethernet
  - Not enough for wireless (collision at receiver)



Hidden terminal: A is hidden from C's CS

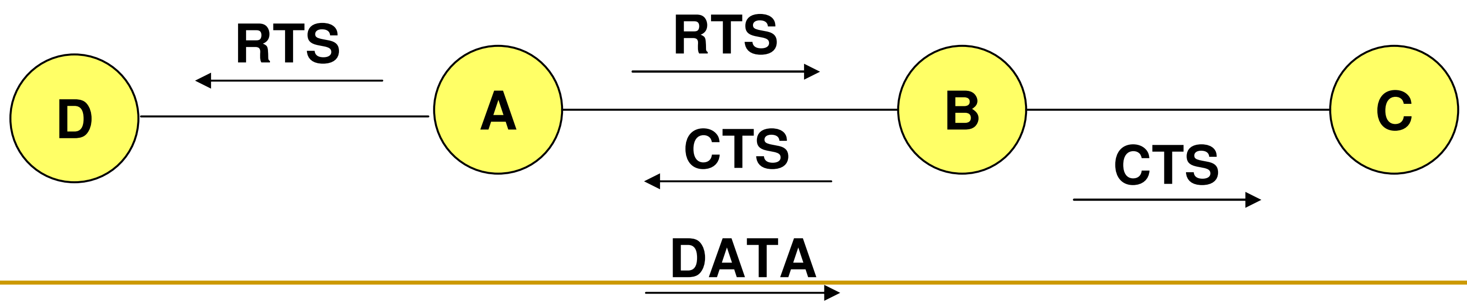
- MACA — Multiple Access w/ Collision Avoidance
  - RTS/CTS for hidden terminal problem
  - RTS/CTS/DATA

Contention-based Protocols -Examples

- MACAW — improved over MACA
  - RTS/CTS/DATA/ACK
  - Fast error recovery at link layer
- IEEE 802.11 Distributed Coordination Function (DCF)
  - Largely based on MACAW

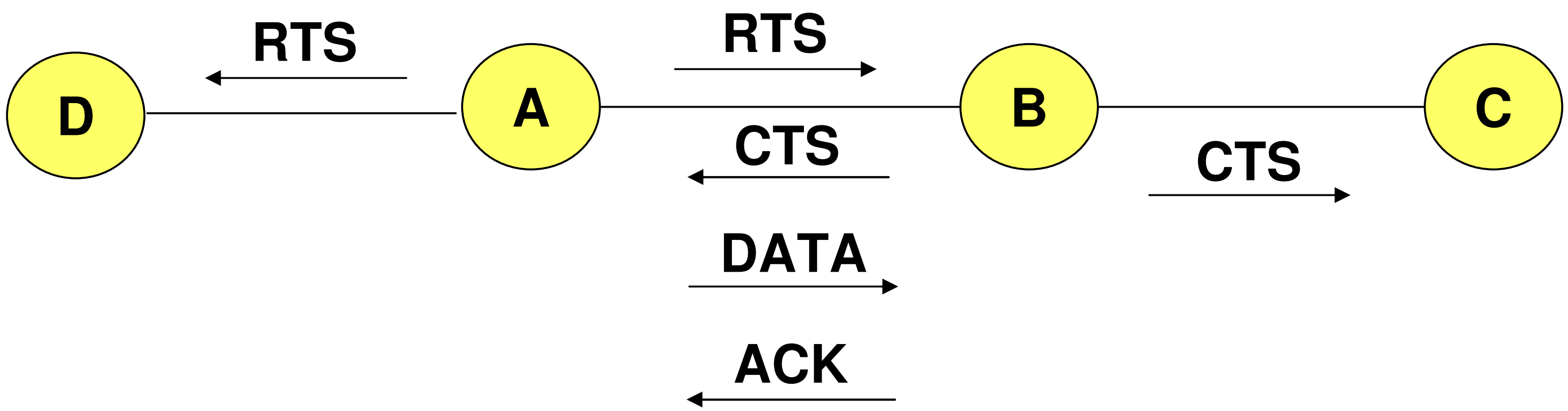
Solution for Hidden Terminals

- A first sends a *Request-to-Send (RTS)* to B
- On receiving RTS, B responds *Clear-to-Send (CTS)*
- Hidden node C overhears CTS and keeps quiet
  - Transfer duration is included in both RTS and CTS
- Exposed node overhears a RTS but not the CTS
  - D's transmission cannot interfere at B



802.11 – Reliability: ACKs

- When B receives DATA from A, B sends an ACK
- If A fails to receive an ACK, A retransmits the DATA
- Both C and D remain quiet until ACK (to prevent collision of ACK)
- Expected duration of transmission+ACK is included in RTS/CTS packets

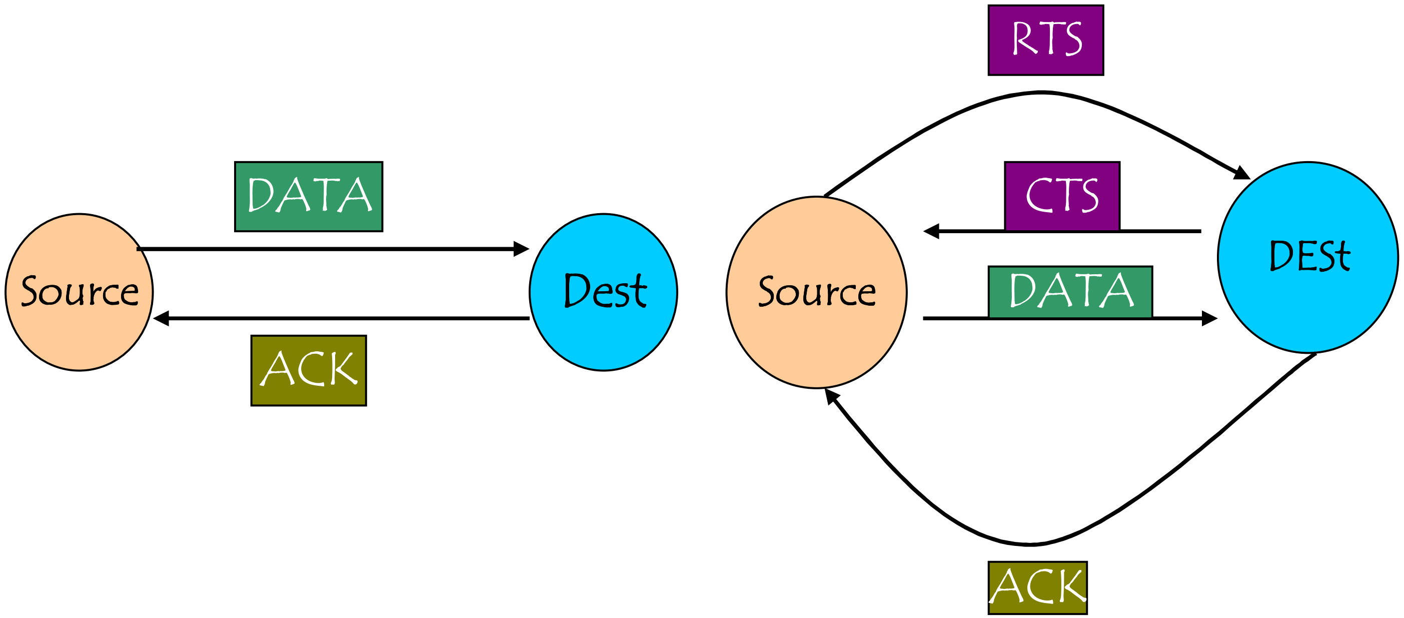


IEEE 802.11 DCF

- Distributed coordinate function: ad hoc mode
  - Virtual and physical carrier sense (CS)
    - Network allocation vector (NAV), duration field
  - Binary exponential backoff
  - RTS/CTS/DATA/ACK or DATA/ACK for unicast packets
  - Broadcast packets are directly sent after CS
  - Fragmentation support
    - RTS/CTS reserve time for first (frag + ACK)
    - First (frag + ACK) reserve time for second…
    - Give up tx when error happens

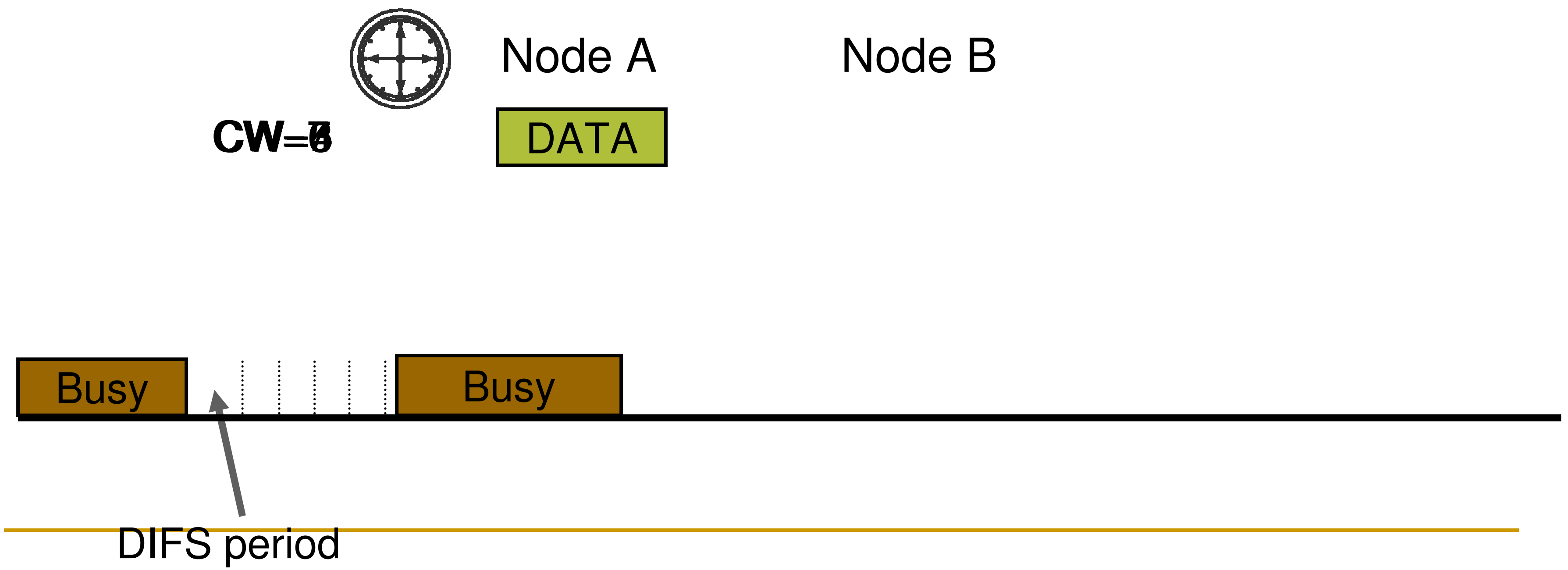
IEEE 802.11 Handshake

- Basic mechanism: 2 way handshaking
- RTS/CTS mechanism: 4 way handshaking



IEEE 802.11 DCF (2)

- Carrier-sensing until channel idle for DIFS period
- If channel not idle, random backoff based on contention window
- If channel idle, RTS-CTS-DATA-ACK or DATA-ACK handshake
- If transmission unsuccessful, double contention window size



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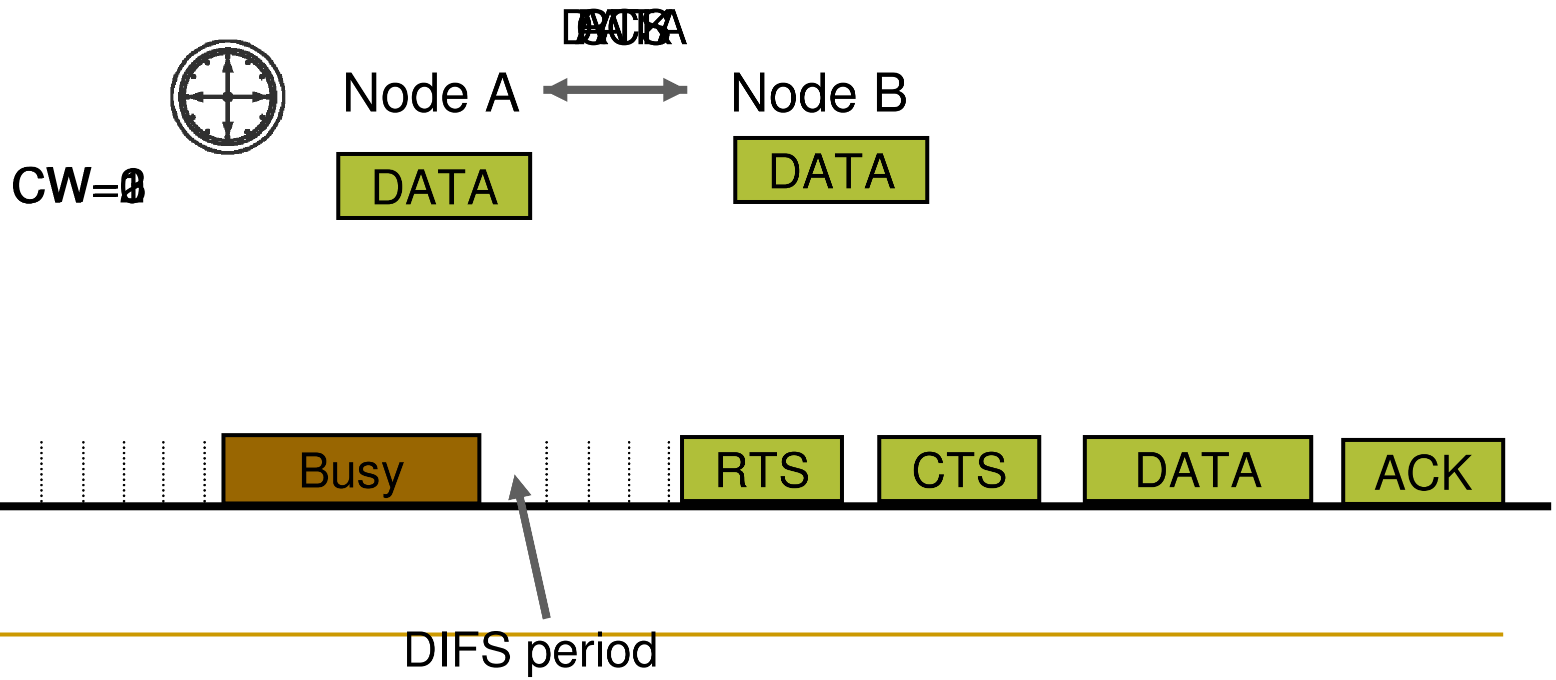
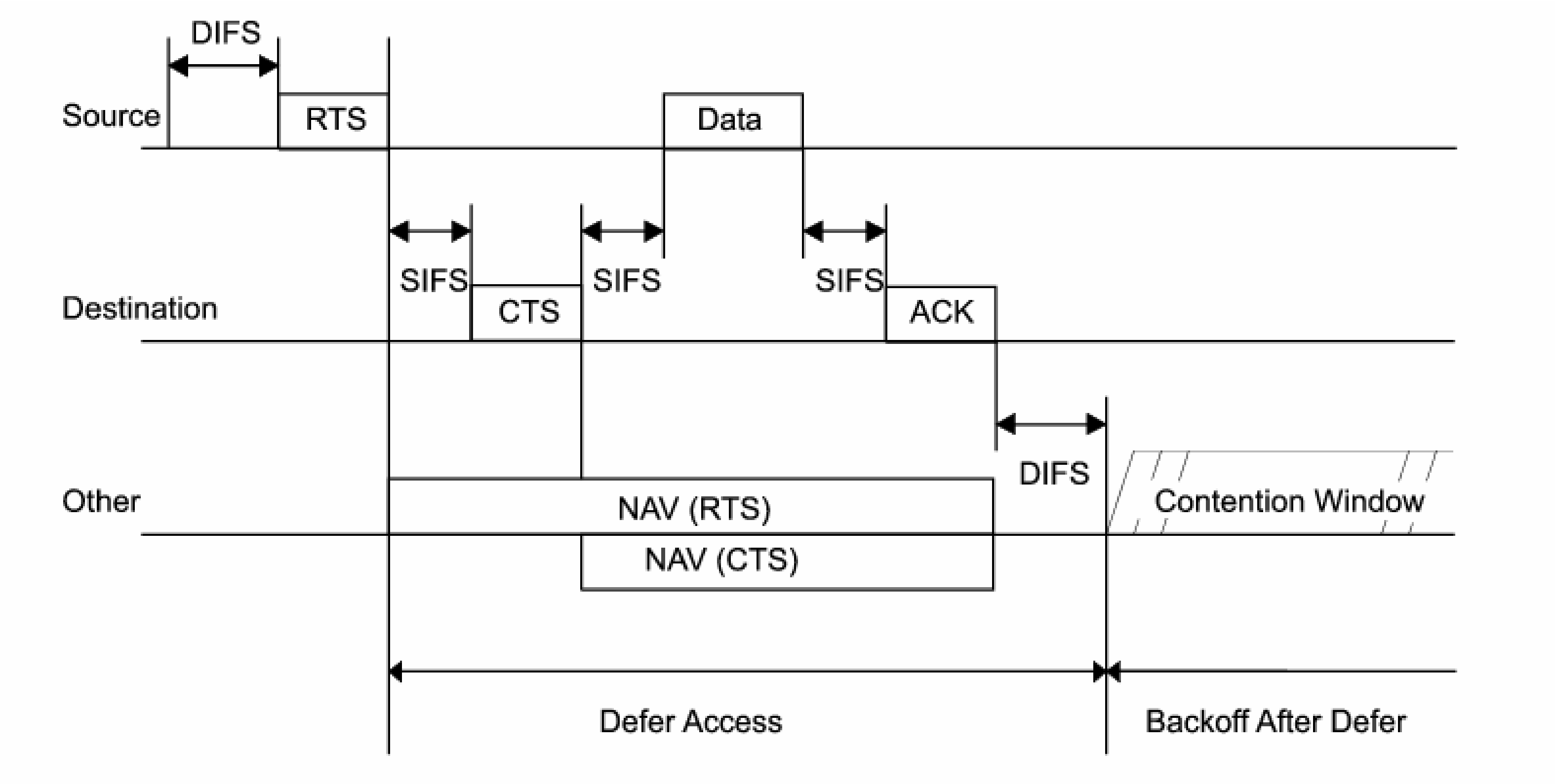
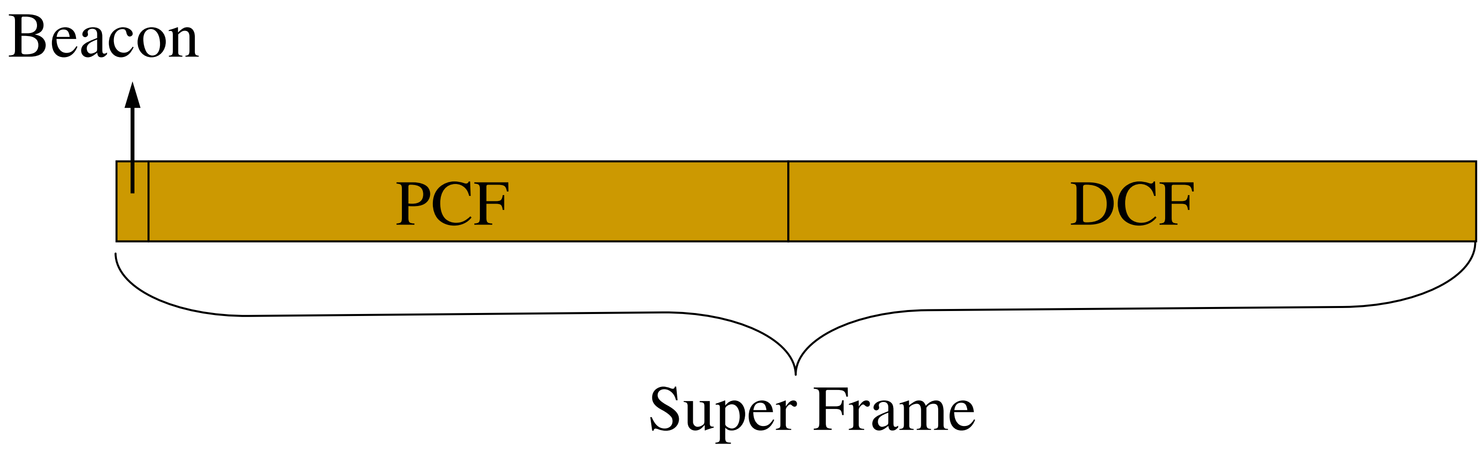


IEEE 802.11 DCF (3)

- Timing relationship





DCF - Distributed Coordinated Function

(**Contention Period** - *Ad-hoc Mode*)

PCF - Point Coordinated Function

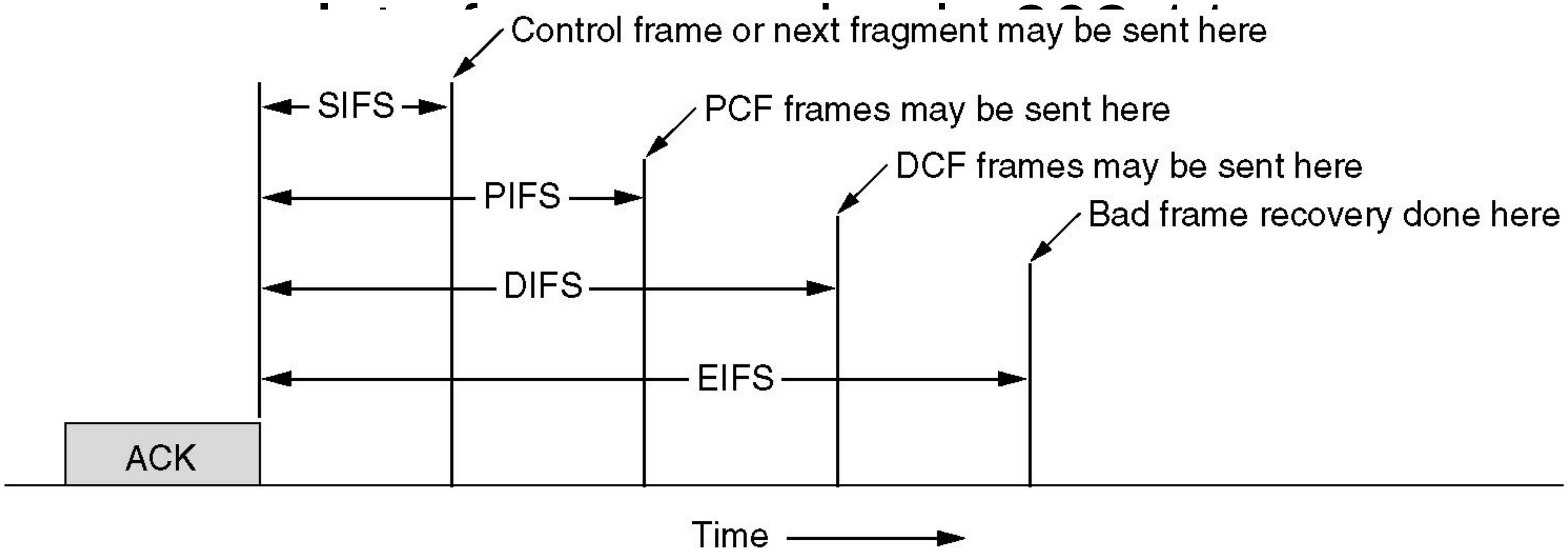
(**Contention Free Period** – *Infrastructure BSS*)

Beacon - Management Frame

Synchronization of Local timers

Delivers protocol related parameters

The 802.11 MAC Sublayer Protocol



Inter-Frame Spacing :

DIFS - 34 μsec

PIFS - 25 μsec (*Used in PCF*)

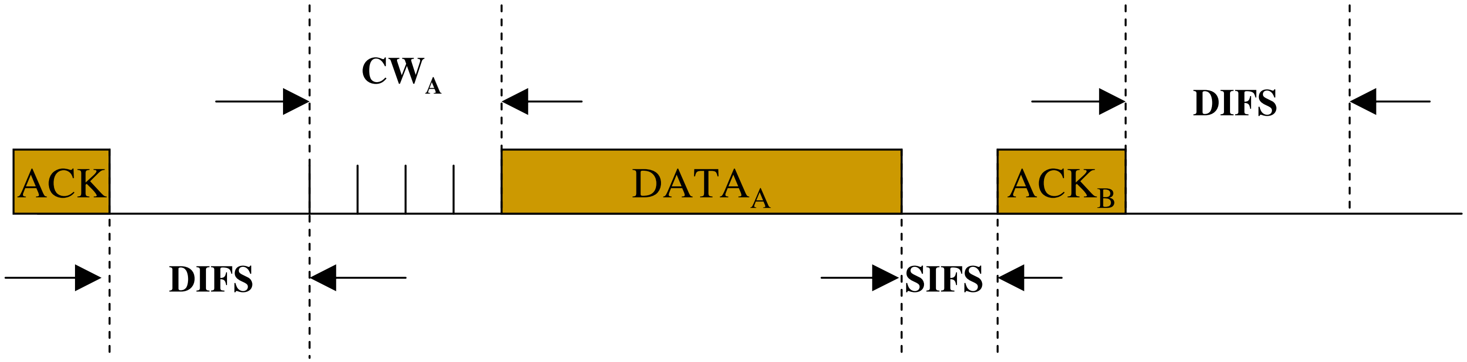
SIFS - 16 μsec

Slot Time - 9 μsec

DIFS = SIFS + (2 * Slot Time)

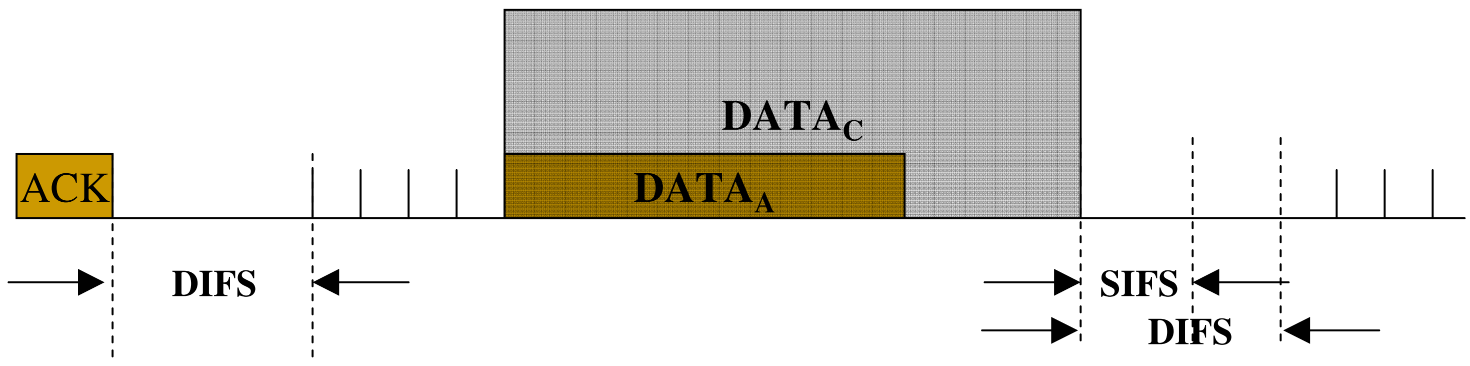
SIFS required for turn around of Tx to Rx and vice versa

Data Transmission from Node A to B



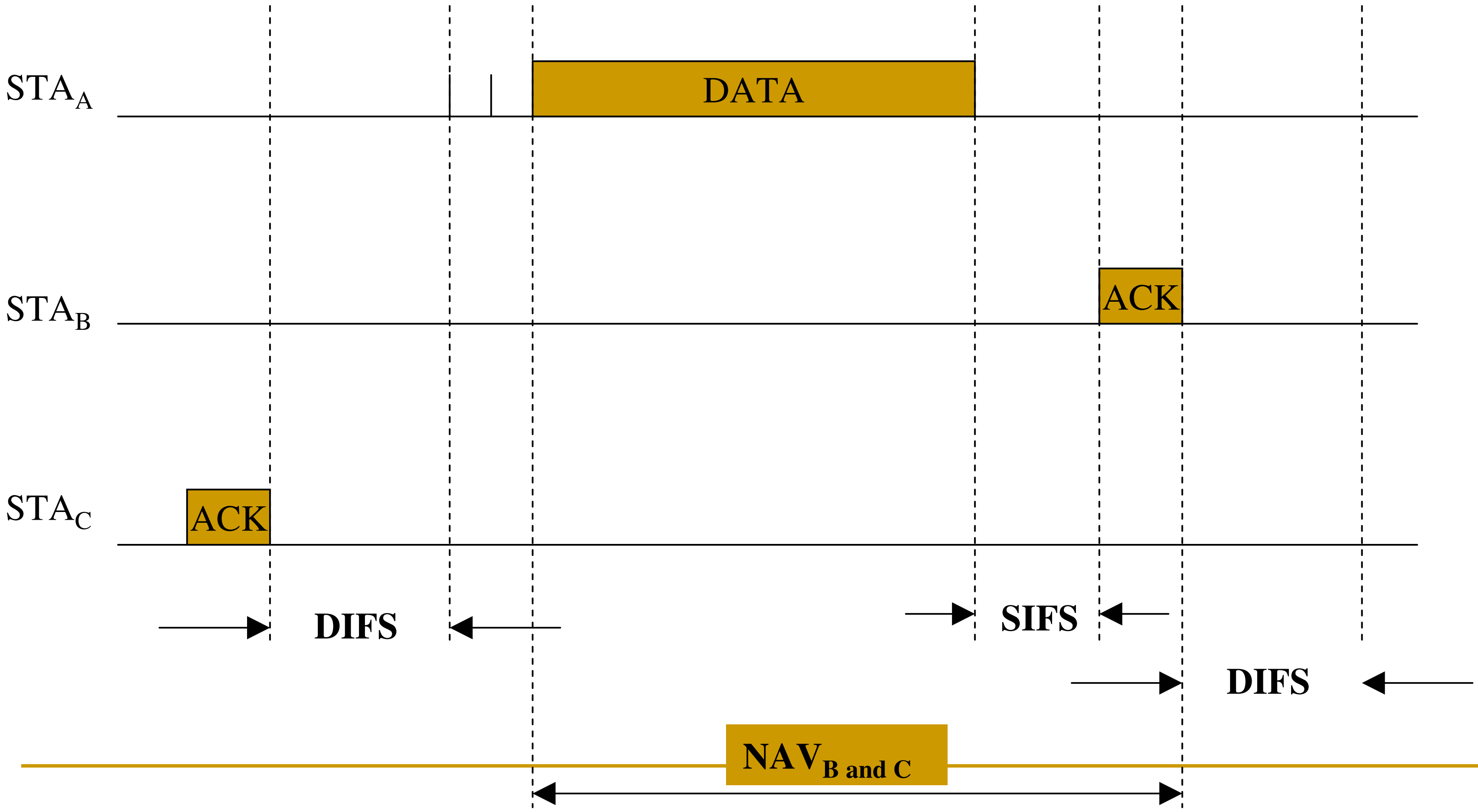
- CW – Contention Window. Starts only after DIFS.
- Random number ‘r’ picked form range (0-CW)
- CW_{min} minimum value of CW
- CW_{max} maximum value the CW can grow to after collisions
- ‘r’ can be decremented *only* in CW
- CW doubles after every collision

A Collision between nodes A and C



- Length ($DATA_A$) = 10 Slot times
- Length ($DATA_C$) = 15 Slot times
- CW after Collision 1 → 0 – 7
- CW after Collision 2 → 0 – 15
- CW after Collision 3 → 0 – 31
- CW after Collision 4 → 0 – 6

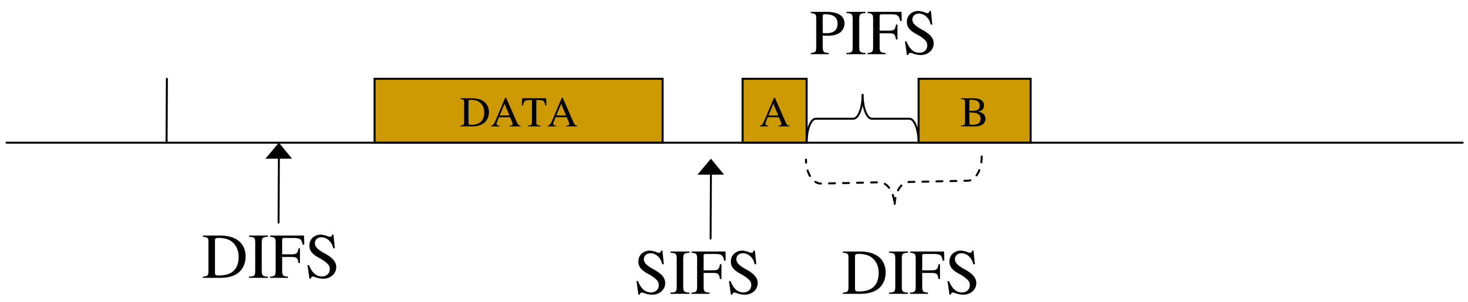
NAV – Network Allocation Vector



Point Coordinated Function (PCF)

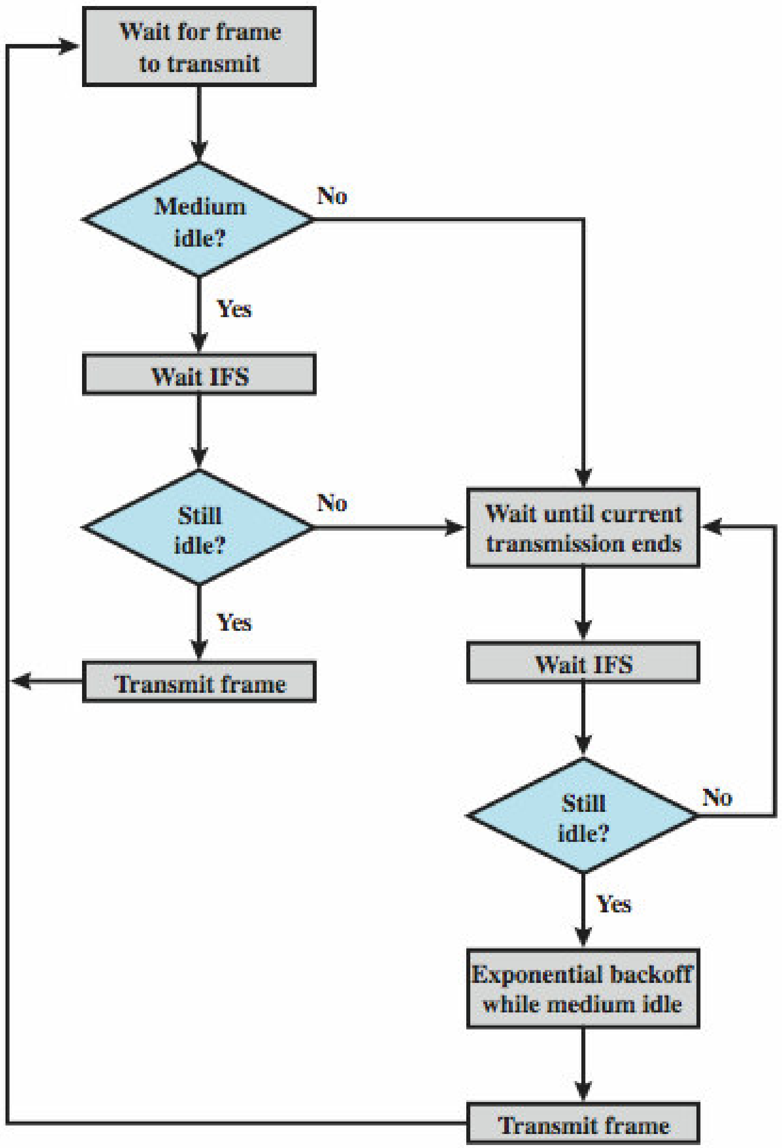
- Also known as the CFP (Contention Free Period)
- Operation in an Infrastructure BSS
- STAs communicate using central authority known as PC (Point Coordinator) or AP (Access Point)
- No Collisions take place
- AP takes over medium after waiting a period of PIFS
- Starts with issue of a Beacon

AP taking over the Wireless medium using PIFS

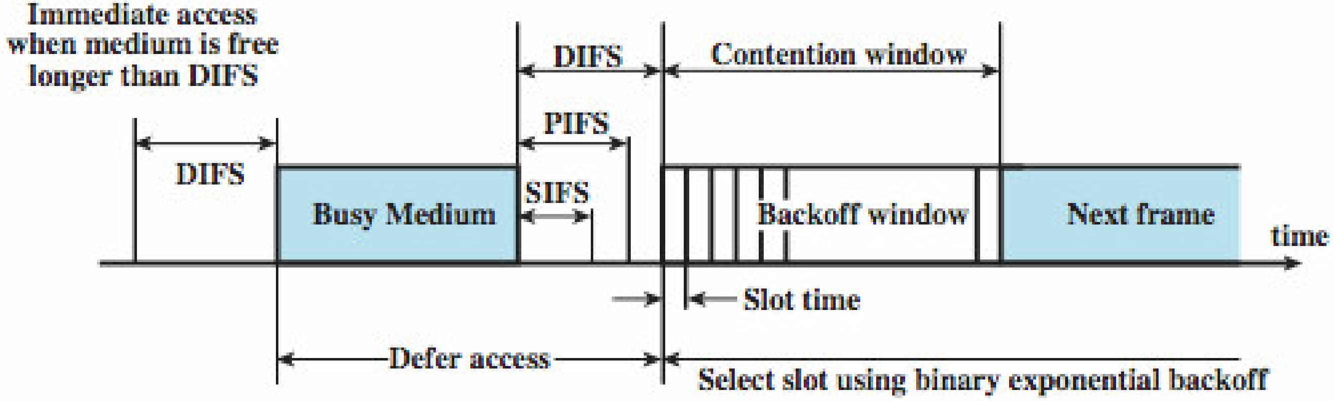


DIFS - 34 μsec
PIFS - 25 μsec
SIFS - 16 μsec
Slot Time - 9 μsec
B - Beacon

IEEE 802.11 Medium Access Control Logic

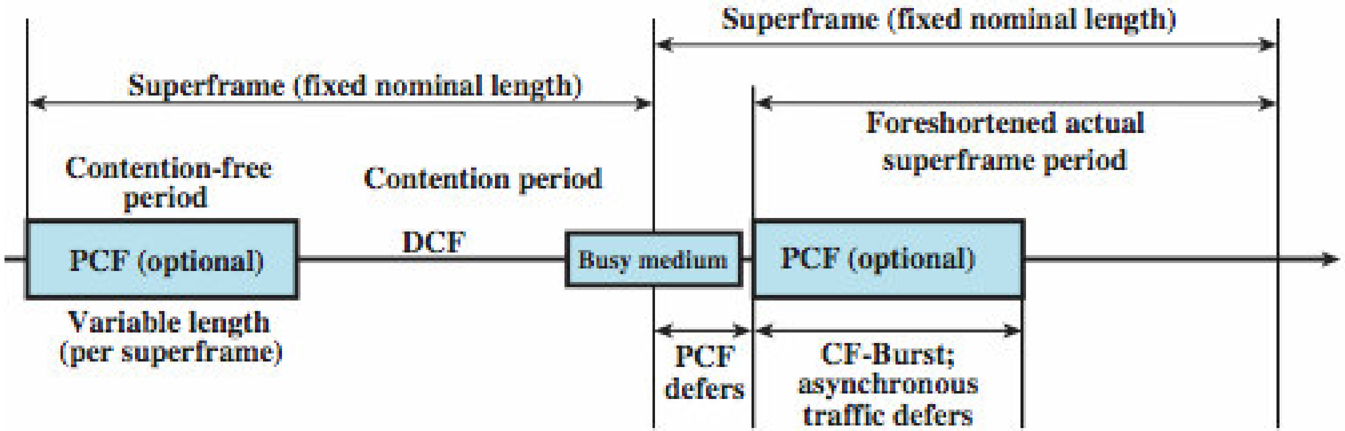


IEEE 802.11 MAC Timing Basic Access Method



(a) Basic Access Method

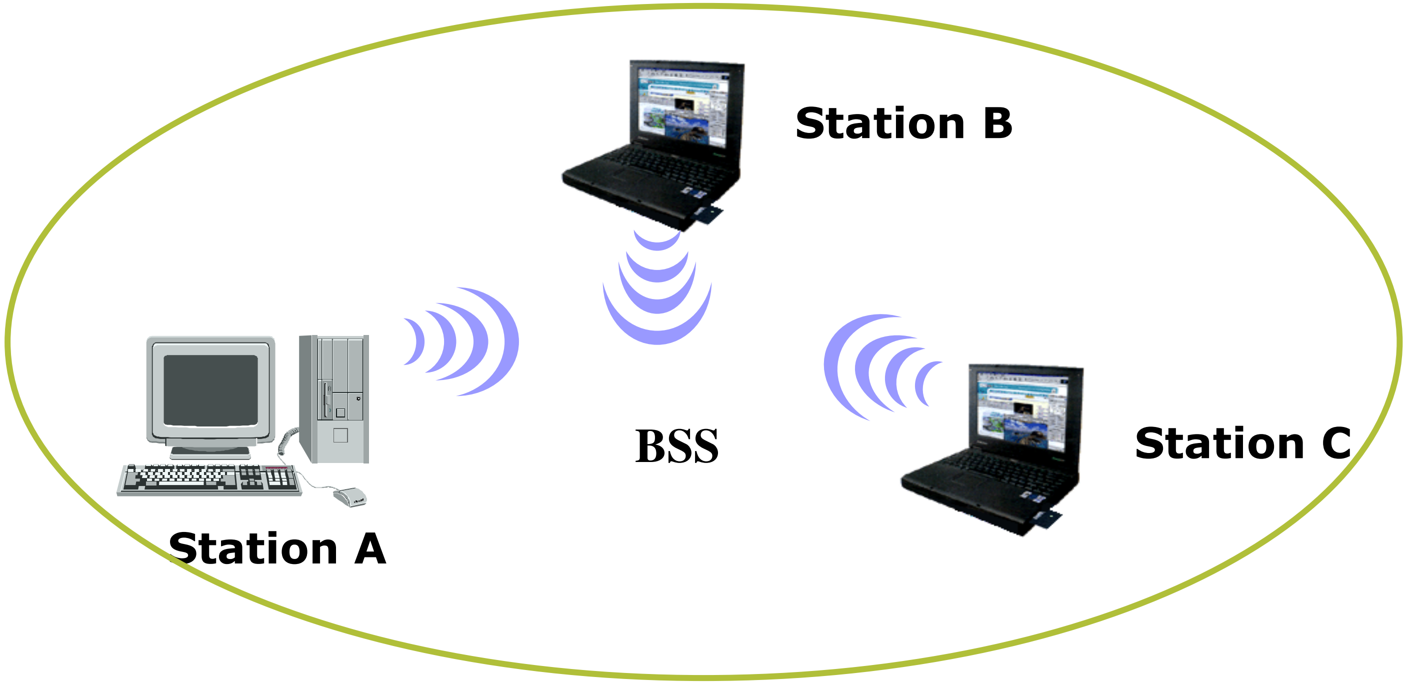
PCF Superframe Timing



(b) PCF Superframe Construction

Ad-Hoc Network

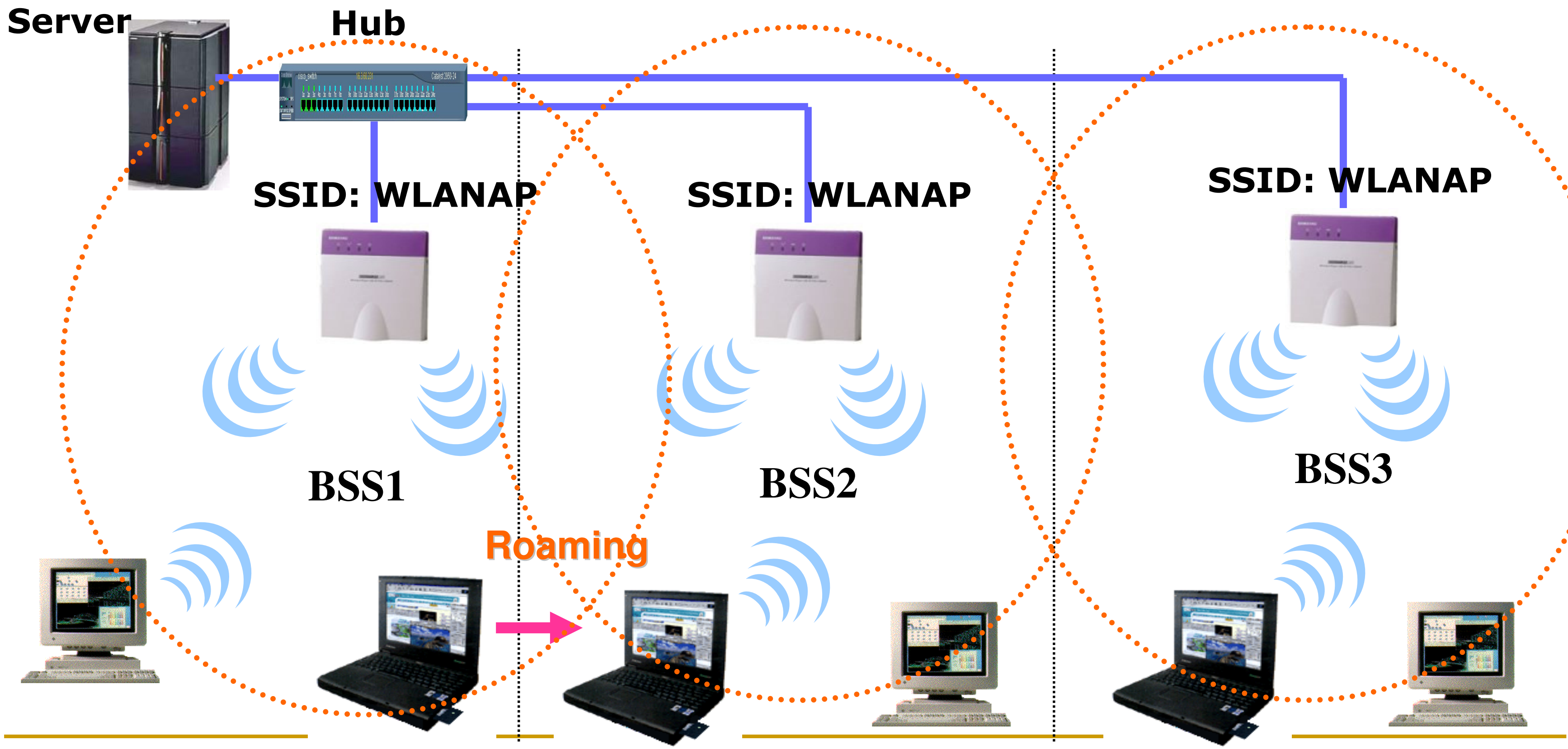
- Ad-Hoc Mode supports mutual communication among wireless clients only



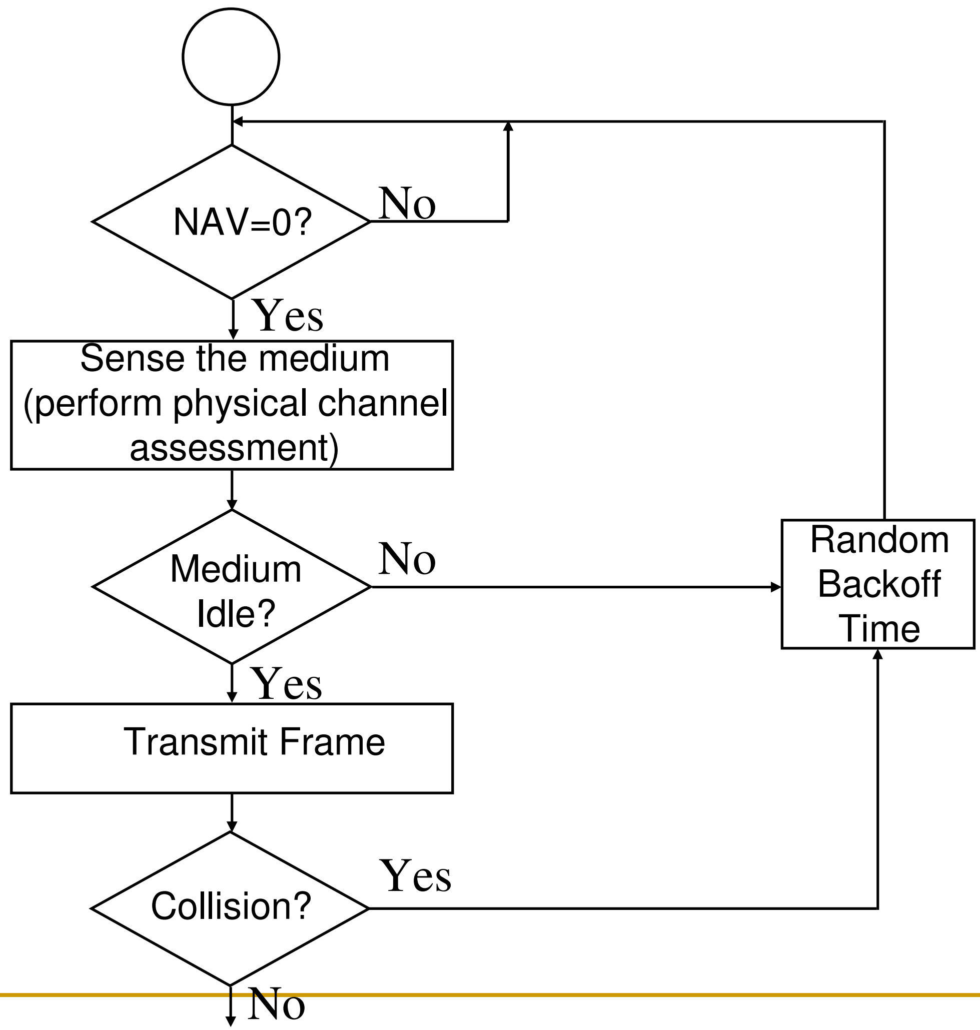
• **Basic Service Set (BSS) - BSSID**

Infrastructure Network

- Provides the communication between wireless clients and wired network through AP (Access Point).

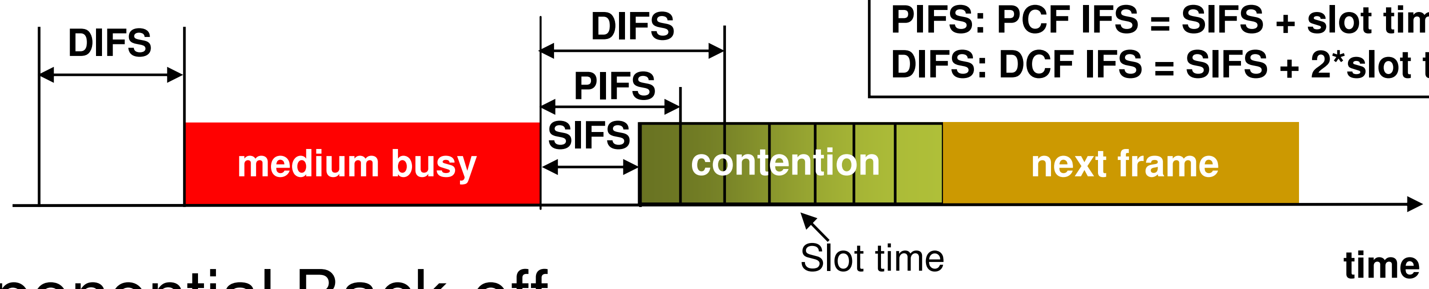


Basic Transmission Algorithm



Medium Access and IFS

- IFS (Inter-Frame Spacing)



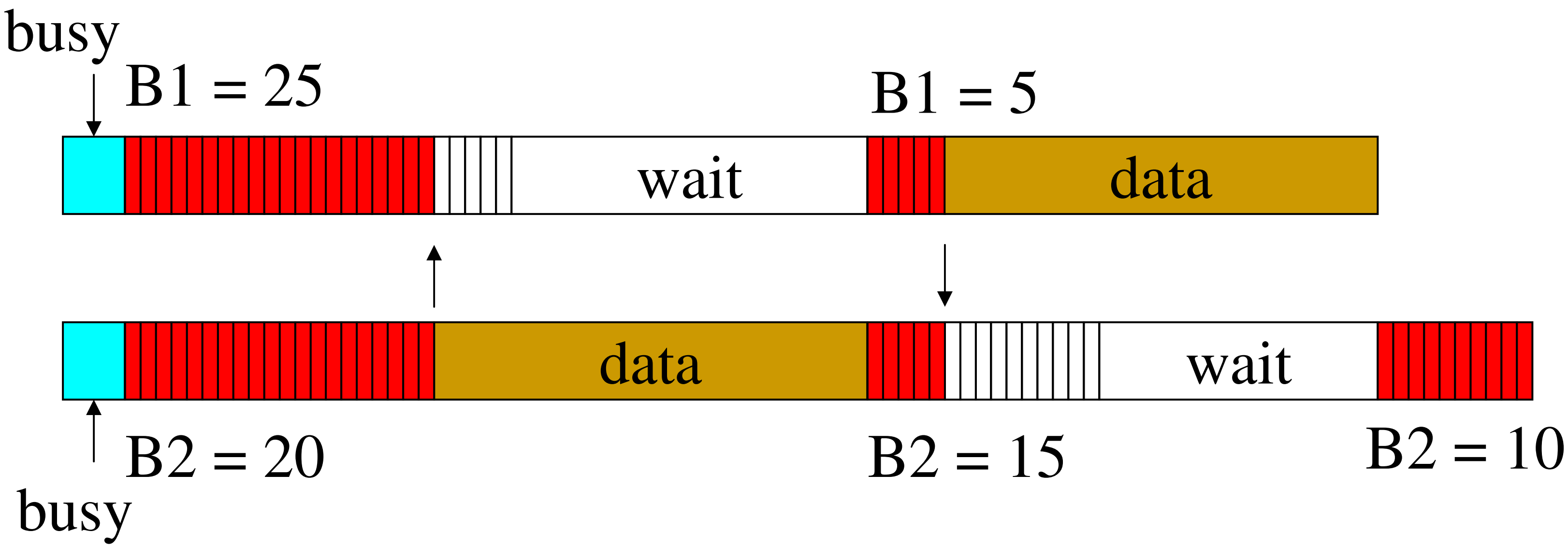
SIFS: Short IFS
PIFS: PCF IFS = SIFS + slot time
DIFS: DCF IFS = SIFS + 2*slot time

- Exponential Back-off
  - Random back-off time within a contention window [0, CW]
  - Contention window size increases with retransmission
  - Back-off time = random() * slot time
  - Random() = a pseudo random integer in [0,CW]
  - CWmin <= CW <= CWmax, CW starts with CWmin and increases by every retransmission up to CWmax, and is reset to Cwmin after successful transmission

DCF
(Distributed Coordination Function)

- Listen before-talk scheme based on the CSMA
- Stations transmits when medium is free for time greater than a DIFS period
- Random backoff is issued when medium busy
  - All backoff slots occur after a DIFS

Congestion Avoidance: Example



cw = 31

B1 and B2 are backoff intervals at nodes 1 and 2

Backoff Interval

- The time spent counting down backoff intervals is a part of MAC overhead
  - large CW ➔ large overhead
  - however, small CW ➔ may lead to many collisions (when two nodes count down to 0 simultaneously)

- Since the number of nodes attempting to transmit simultaneously may change with time, we need some mechanism to manage contention

- IEEE 802.11: contention window CW is adapted dynamically depending on collision occurrence
  - after each collision, CW is doubled

Overview of IEEE 802.11 DCF

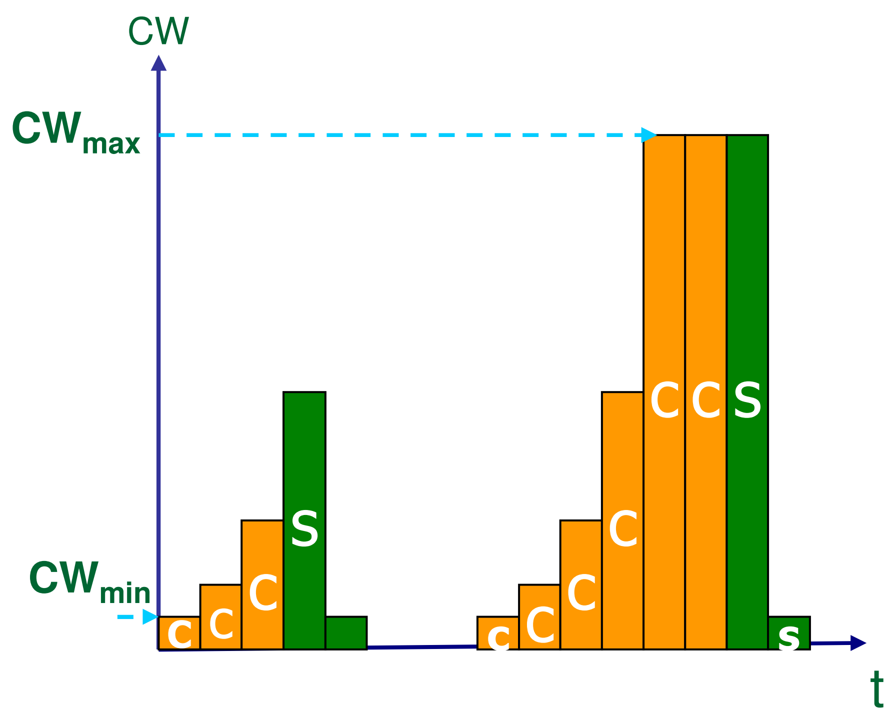
Backoff procedure—BEB algorithm

Backoff counter:

·Initial: uni~[0,CW-1]

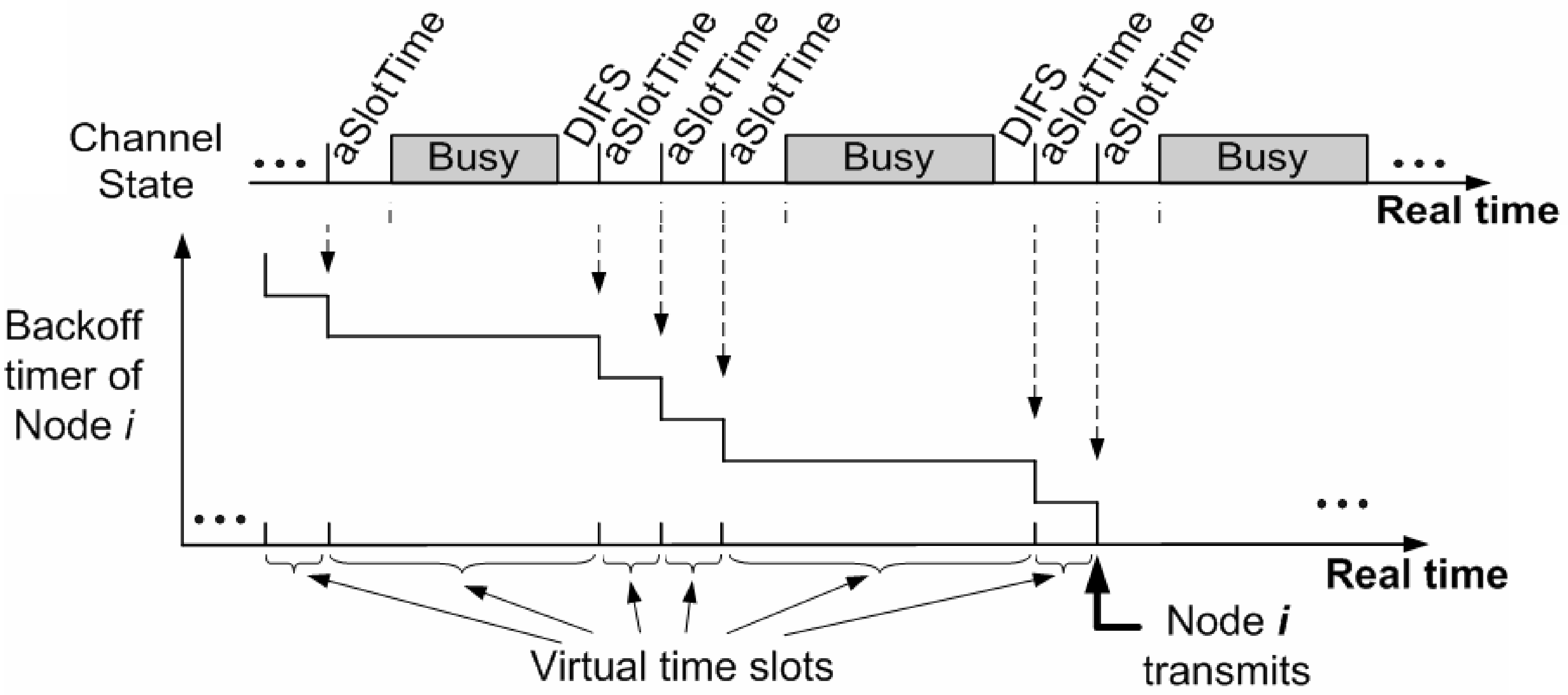
·Non zero: decremented for each idle slot

·Zero: transmit



Discrete Time Model

- Discrete and integer time scale
- At beginning of a slot time, backoff time counter decrements or regenerated
- [t, t+1], interval between 2 consecutive slot time, can be variable length



Thank you