IEEE 802.11 MAC

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- The IEEE 802.11 specification includes both the Physical (PHY) layer and the link layer.
- IEEE 802.11 wireless LAN standard is used for infrastructure as well as ad-hoc networks.

Main Requirements for 802.11 MAC

- **Single MAC to support multiple PHYs.**
  - **Support single and multiple channel PHYs.**
  - **and PHYs with different *Medium Sense* characteristics**
- **Should allow overlap of multiple networks in the same area and channel space.**
  - **Need to be able to share the medium.**
  - **Allow re-use of the same medium.**

Main Requirements (cont'd)

- **Need to be *Robust for Interference*.**
  - **Microwave interferers**
  - **Other un-licensed spectrum users**
  - **Co-channel interference**
- **Need mechanisms to deal with *Hidden Nodes*.**
- **Need provisions for *Time Bounded Services*.**
- **Need provisions for Privacy and Access Control.**

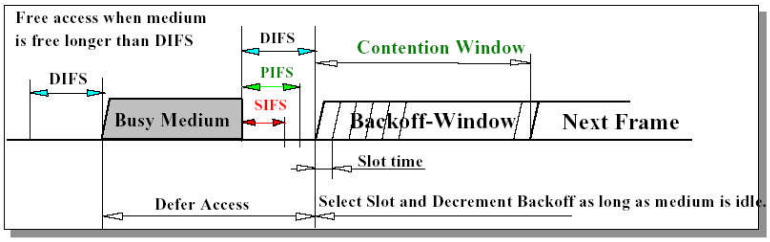
Basic Access Protocol Features

- **Use Distributed Coordination Function (DCF) for efficient medium sharing without overlap restrictions.**
  - **Use CSMA with Collision Avoidance derivative.**
  - **Based on *Carrier Sense* function in PHY called *Clear Channel Assessment* (CCA).**
- **Robust for interference**
  - ***CSMA/CA + ACK* for unicast frames, with MAC level recovery.**
  - **CSMA/CA for Broadcast frames.**

Basic Access Protocol Features

- **Parameterized use of RTS / CTS to provide a *Virtual Carrier Sense* function to protect against *Hidden Nodes*.**
  - ***Duration* information is distributed by both transmitter and receiver through separate RTS and CTS Control Frames.**
- **Includes fragmentation to cope with different PHY characteristics.**
- **Frame formats to support the access scheme**
  - **For Infrastructure and Ad-Hoc Network support**
  - **and *Wireless Distribution System*.**

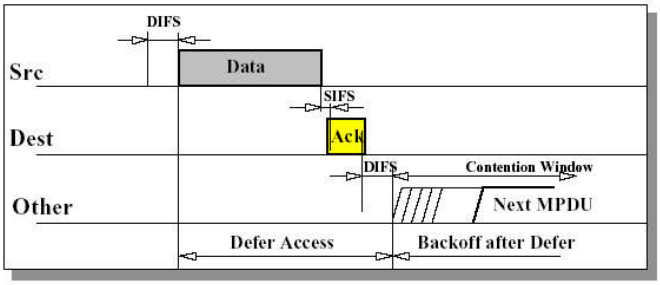
CSMA/CA



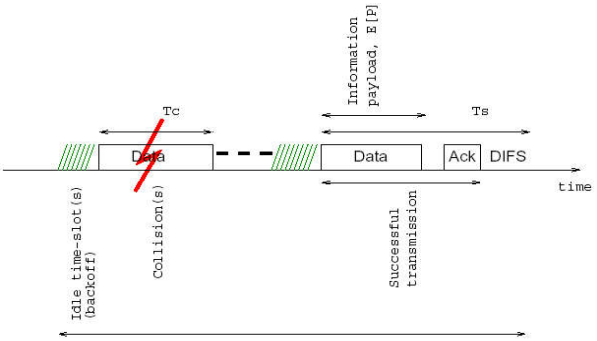
CSMA/CA

- **Reduce collision probability where mostly needed.**
  - **Stations are waiting for medium to become free.**
  - **Select Random Backoff after a Defer, resolving contention to avoid collisions.**
- **Efficient Backoff algorithm stable at high loads.**
  - **Exponential Backoff window increases for retransmissions.**
  - **Backoff timer elapses only when medium is idle.**
- **Implement different fixed priority levels.**
  - **To allow immediate responses and PCF coexistence.**

CSMA/CA + ACK



Performance Analysis



Average throughput can be obtained by

$$Th = \frac{E[Payload]}{E[length\ of\ a\ round]}$$

Giuseppe Bianchi, Performance Analysis of the IEEE 802.11 Distributed Coordination Function, *IEEE JSAC*, Vol. 18, No 3, pp. 535-547, Mar. 2000.

$$Th = \frac{P_s P_{tr} E[P]}{(1-P_{tr})\sigma + P_{tr} P_s T_s + P_{tr}(1-P_s) T_c}$$

P_{tr} : transmission probability
P_s : success probability
T_s : Duration of a successful transmission (in s)
T_c : Duration of a colliding transmission (in s)
$E[P]$: Average packet length (in bits)

PHY	Slot Time (σ)	CW_{min}	CW_{max}
FHSS	50 μs	16	1024
DSSS	20 μs	32	1024
IR	8 μs	64	1024

$$Th = \frac{P_s P_{tr} E[P]}{(1-P_{tr})\sigma + P_{tr} P_s T_s + P_{tr}(1-P_s) T_c}$$

P_{tr} = at least one node transmits $= 1-(1-\tau)^n$
P_s = only one node is transmitting, knowing that there is a transmission

$$= \frac{n\tau(1-\tau)^{n-1}}{P_{tr}} = \frac{n\tau(1-\tau)^{n-1}}{1-(1-\tau)^n}$$

where n is the number of nodes, and τ is the probability that a given node tries to access the channel.

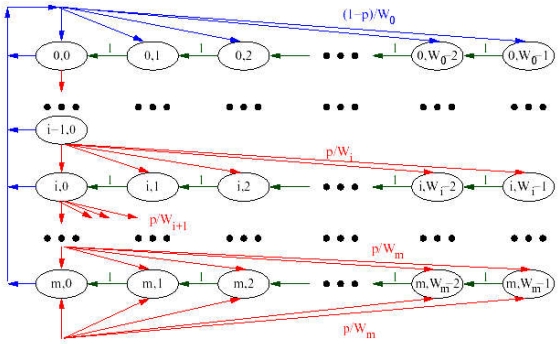
How do we compute τ?

To find τ, 2 nonlinear equations to solve with unknowns p and τ. First equation:

- p = collision prob. during a transmission. $= 1 - (1 - \tau)^{n-1}$

- Second equation is derived from a Markov Chain.
  - Observe the state of a node
  - Assumptions:
    - There are a number of nodes always have packets to transmit (saturated senders)
    - Constant collision probability

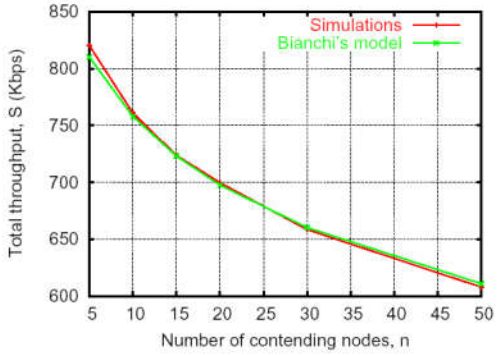
Second equation is derived from:



where i is the backoff level, W_i is the contention window for level i, and m is the max backoff level.

To find τ, 2 nonlinear equations to solve:

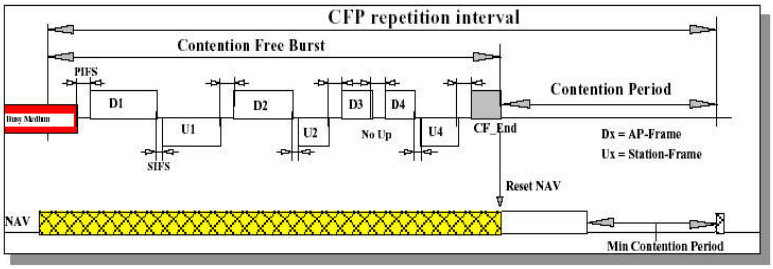
- $p = 1 - (1 - \tau)^{n-1}$
- $\tau = \frac{2(1-2p)}{(1-2p)(W+1)+pW(1-(2p)^m)}$
- $\rightarrow$ solve the 2 equations using Matlab



Channel capacity: 1Mbps, no RTS/CTS, sims. using ns-2.

Optional Point Coordination Function (PCF)

- **Contention Free Service uses Point Coordination Function (PCF) on a DCF Foundation.**
  - **PCF can provide lower *transfer delay* variations to support *Time Bounded Services***
  - **Asynchronous Data, Voice or mixed implementations possible.**
  - **Point Coordinator resides in AP.**
- **Coexistence between Contention and optional Contention Free does not burden the implementation.**


CFP repetition interval
Contention Free Burst
PIFS
D1
Busy Medium
U1
SIFS
D2
U2
D3
No Up
D4
U4
CF_End
Contention Period
Dx = AP-Frame
Ux = Station-Frame
Reset NAV
NAV
Min Contention Period