Mobile Communication Performance at Link Layer

Medium Access Control

Performance Model (DCF fundamentals)

- DCF is based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)
- Station with a packet to transmit monitors wireless channel activity
- Channel is idle during Distributed Interframe Space (DIFS) – station transmits
- Otherwise channel is busy and station continues monitoring until DIFS is observed

Performance Model (DCF fundamentals)

- Station generates random back off interval and then transmits
- Station must generate random back of between two consecutive packet transmission even if DIFS was observed

Performance Model (DCF fundamentals)

- DFC employs discrete back off scale
- Time after DIFS is slotted.
- Station may transmit only in the beginning of each slot
- Slot size is enough to detect transmission from any other station

Performance Model (DCF fundamentals)

- Back off time is uniformly chosen form the range (0, w-1). w is **contention** window
- Contention window depends on number of failed transmissions
- At each fail contention window changes from Cw_{min} to $2^m Cw_{min}$. Vales are defined by 802.11 standard
- Back off counter is decremented or frozen

Performance Model (DCF fundamentals)

- Destination station sends ACK
- ACK is transmitted immediately after receiving packet and Short Interframe Space (SIFS)
- Two-way handshaking is Basic Access Mechanism
- Four-way handshaking RTS/CTS fights ‘Hidden Terminal problem’

Performance Model (DCF fundamentals)

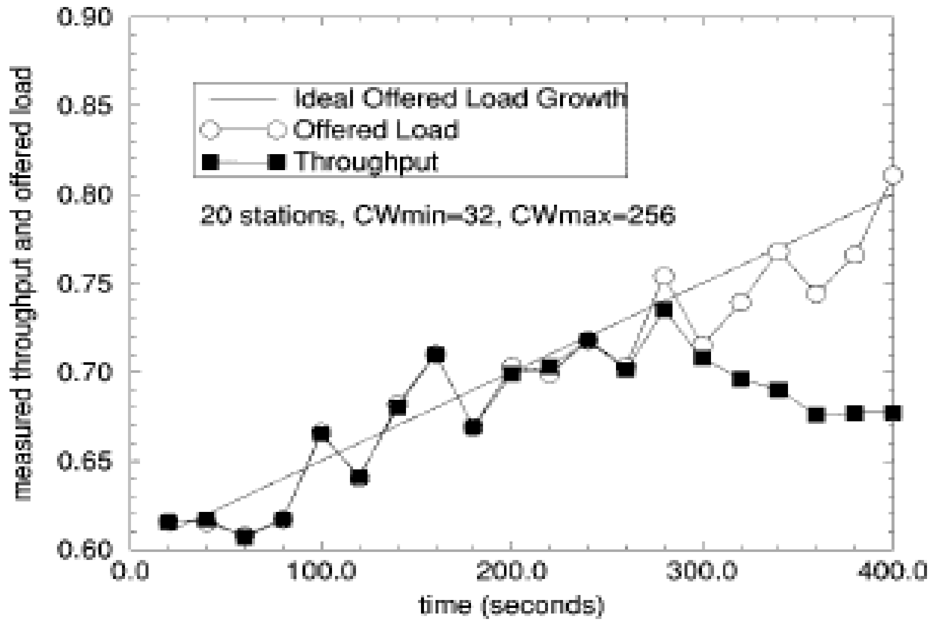
TABLE I

SLOT TIME, MINIMUM, AND MAXIMUM CONTENTION WINDOW VALUES FOR THE THREE PHY SPECIFIED BY THE 802.11 STANDARD: FREQUENCY HOPPING SPREAD SPECTRUM (FHSS), DIRECT SEQUENCE SPREAD SPECTRUM (DSSS), AND INFRARED (IR)

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

Performance Model (DCF fundamentals)

- Random access scheme exibit unstable behavior
- It is inpossible to operate at maximum throughput during long time.
  Instability property



Performance Model (DCF fundamentals)

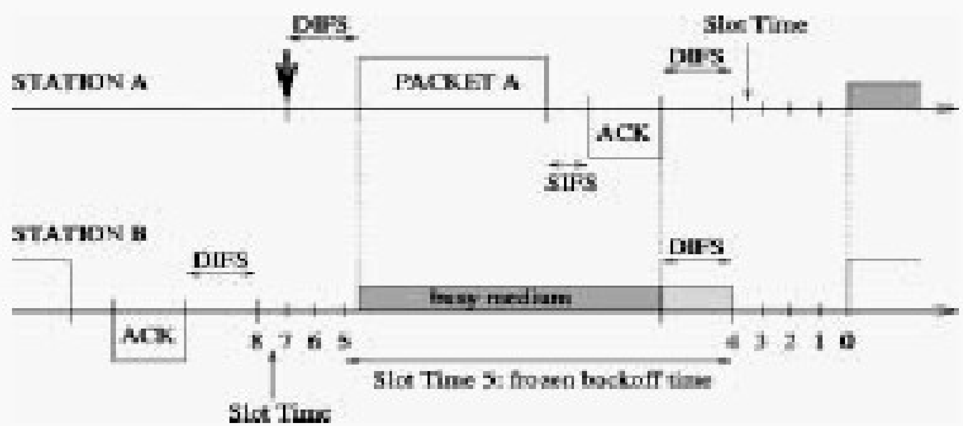


Fig. 1. Example of basic access mechanism.

Performance Model (DCF fundamentals)

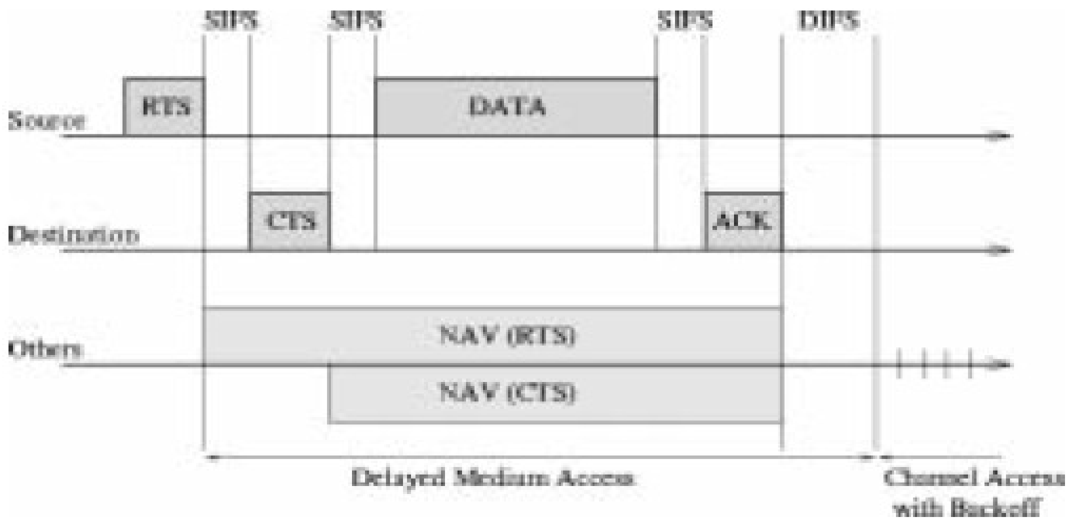


Fig. 2. RTS/CTS Access Mechanism.

Performance Model (DCF fundamentals)

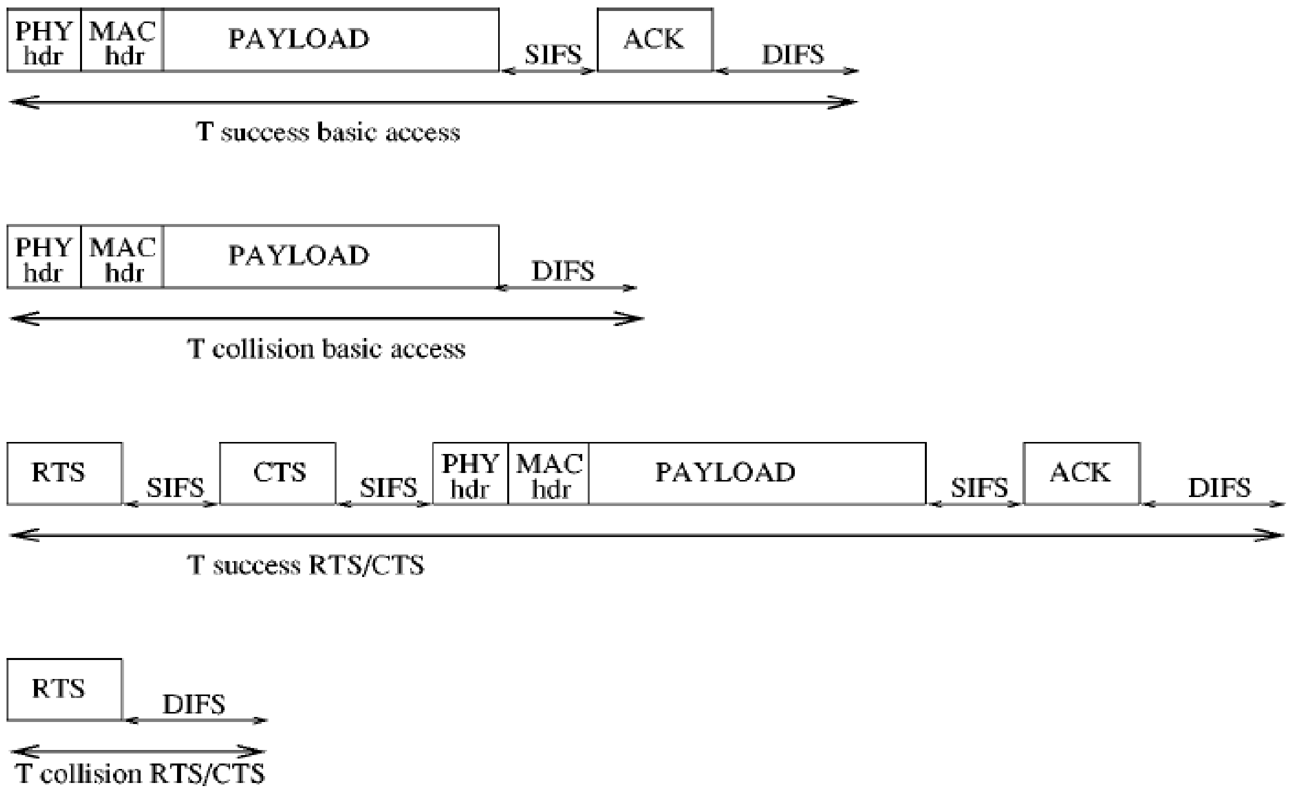
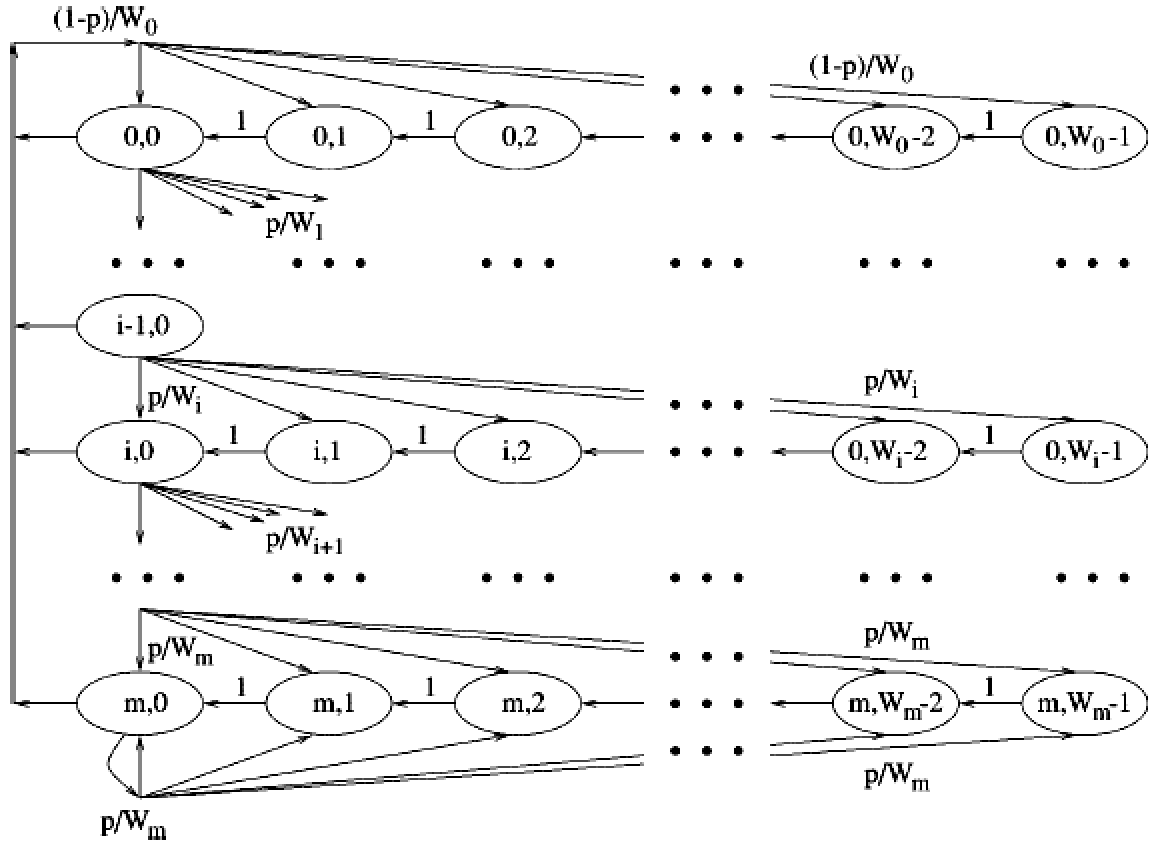


Fig. 5. T_s and T_c for basic access and RTS/CTS mechanisms.

Markovian Model (G. Bianchi)

- In the WLAN n stations contend
- We consider back off counter at a single station
- Discrete integer time scale is adopted
- No hidden stations
- Each packet collides with independent constant probability p

Markovian Model (G. Bianchi)



Markovian Model (G. Bianchi)

- Each packet collides with constant independent provability regardless of retransmission history at each transmission attempt
- b(t) back off counter, s(t) contention level

$$\begin{cases} P\{i,k \mid i,k+1\} = 1 & k \in (0, W_i - 2) \quad i \in (0,m) \\ P\{0,k \mid i,0\} = (1-p)/W_0 & k \in (0, W_0 - 1) \quad i \in (0,m) \\ P\{i,k \mid i-1,0\} = p/W_i & k \in (0, W_i - 1) \quad i \in (1,m) \\ P\{m,k \mid m,0\} = p/W_m & k \in (0, W_m - 1). \end{cases}$$

Markovian Model (G. Bianchi)

- Let τ be probability that station transmit

$$\tau = \sum_{i=0}^{m} b_{i,0} = \frac{b_{0,0}}{1-p} = \frac{2(1-2p)}{(1-2p)(W+1)+pW(1-(2p)^m)}$$

$$p = 1-(1-\tau)^{n-1}$$

Throughput Modeling

- S is normalized system throughput
- E[P] av. payload, P_{tr} probability of transmission

$$S = \frac{E\left[\text{payload information transmitted in a slot time}\right]}{E\left[\text{length of a slot time}\right]}$$

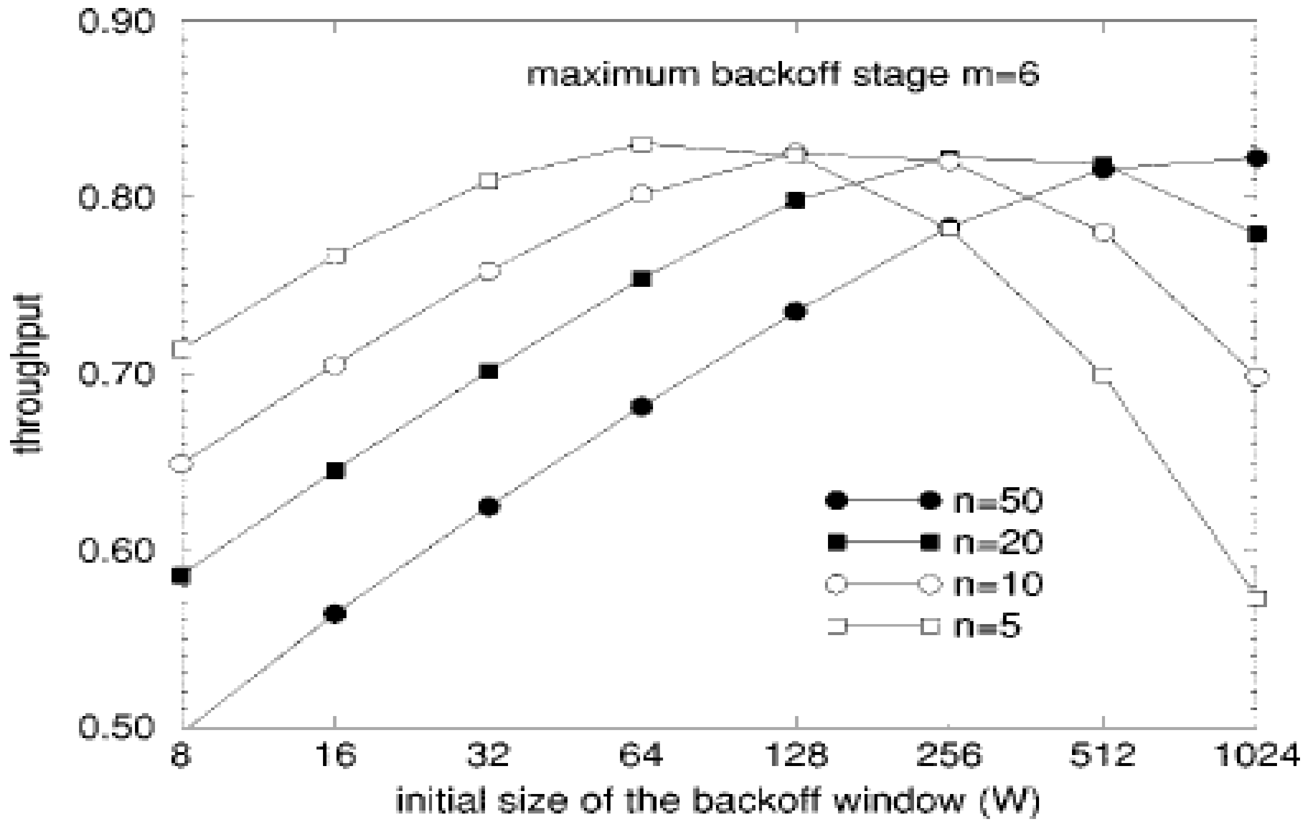
$$P_{\text{tr}} = 1 - (1-\tau)^n.$$

Throughput Modeling

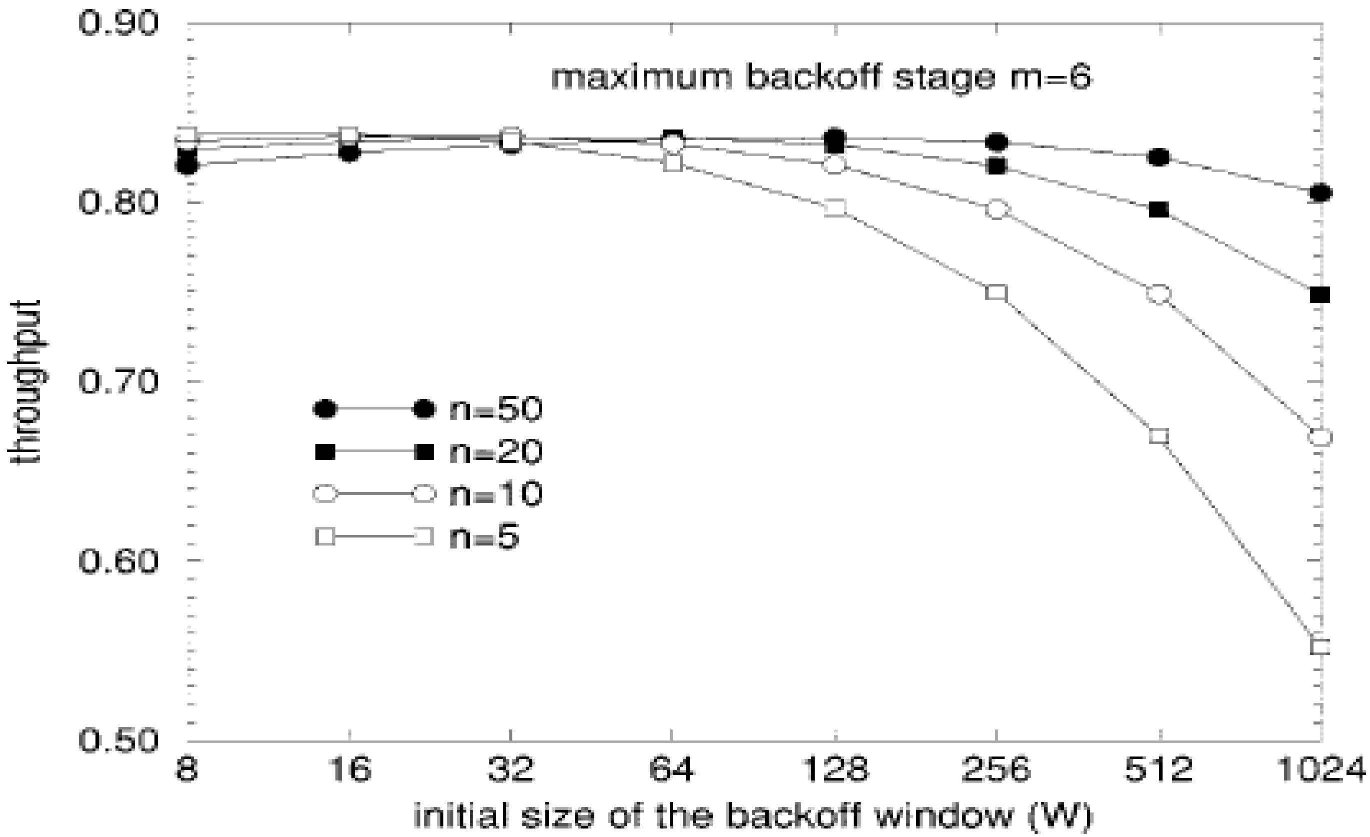
- P_s probability of successful transmission
- T_s busy for success, T_c busy for collision,

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

Numerical Examples



Numerical Examples



Planning solutions

- Find optimal parameters to meet or approach requirements
- Compute optimal transmission probability each station should adopt
- Compute backoff window that maximizes throughput

$$\tau = \frac{\sqrt{[n+2(n-1)(T_c^*-1)]/n}-1}{(n-1)(T_c^*-1)} \approx \frac{1}{n\sqrt{T_c^*/2}}. \qquad W_{\text{opt}} \approx n\sqrt{2T_c^*}.$$