Topology control in wireless networks

- Channel
- Transmission rate ➔ this class
- Transmission power
- Directional antennas’ direction
- Node placement
Phase Shift Keying

- **BPSK (Binary Phase Shift Keying):**
  - bit value 0: sine wave
  - bit value 1: inverted sine wave
  - very simple PSK
  - low spectral efficiency
  - robust, used in satellite systems

- **QPSK (Quadrature Phase Shift Keying):**
  - 2 bits coded as one symbol
  - needs less bandwidth compared to BPSK
  - symbol determines shift of sine wave
  - Often also transmission of relative, not absolute phase shift: DQPSK - Differential QPSK
Quadrature Amplitude Modulation

- Quadrature Amplitude Modulation (QAM): combines amplitude and phase modulation
- It is possible to code $n$ bits using one symbol
  - $2^n$ discrete levels
- bit error rate increases with $n$

Example: 16-QAM (4 bits = 1 symbol)
- Symbols 0011 and 0001 have the same phase $\varphi$, but different amplitude $a$. 0000 and 1000 have the same amplitude but different phase
- Used in Modem
Rate Adapation

• **802.11b**
  - 11, 5.5, 2, 1 Mbps

• **802.11a**
  - 6, 9, 12, 18, 24, 36, 48, 54 Mbps

• **802.11n per stream**
  - 20MHz: 7.2, 14.4, 21.7, 28.9, 43.3, 57.8, 65, 72.2 Mbps
  - 40MHz: 15, 30, 45, 60, 90, 120, 135, 150 Mbps
Question

• What happens if we have both “slow” and “fast” senders associated with the same AP?
Intuition

• Every node gets the same chance to access the network
• When a node grabs the medium, it can send the same sized packet (regardless of its rate)
• So fast and slow senders will both experience low throughput
Performance Anomaly of 802.11

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Grenoble, France
Performance of DCF

Fig. 1. Successful transmission of a single frame
Performance of DCF

Overall Transmission time (T):

\[ T = t_{tr} + t_{ov} \]

Constant Overhead (t_{ov}):

\[ t_{ov} = DIFS + t_{pr} + SIFS + t_{pr} + t_{ack} \]

Proportion of useful throughput (p):

\[ p = \frac{t_{tr}}{T} \times \frac{1500}{1534} = 0.70. \]
**Performance of DCF**

Taking into account collisions and exponential backoff, Overall Transmission Time \((T(N))\) becomes:

\[
T(N) = t_{tr} + t_{ov} + t_{cont}(N)
\]

Time spent in contention \((t_{cont}(N))\):

\[
t_{cont}(N) \simeq SLOT \times \frac{1 + P_c(N)}{2N} \times \frac{CW_{min}}{2}
\]
Performance of DCF

Assuming that multiple successive collisions are negligible, the proportion of collisions ($P_c(N)$) experienced for each packet acknowledged successfully is given by:

$$P_c(N) = 1 - (1 - 1/CW_{\text{min}})^{N-1}$$

The proportion ($p$) of useful throughput obtained by a host is:

$$p(N) = t_{\text{tr}} / T(N)$$
Performance Anomaly of 802.11b

Fast Host:

\[ T_f = t_{ov}^R + \frac{s_d}{R} + t_{cont} \]

Slow Host:

\[ T_s = t_{ov}^r + \frac{s_d}{r} + t_{cont} \]

R : transmission rate of ‘fast’ host (11Mbps)

r : transmission rate of ‘slow’ host (5.5, 2 or 1 Mbps)

\( t_{ov}^R \) : overhead time of ‘fast’ host

\( t_{ov}^r \) : overhead time of ‘slow’ host
Model

Throughput of a fast sender and a slow sender are as follow:

\[ X_f = \frac{S_d}{(N-1)T_f + T_s + P_c(N) \times t_{jam} \times N} \]

\[ X_s = \frac{S_d}{(N-1)T_f + T_s + P_c(N) \times t_{jam} \times N} \]
Performance Anomaly of 802.11b

Result:

The fast hosts transmitting at a higher rate ‘R’ obtain the same throughput as the slow host transmitting at a lower rate ‘r’.

i.e. \[ X_s = X_f = X. \]
Simulation Studies

Throughput experienced by a 802.11b host when all hosts except one transmit at 11Mb/s
Performance Measurements

• 4 notebooks – Marie, Milos, Kea, and Bali
• Linux RedHat 7.3 (kernel 2.4.18)
• 802.11 cards based on Lucent Orinoco and Compaq WL 110
• Lucent Access Point
• Wvlan driver for the wireless card
Performance Measurements

• Tools used
  • *netperf* – generates TCP and UDP traffic to a target host running *netserver* and measures throughput obtained at each second.
  • *tcpperf* – generates TCP traffic and measures throughput obtained at each second.
  • *udpperf* – generates UDP traffic and measures throughput obtained at each second.
Performance Measurements

- **Hosts with different rates, no mobility**

<table>
<thead>
<tr>
<th>Bit rate of Bali</th>
<th>Bali</th>
<th>Marie</th>
<th>Milos</th>
<th>Kea</th>
<th>Eq. 7</th>
<th>observed $P_c$</th>
<th>Eq. 4</th>
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**TABLE II**

Measured throughputs in Mb/s for a varying number of hosts, UDP traffic
Performance Measurements

- *Hosts with different rates, no mobility*

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<thead>
<tr>
<th>Bit rate of Bali</th>
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**TABLE I**

*Measured throughputs in Mb/s for a varying number of host, TCP traffic*
Performance Measurements

- *Hosts with different rates, real mobility*

![Graph showing measured throughput in Mb/s for two hosts (one mobile), UDP traffic.](image)
How to make fast hosts send fast and avoid being slowed down by slow hosts?