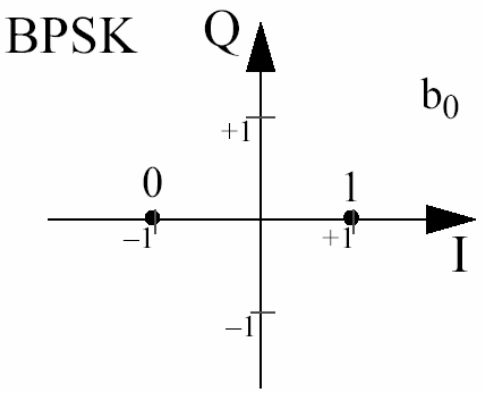
Multi-rate Medium Access Control

David Holmer
dholmer@jhu.edu

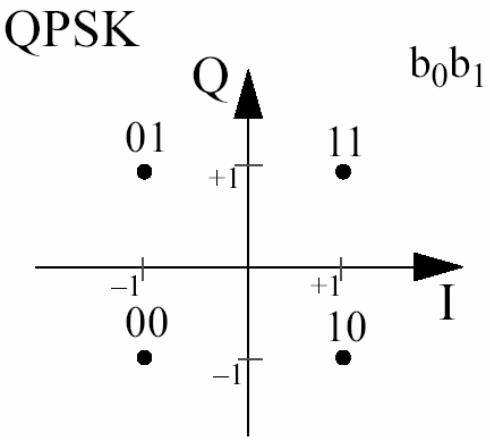
What is Multi-Rate?

- Ability of a wireless card to automatically operate at several different bit-rates
  (e.g. 1, 2, 5.5, and 11 Mbps for 802.11b)
- Part of many existing wireless standards
  (802.11b, 802.11a, 802.11g, HiperLAN2…)
- Virtually every wireless card in use today employs multi-rate

Example Carrier Modulations



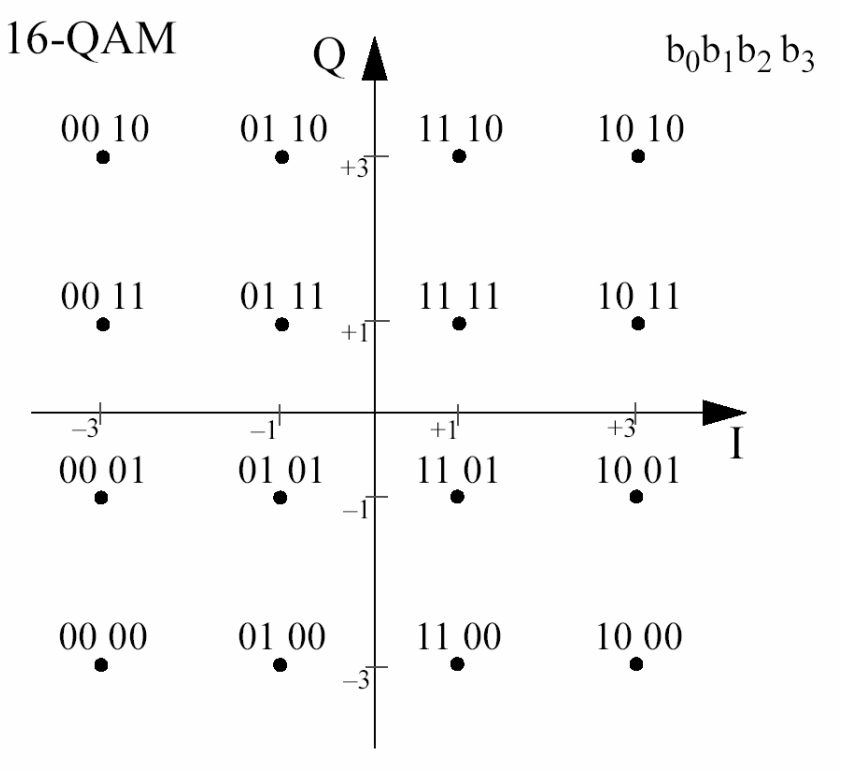
- Binary Phase Shift Keying
  - One bit per symbol
  - Made by the carrier and its inverse



- Quadrature Phase Shift Keying
  - Two bits per symbol
  - Uses quadrature carrier in addition to normal carrier

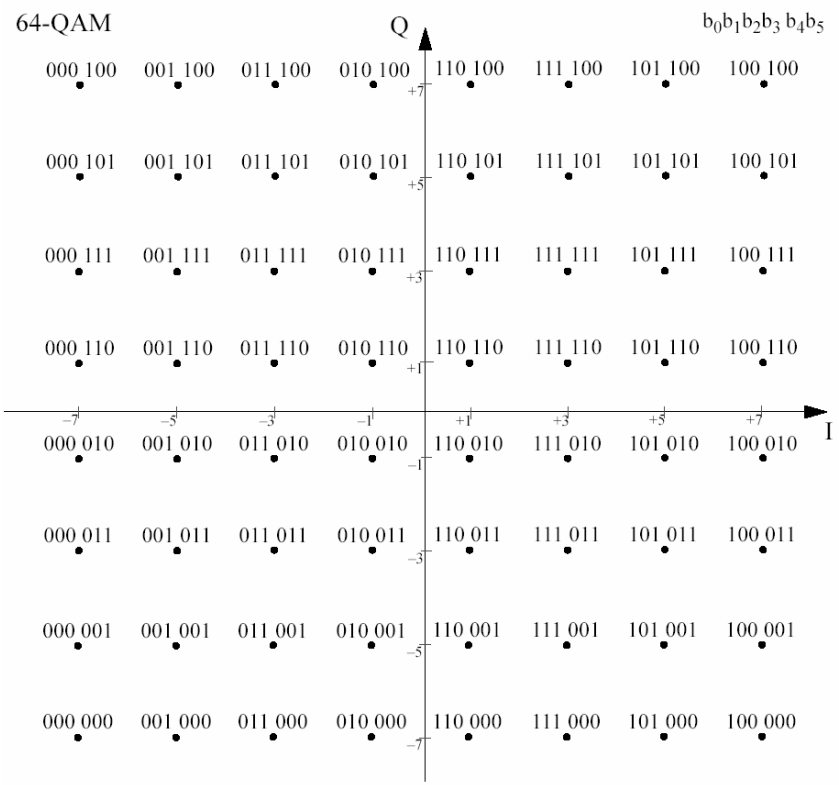
    (90° phase shift of carrier)
  - 4 permutations for the inverse or not of the two carriers

Example Carrier Modulations (cont.)



- 16 - Quadrature Amplitude Modulation
  - 4 bits per symbol
  - Also uses quadrature carrier
  - Each carrier is multiplied by +3, +1, -1, or -3 (amplitude modulation)
  - 16 possible combinations of the two multiplied carriers

Example Carrier Modulations (cont.)

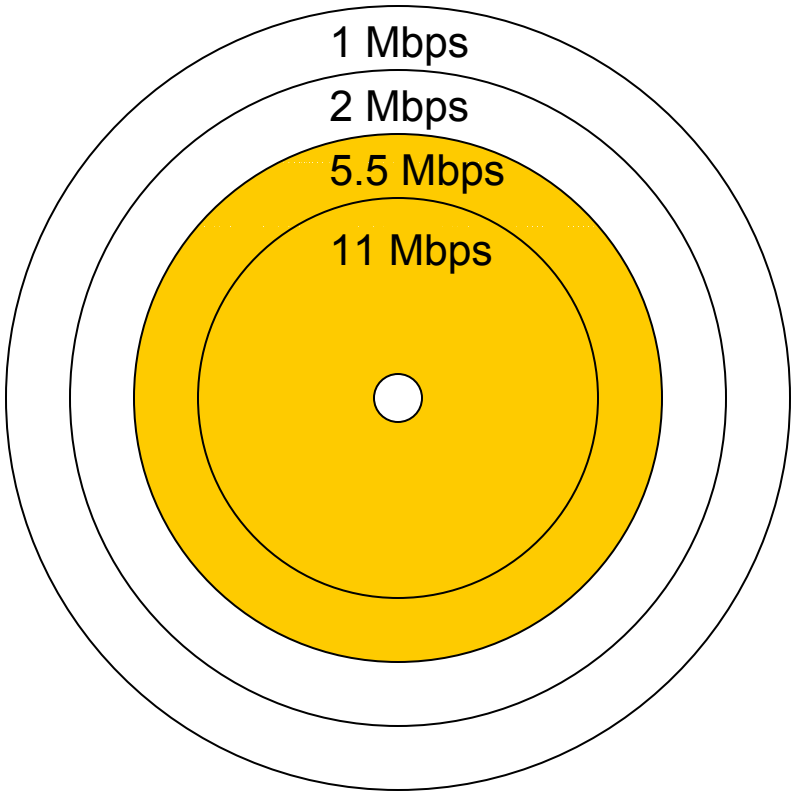


- 64 - Quadrature Amplitude Modulation
  - 6 bits per symbol
  - Also uses quadrature carrier
  - Each carrier is multiplied by +7, +5, +3, +1, -1, -3, -5, or -7 (amplitude modulation)
  - 64 possible combinations of the two multiplied carriers

802.11a Rates resulting from Carrier Modulation and Coding

Data rate (Mbits/s)	Modulation	Coding rate (R)	Coded bits per subcarrier (N_{BPSC})	Coded bits per OFDM symbol (N_{CBPS})	Data bits per OFDM symbol (N_{DBPS})
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

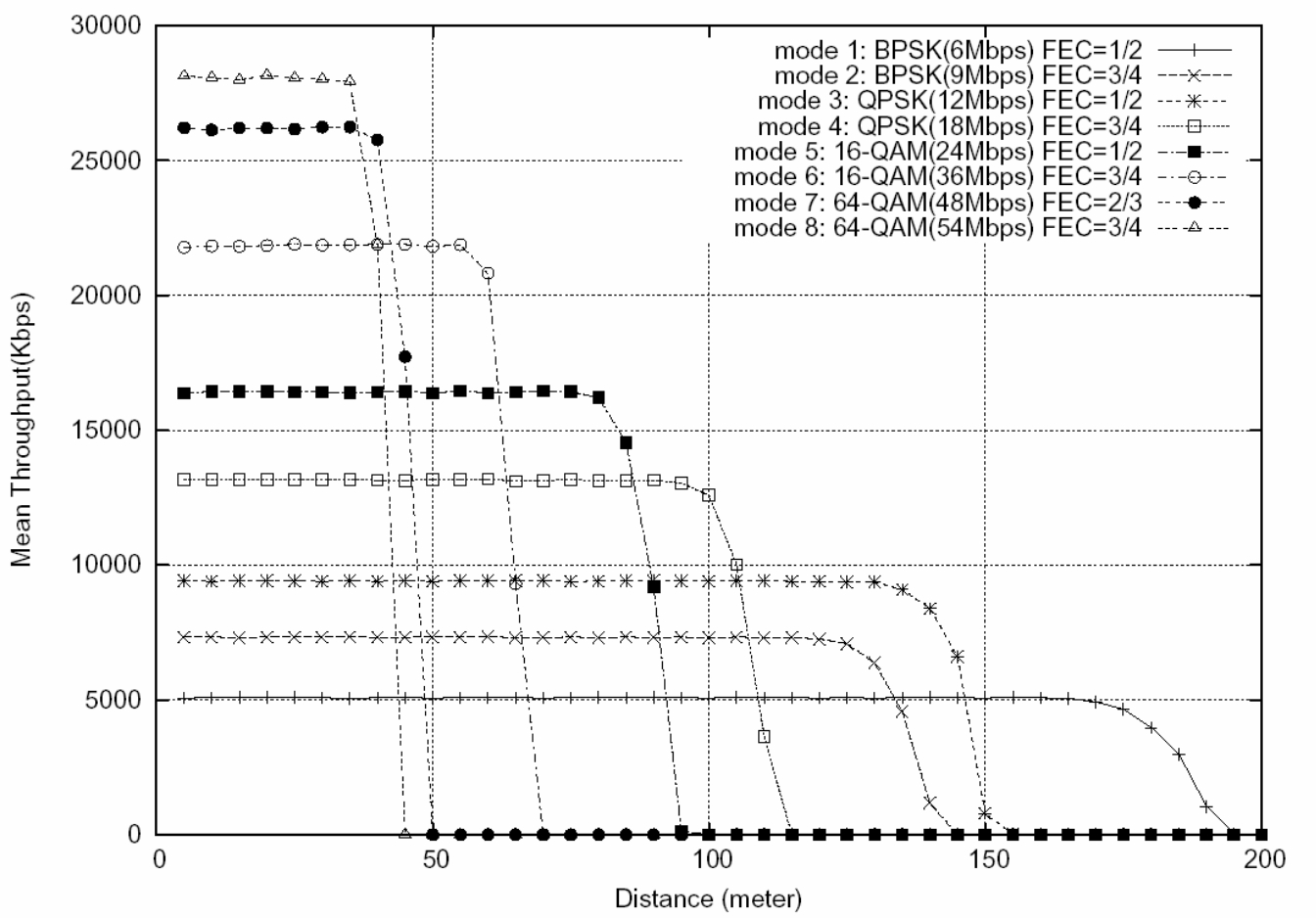
Advantage of Multi-Rate?



Lucent Orinoco 802.11b card ranges using NS2 two-ray ground propagation model

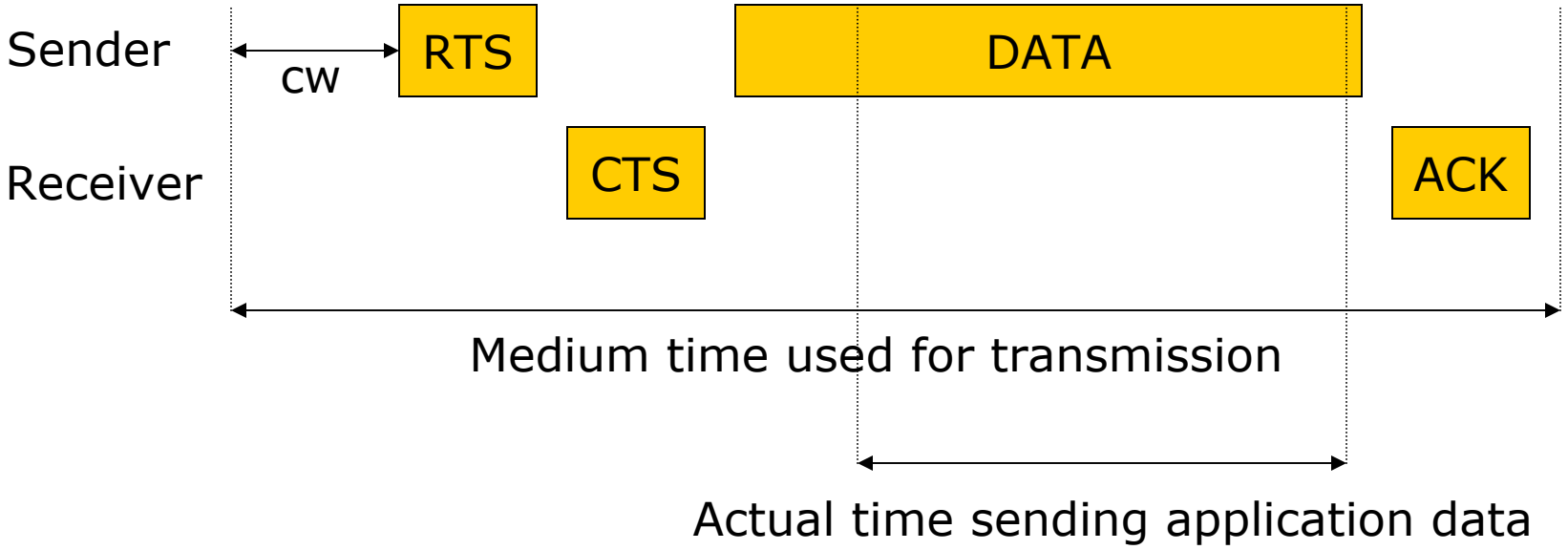
- Direct relationship between communication rate and the channel quality required for that rate
- As distance increases, channel quality decreases
- Therefore: tradeoff between communication range and link speed
- Multi-rate provides flexibility to meet both consumer demands

Throughput vs. Distance for 802.11a



802.11 Frame Exchange Overhead

- Exchange means not all time is spend sending actual data



Multi-rate Frame in 802.11b

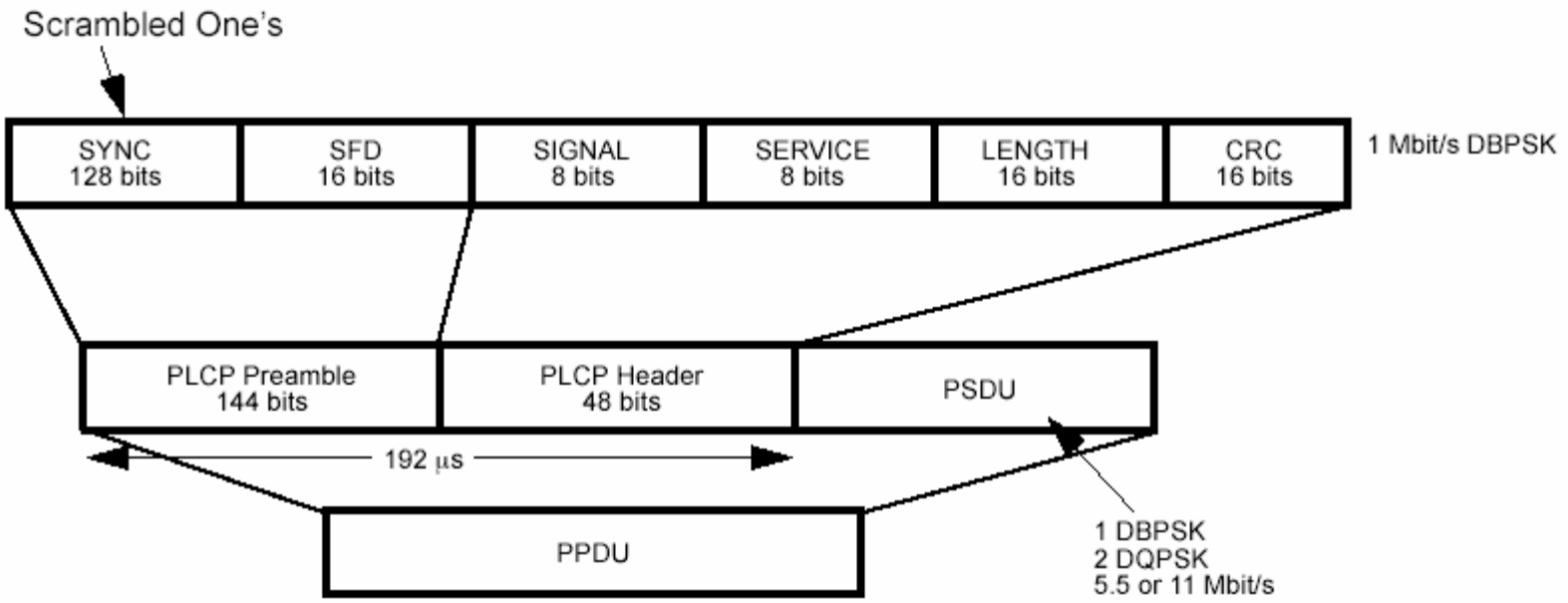
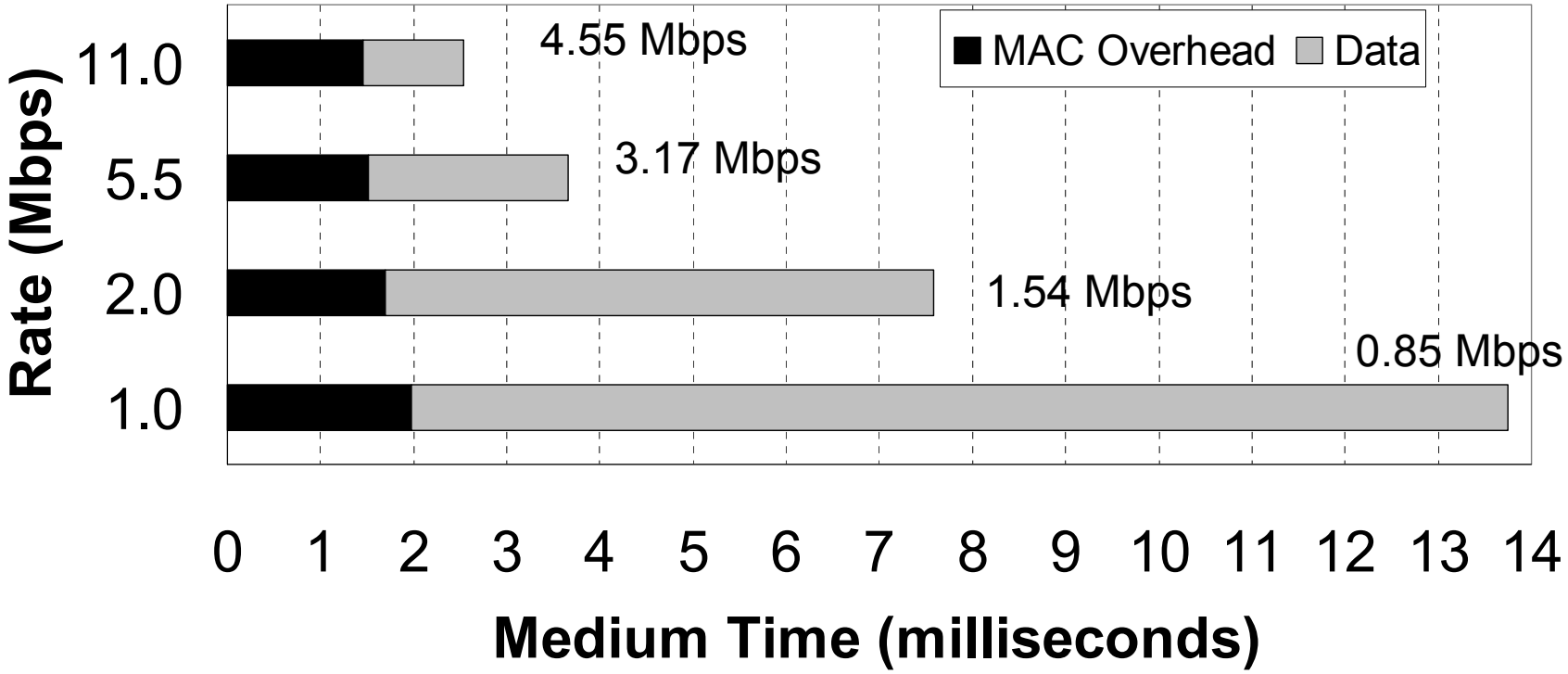


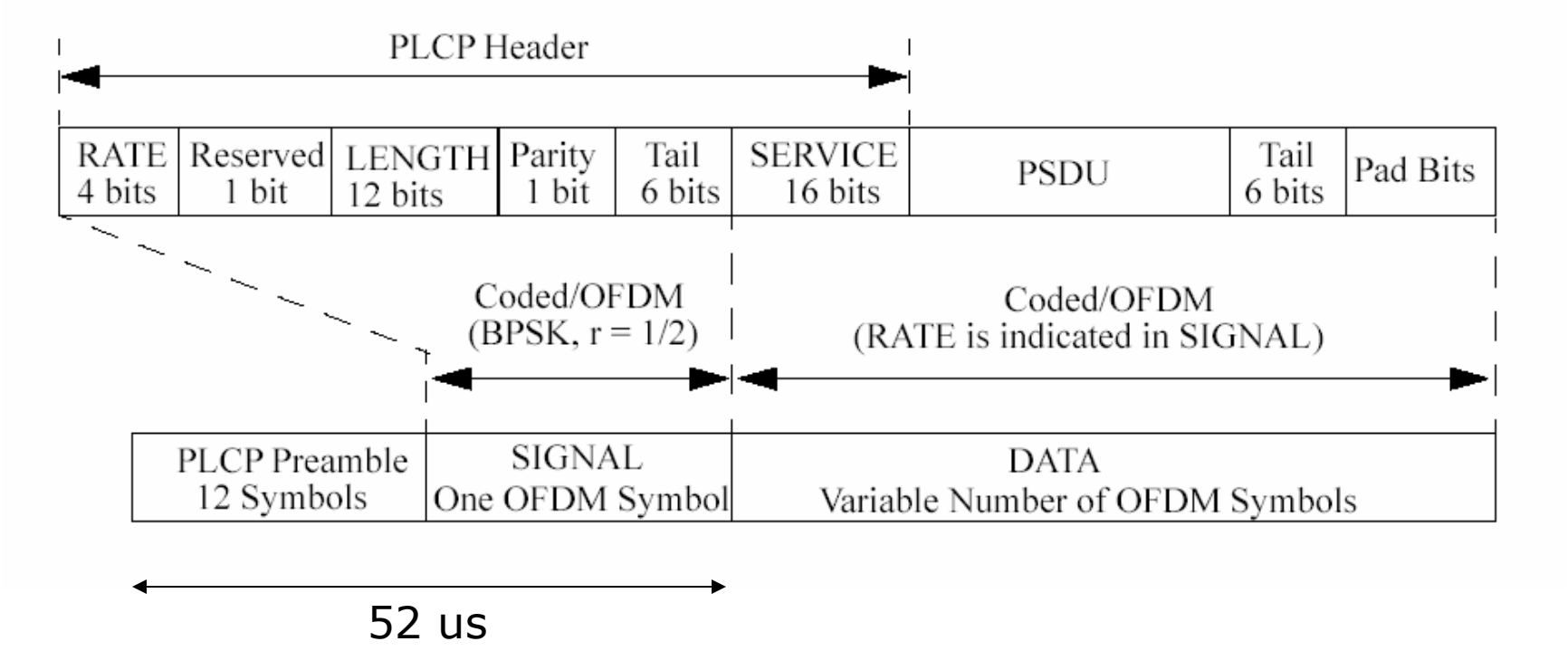
Figure 127—Long PLCP PPDU format

802.11b Frame Exchange Duration



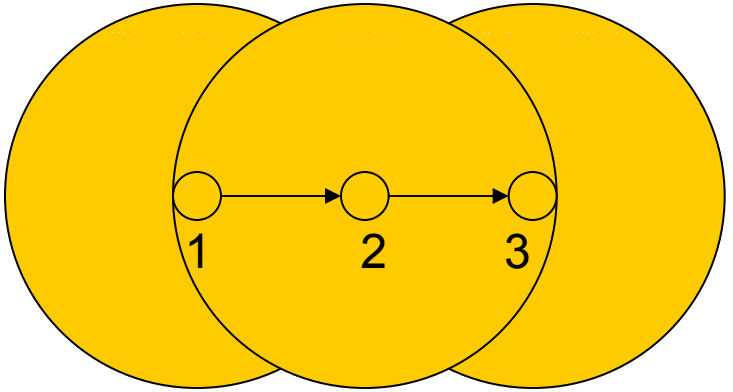
Medium Time consumed to transmit 1500 byte packet

Multi-rate Frame in 802.11a

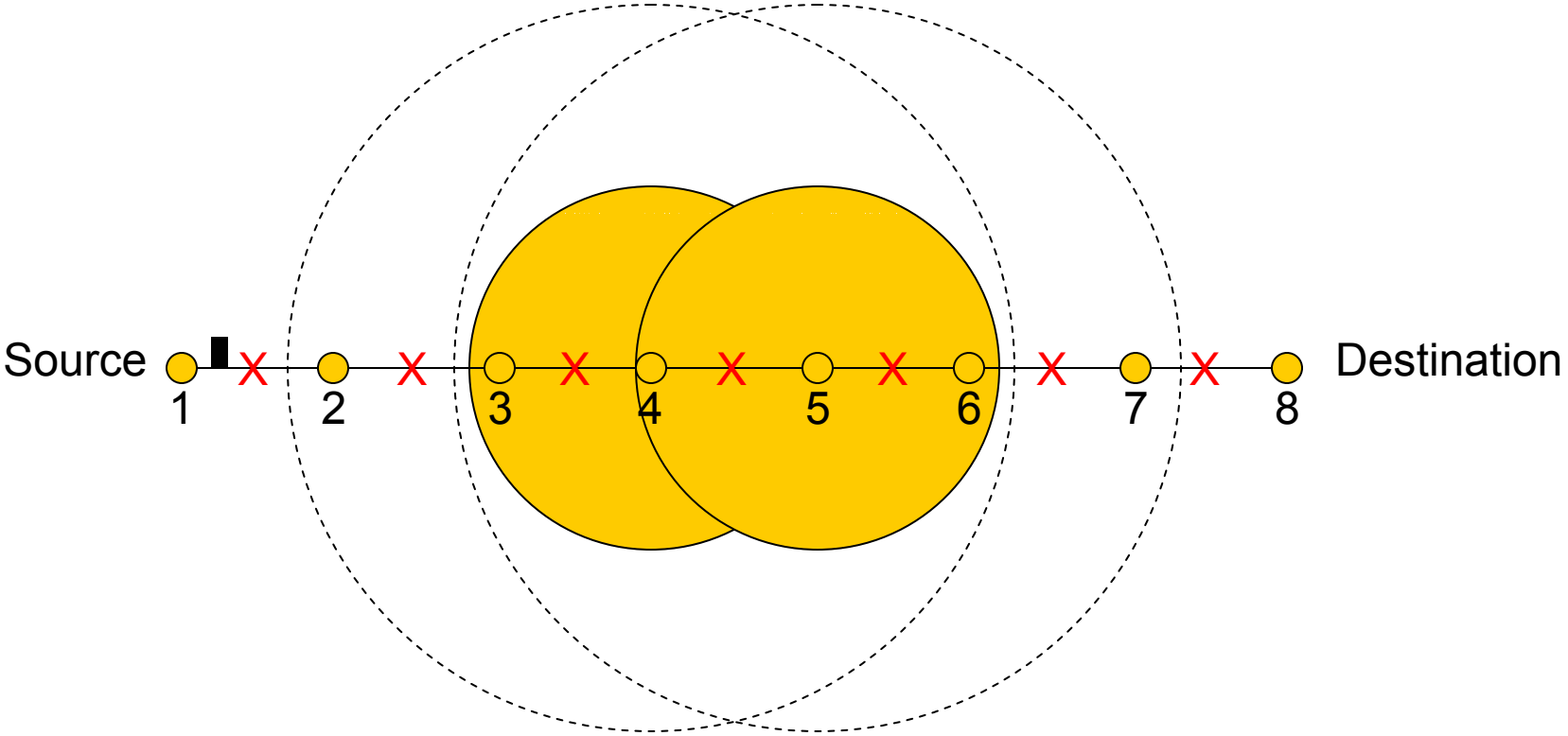


Hops vs. Throughput

- Since the medium is shared, adjacent transmissions compete for medium time
- Effective end-to-end throughput decreases when sending across multiple hops

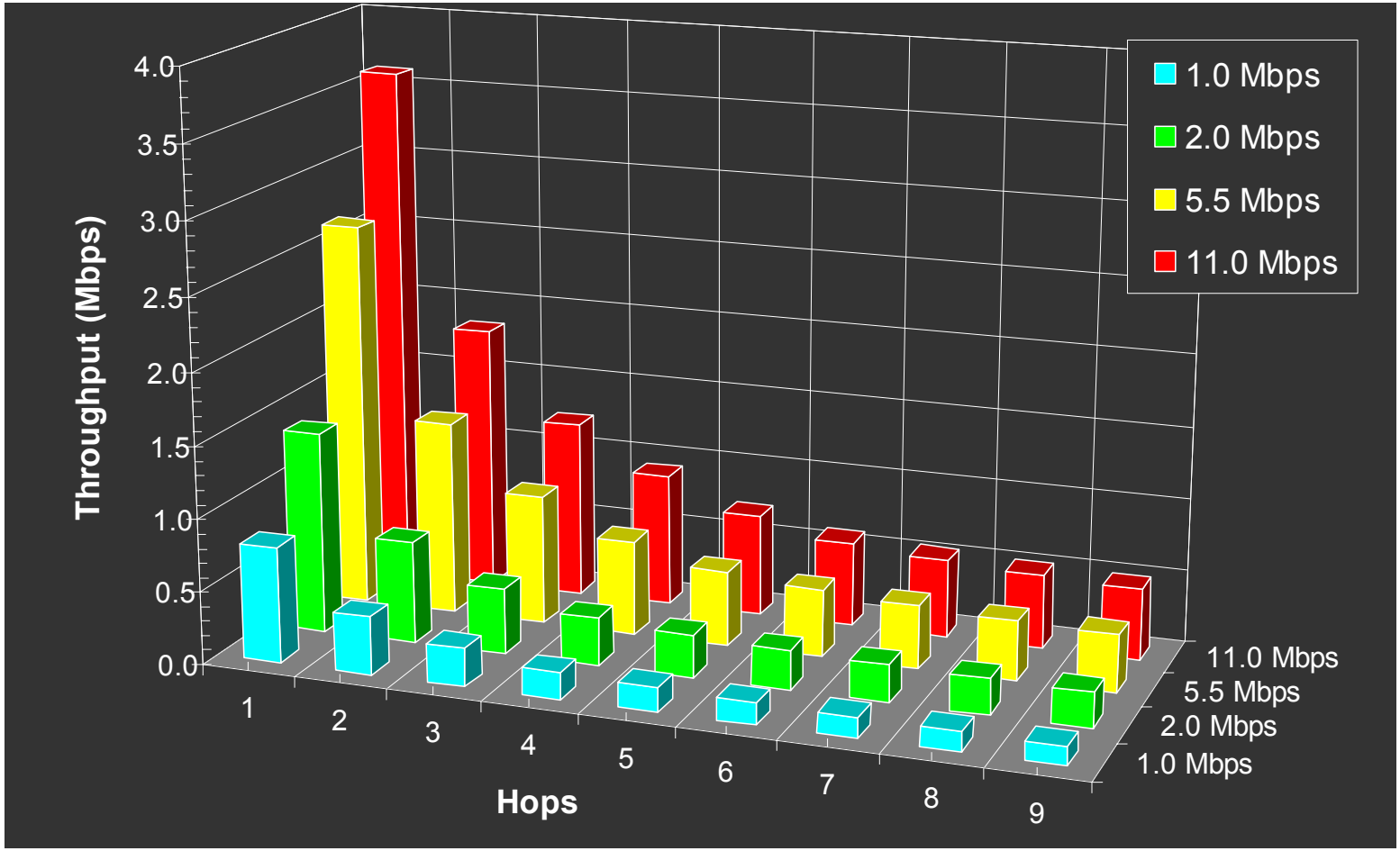


Effect of Transmission



Request to Send (RTS)

Multi-Hop Throughput Loss (TCP)



Auto Rate Protocols

- Selects the rate to use for a packet
- ARF
  - Adaptive based on success/failure of previous packets
  - Simple to implement
  - Doesn’t require the use of RTS CTS or changes to 802.11 spec
- Receiver Based Auto Rate (RBAR)
  - Uses SNR measurement of RTS to select rate
  - Faster & more accurate in changing channel
  - Requires some tweaks to the header fields
- Opportunistic Auto Rate (OAR)
  - Adds packet bursting to RBAR
  - Allows nodes to send more when channel conditions are good
  - Implements temporal fairness instead of packet fairness

MAC Layer Fairness Models

- **Per Packet Fairness**: If two adjacent senders continuously are attempting to send packets, they should each send the same *number of packets*.
- **Temporal Fairness**: If two adjacent senders are continuously attempting to send packets, they should each be able to send for the same *amount of medium time.*
- In single rate networks these are the SAME!

Temporal Fairness Example

	802.11 Packet Fairness	OAR Temporal Fairness
11 Mbps Link	0.896	3.533
1 Mbps Link	0.713	0.450
Total Throughput	1.609	3.983