

# Chapter 5: Relay-Based Multi-Rate MAC Protocol

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# Outline

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- Background
- Related Work
- Motivation
- “rDCF: A Relay-enabled Medium Access Control Protocol for Wireless Ad Hoc Networks”, IEEE Trans. on Mobile Computing, Sep. 06.
- “A Relay-Aided Media Access (RAMA) Protocol in Multirate Wireless Networks”, IEEE Trans. On Vehicular Technology, Sep. 06.
- Conclusion

# Background

- The IEEE 802.11 standard supports multiple data rates at PHY layer.
  - 802.11a: 6, 9, 12, 18, 24, 36, 48, 54 Mbps
  - 802.11b: 1, 2, 5.5, 11 Mbps
  - 802.11g: 1, 2, 5.5, 6, 9, 11, 12, 18, 24, 33, 36, 48, 54 Mbps

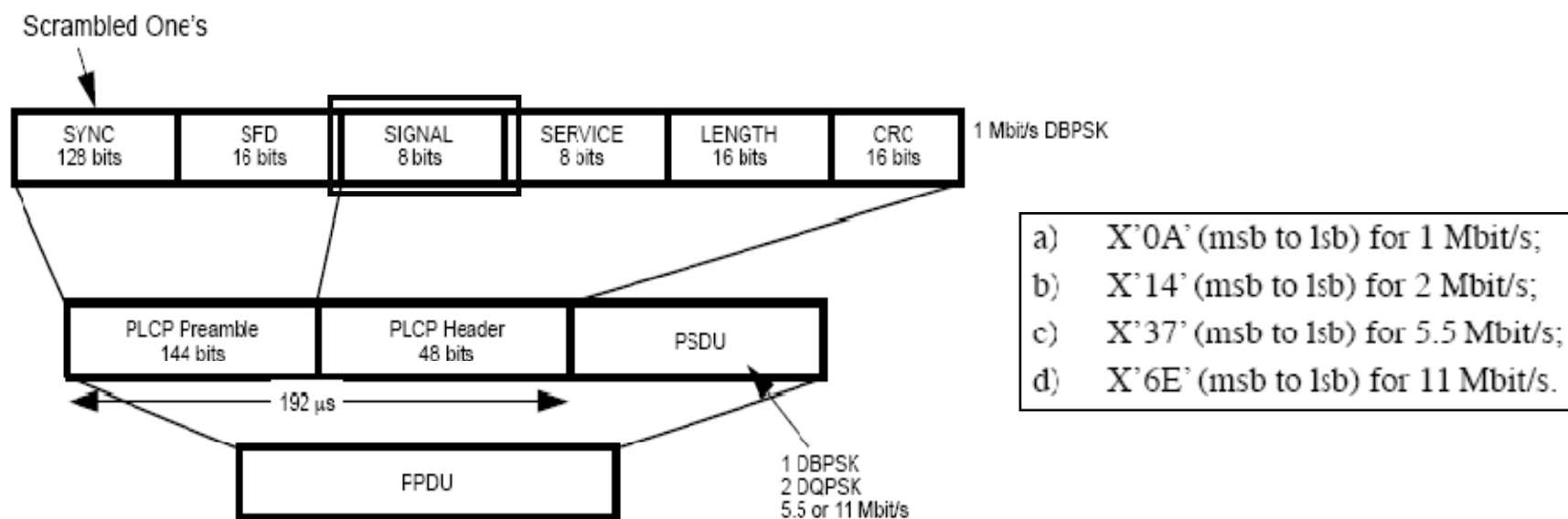


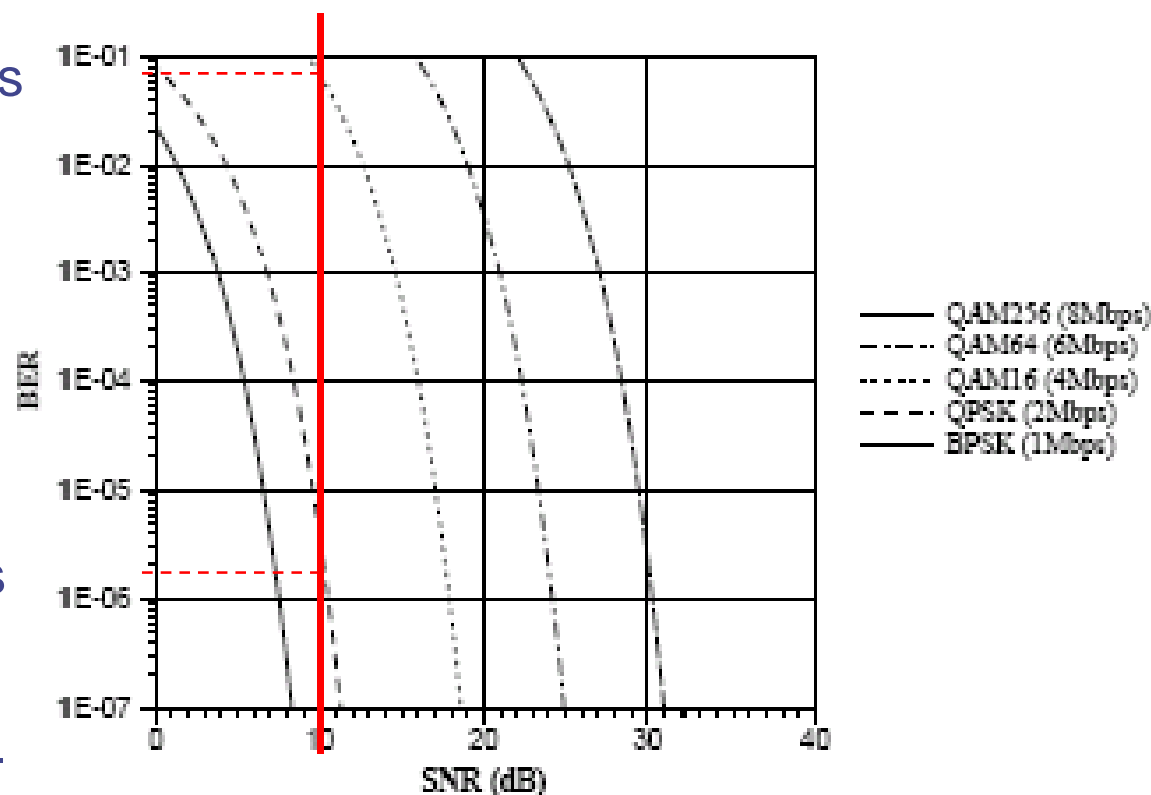
Figure 127–Long PLCP PDU format

# Modulation Scheme V.S. SNR and BER

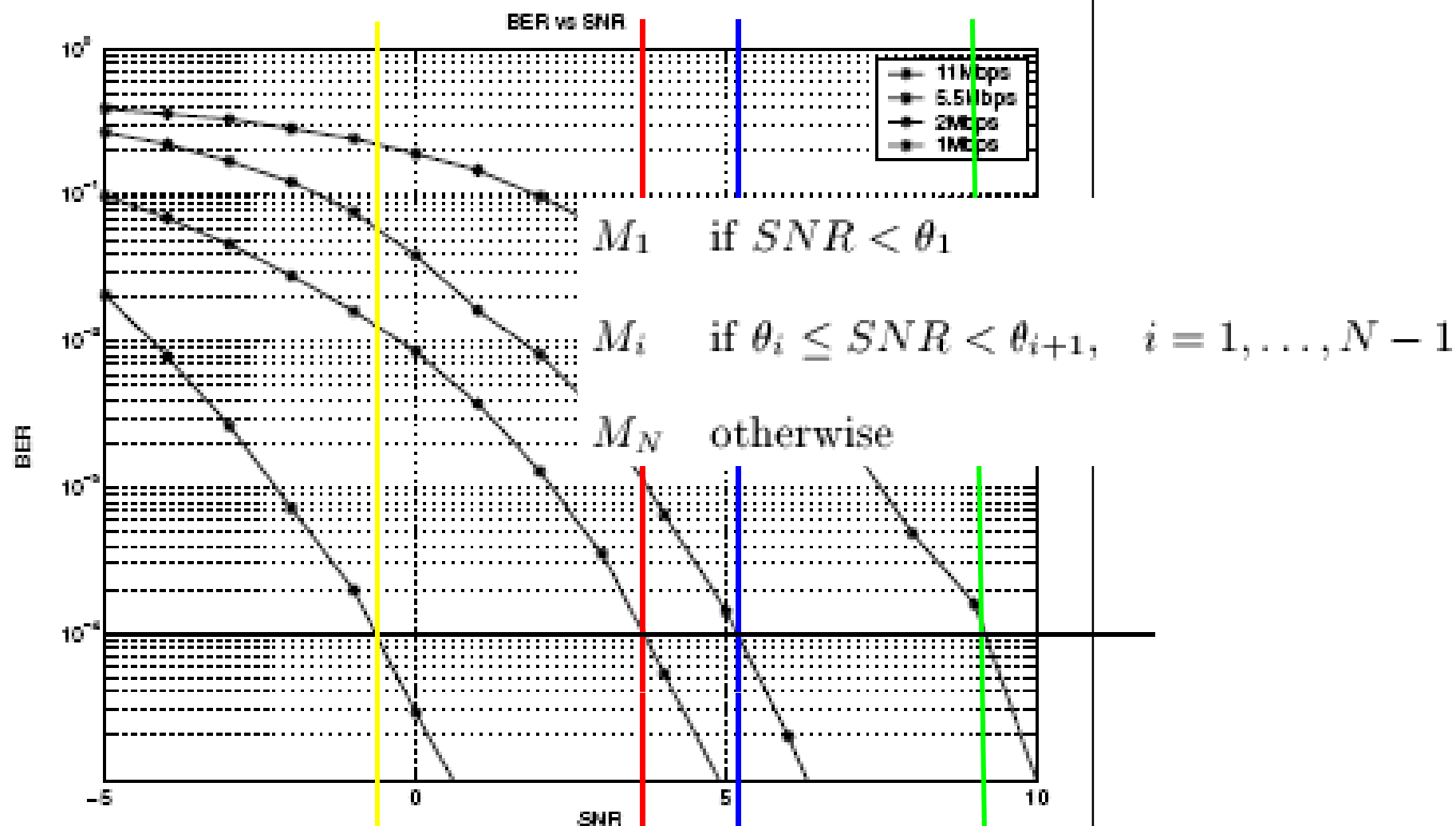
- Path loss, fading, and interference cause variations in the received signal-to-noise (SNR) ratio
- Fixed SNR
  - The higher bit rate modulation, the higher BER (bit error ratio)

QAM16 4Mbps

QPSK 2Mbps

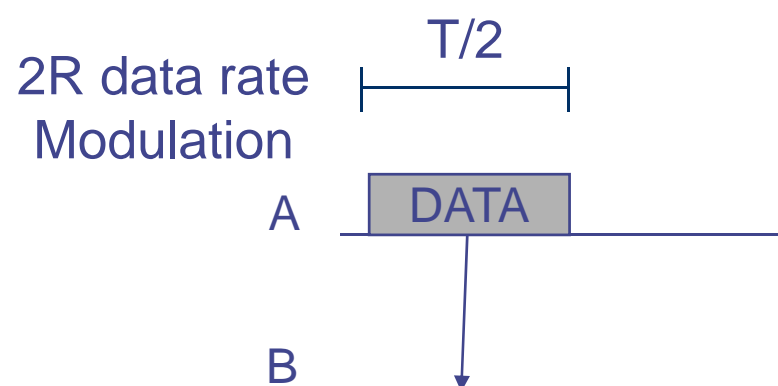
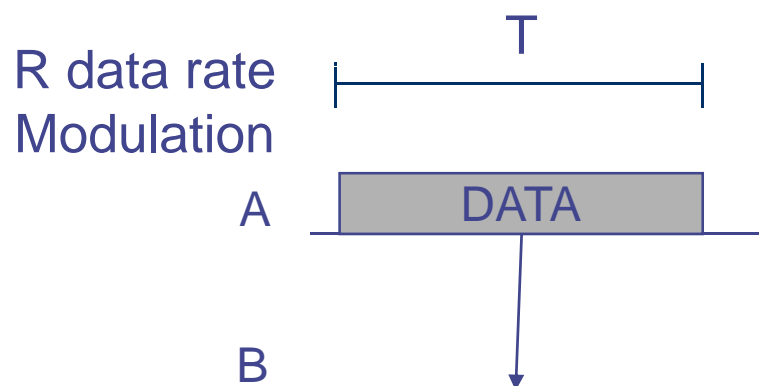


# How to Choose the Bit Rate



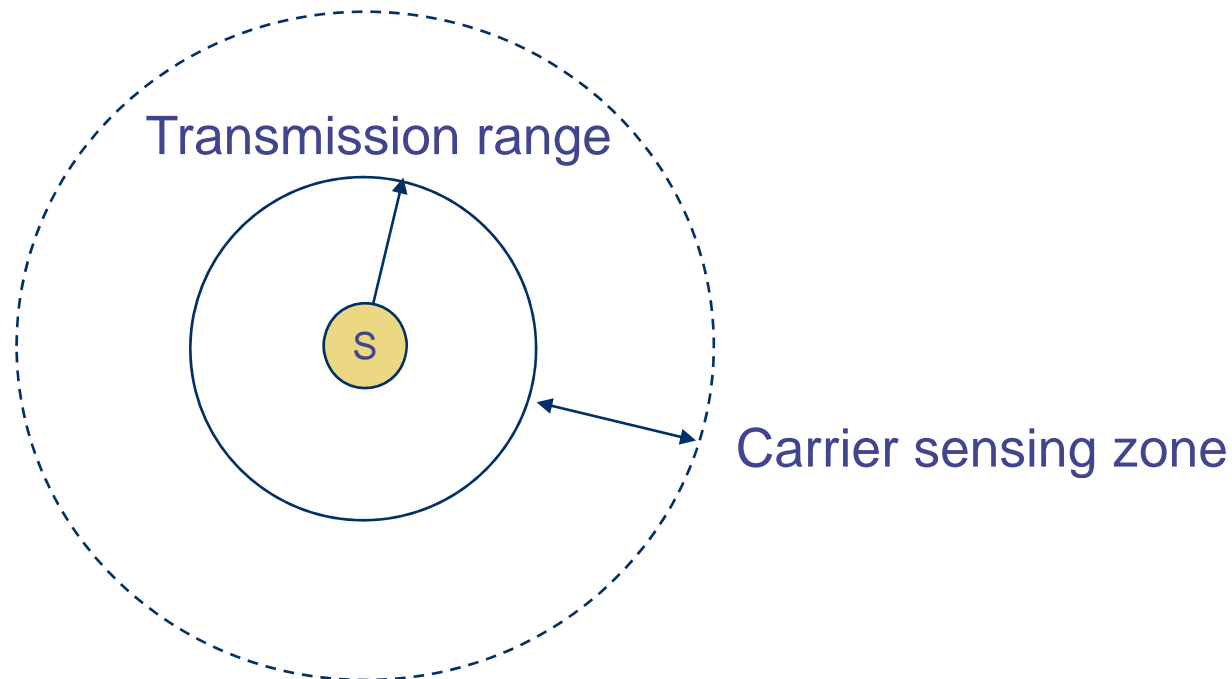
## Background

- A higher data rate modulation scheme requires higher signal-to-noise ratio (SNR)
- The relationship between transmission time and data rate modulation
  - Transmission time requires  $T$  if exploiting  $R$  data rate modulation
  - Transmission time requires  $T/2$  if exploiting  $2R$  data rate modulation



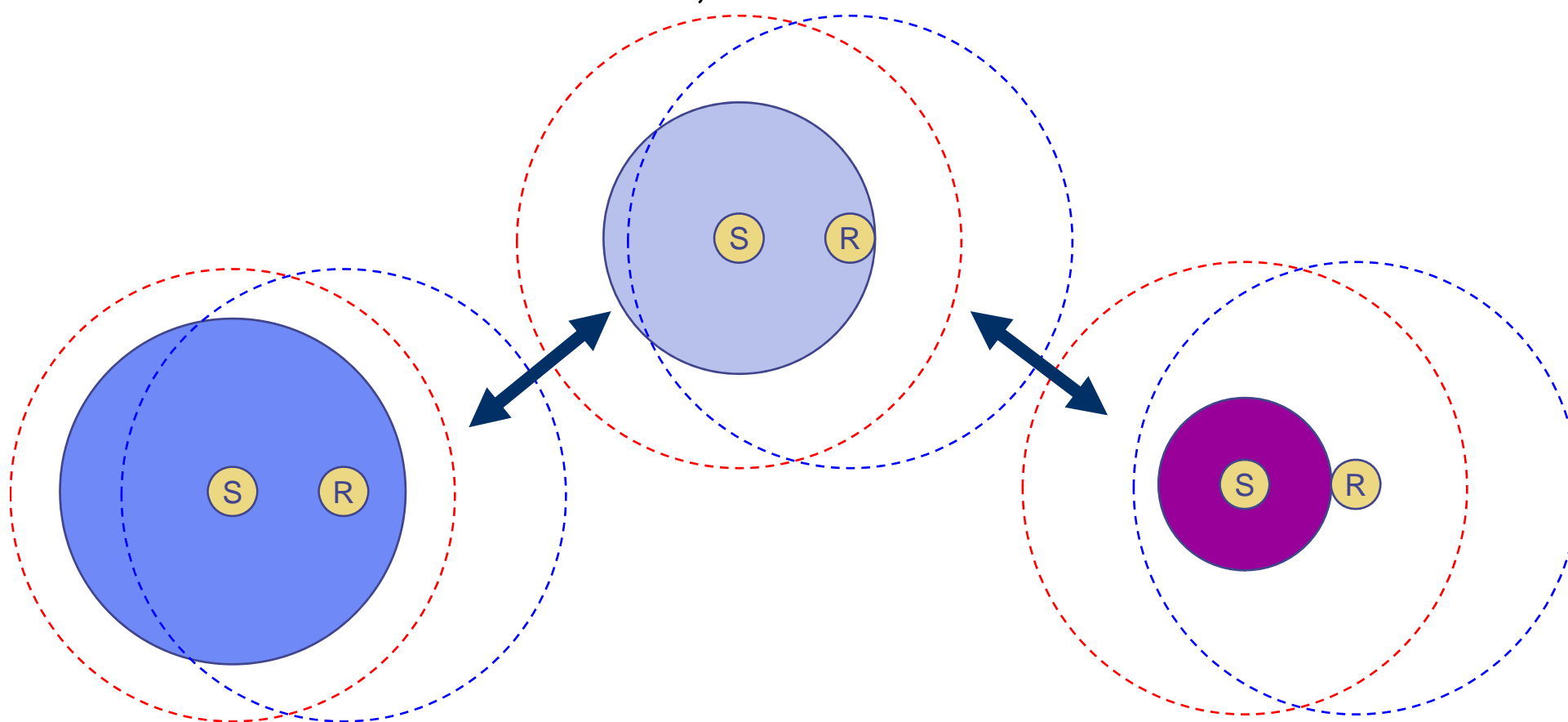
# Background

- Transmission range
  - A node can receive and correctly decode packets.
  - Transmission range is in inverse proportion to data rate modulation.
- Carrier sensing zone
  - A node can sense the signal but cannot decode it correctly.



## Related Work: ARF

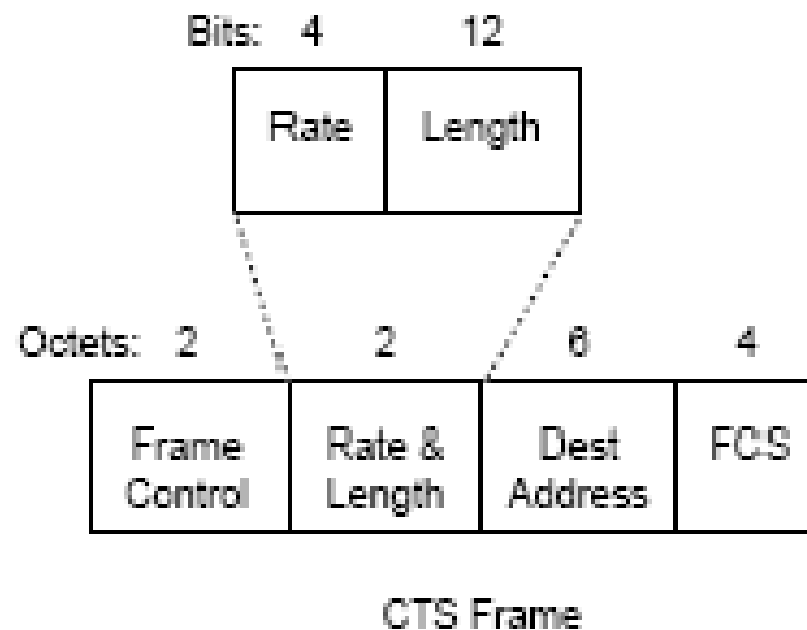
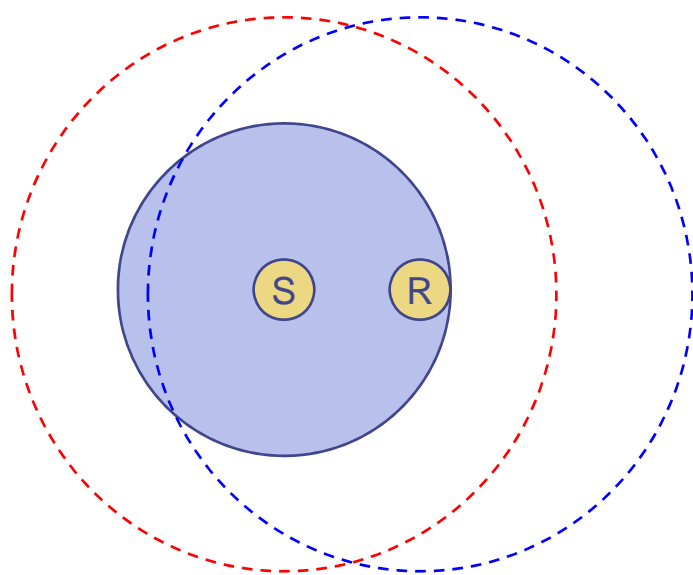
- *A. Kamerman, L. Monteban. “WaveLAN-II: A high-performance wireless LAN for the unlicensed band”, Bell Labs Tech. Journal, 97 Summer.*





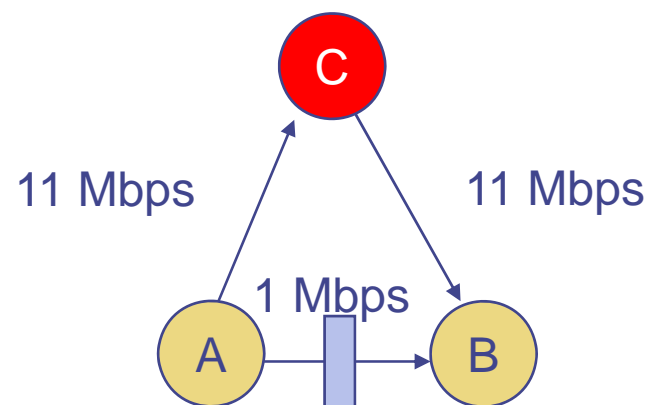
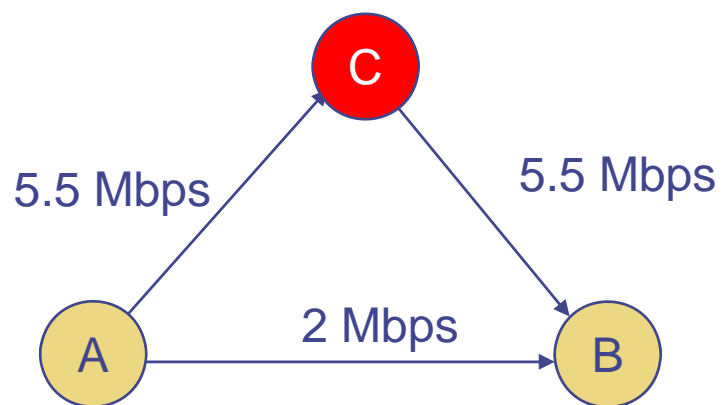
## Related Work: **RBAR**

- *G. Holland, N. Vaidya, P. Bahl, “A Rate-Adaptive MAC Protocol for Multi-Hop Wireless Networks”, ACM Mobicom 01.*



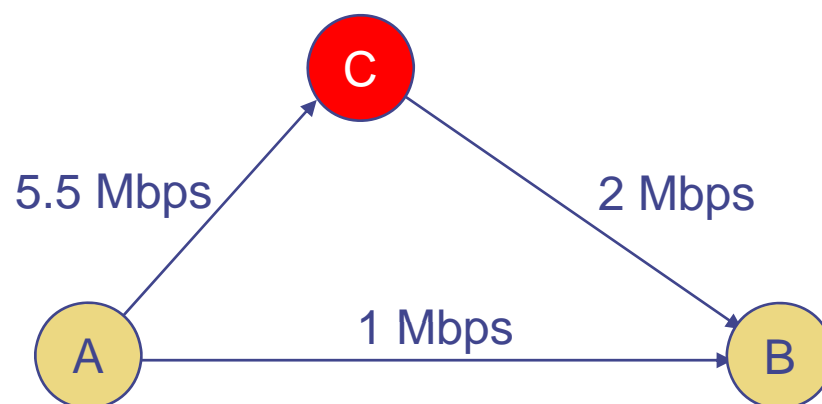
# Motivation

- A lower rate link can be replaced by two higher rate links.
  - $T_{AC} + T_{CB} < T_{AB}$

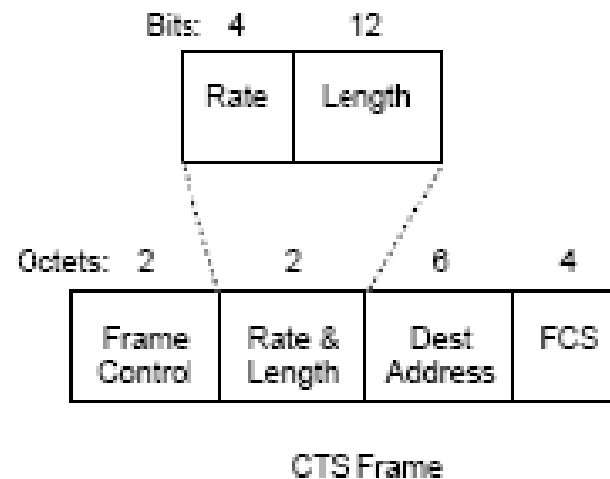


# Relay-based Multi-rate MAC Protocol Process

- Relay node discovery
  - Let A know that a relay node C which exists between A and B can help A transmitting to B via C.
- Relay-based transmission
  - A sends data to B via C if  $T_{AC} + T_{CB} < T_{AB}$

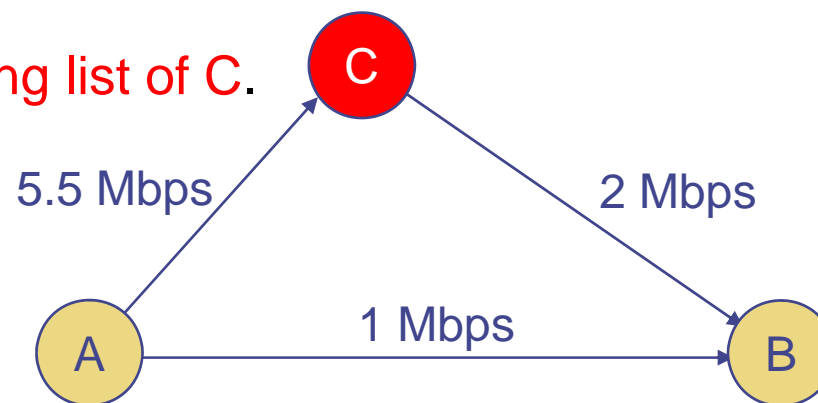


- Assumption
  - Each node transmits its packets using a constant transmission power.
  - The wireless channel between the sender and the receiver is to be almost symmetric.
- Based on RBAR
  - Receiver notifies the sender of the transmission rate via CTS



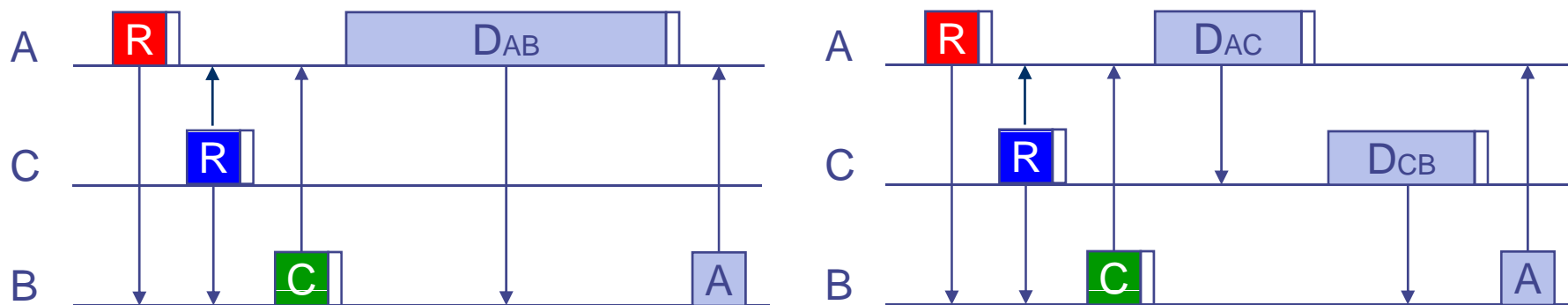
## rDCF (Relay node discovery)

- **C** measures channel quality for a given flow between a pair of sender and receiver.
  - **C** obtains  $R_{AB}$  by extracting the piggybacked transmission rate in the CTS.
  - **C** estimates RTS and CTS to acquire  $R_{AC}$  and  $R_{CB}$ .
- if satisfying relay condition
  - Adding the identity of **A** and **B** into its willing list.
  - Periodically advertising its willing list to its neighbors
- **A** adds **C** into its relay table
  - If finding that **A** -> **B** is in the willing list of **C**.



## rDCF (Relay Transmission) (Decision of B)

- **A** don't find a relay node
  - RBAR
- **A** finds a relay node
  1. **A** broadcasts **RRTS1** (**C** estimates  $R_{AC}$ )
  2. **C** broadcasts **RRTS2** (carry  $R_{AC}$ , **B** estimates  $R_{CB}$ )
  3. if the packet can't be transmitted faster with relay  
**B** broadcasts **CTS** (carry  $R_{AB}$ )  
else  
**B** broadcasts **RCTS** (carry  $R_{CB}$ )



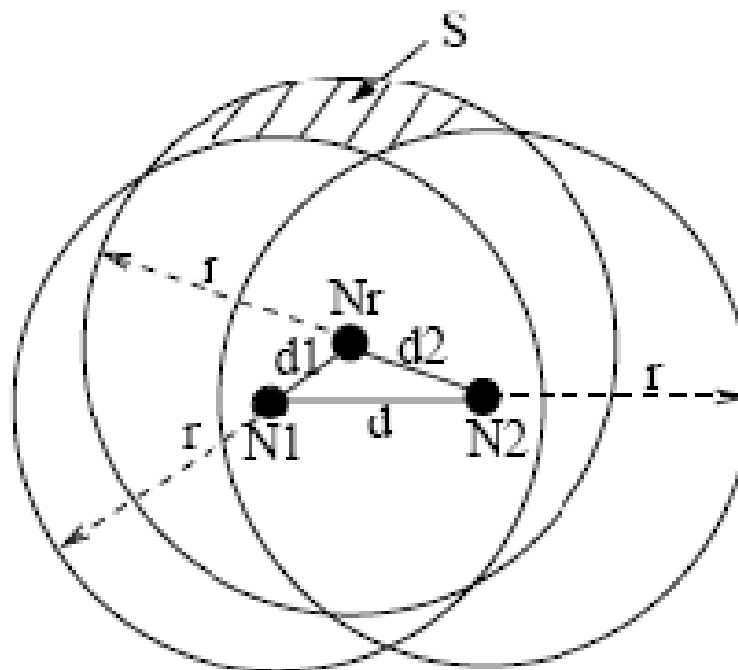
## rDCF (How to Choose One of Relay Nodes)

- The channel condition may change frequently in wireless networks.
  - Relay node may suffer **hidden terminal**.
- Each relay node in the relay table of A
  - Be associated with a **credit** ranging [0.0, 1.0]
- A chooses the one with the **largest credit**
  - Generating a random number in [0.0, 1.0]
    - If random number  $\geq$  credit
      - A does rDCF
      - if rDCF is success
        - the credit of C is increased
      - else if rDCF is failed
        - the credit of C is decreased
    - else if random number  $<$  credit
      - A does RBAR

# Carrier Sensing Zone Analysis

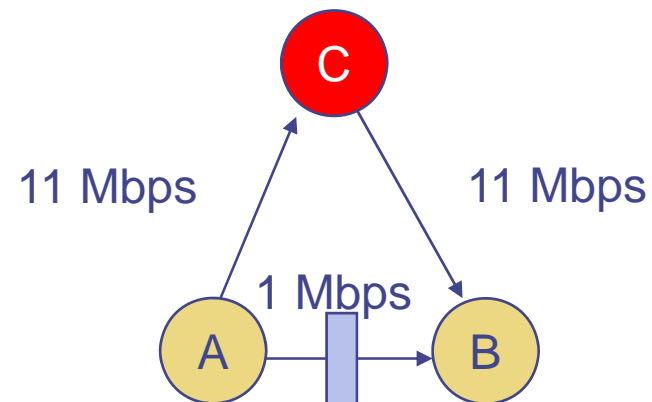
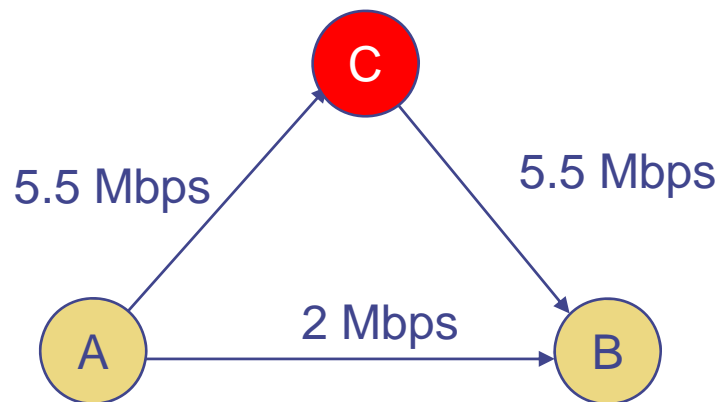
- Increased sensing zone is small

d (meters)	210	220	230	240	250
Upper bound of increased sensing area (%)	11.5	10.5	9.2	8.2	7.2





- Assumption
  - In DCF, each node must transmit with the same power.
  - Channel gain between the two nodes is the same in both directions.  
Based on RBAR

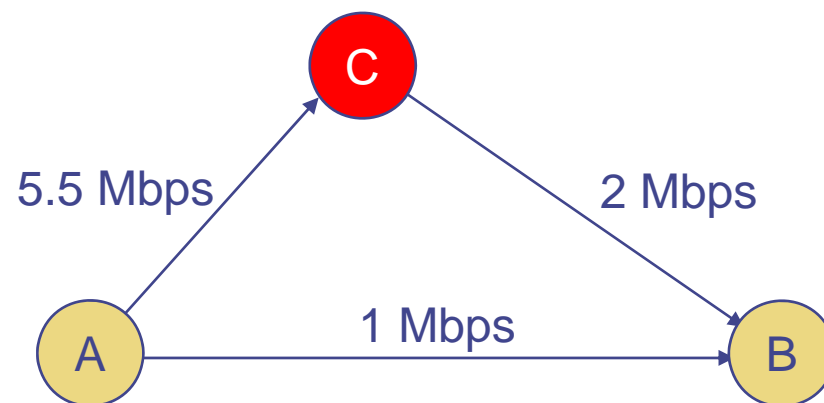


## RAMA (Relay node discovery)

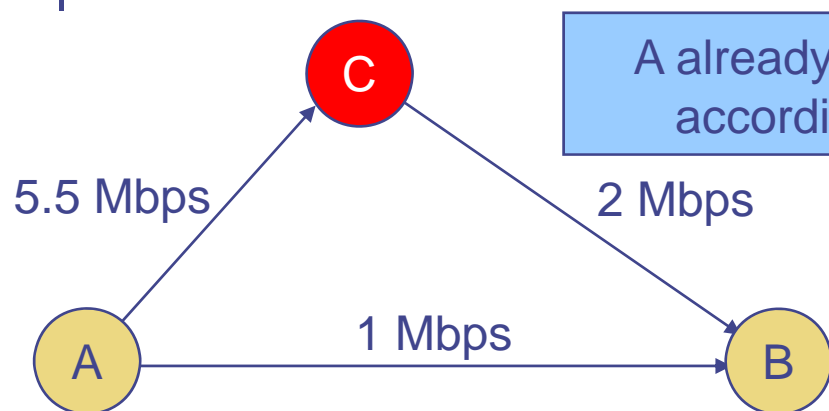
- **C** obtains  $R_{AB}$  from PHY header of  $DATA_{AB}$ .
- **C** estimates  $DATA_{AB}$  and ACK to acquire  $R_{AC}$  and  $R_{CB}$ .  
if satisfying relay condition

C will broadcast an **invitation frame** to A

- **Source, Relay, Destination,  $R_{AC}$  and  $R_{CB}$**
- A will record it in **Relay List**.



# RAMA (Relay Transmission) (Decision of A)

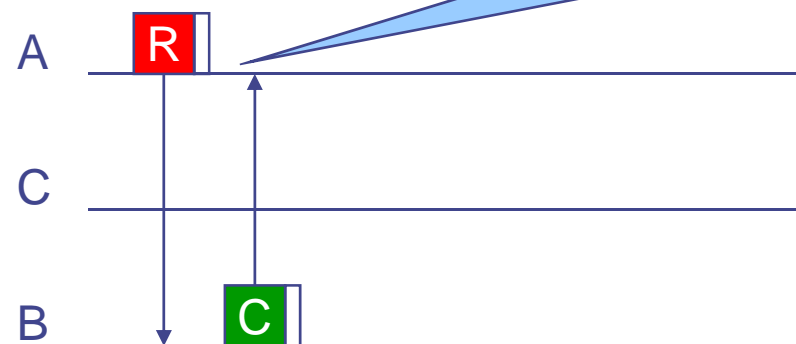


A already has  $R_{AC}$  and  $R_{CB}$   
according to Relay List

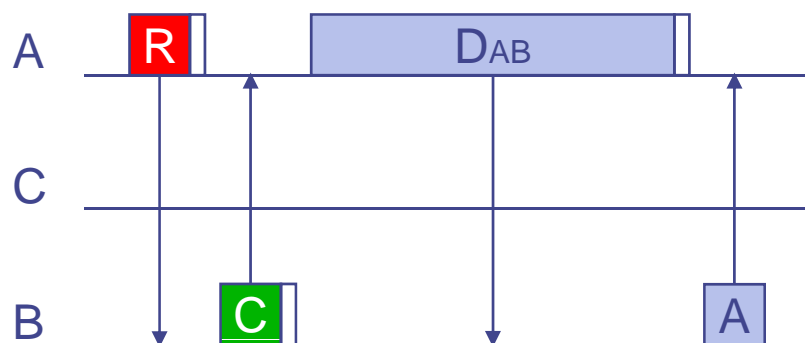
A knows  $R_{AB}$

Relay List:

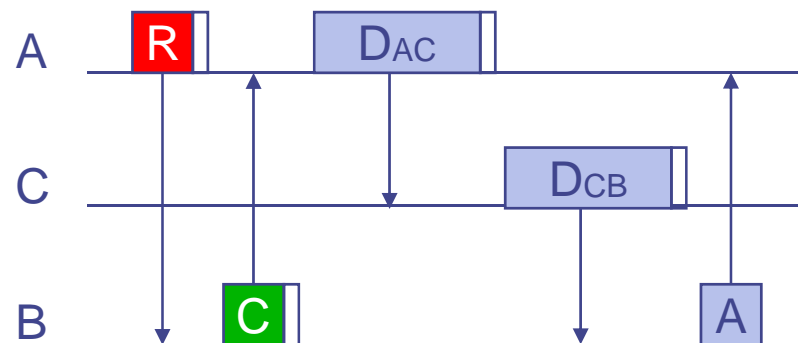
Source, Relay, Destination,  $R_{AC}$  and  $R_{CB}$



Case 1



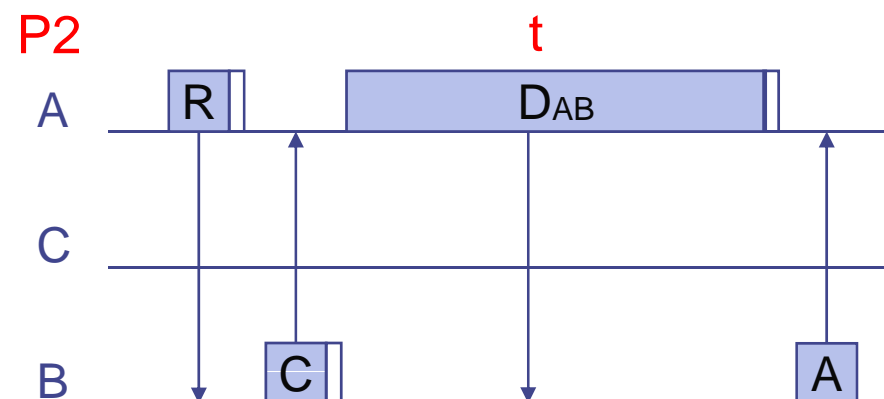
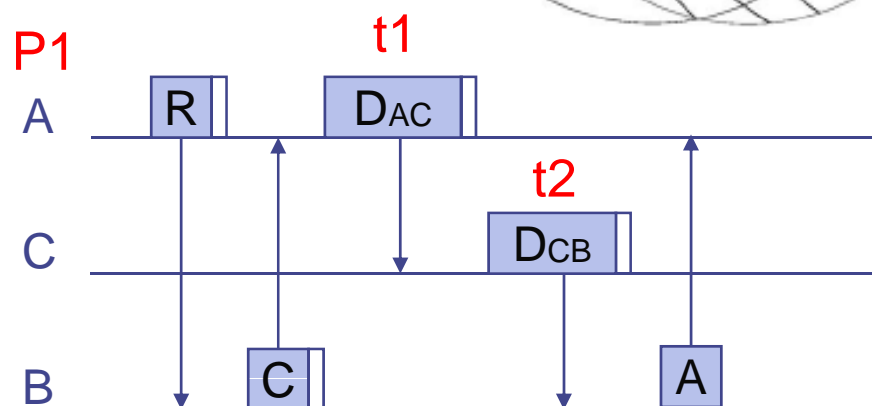
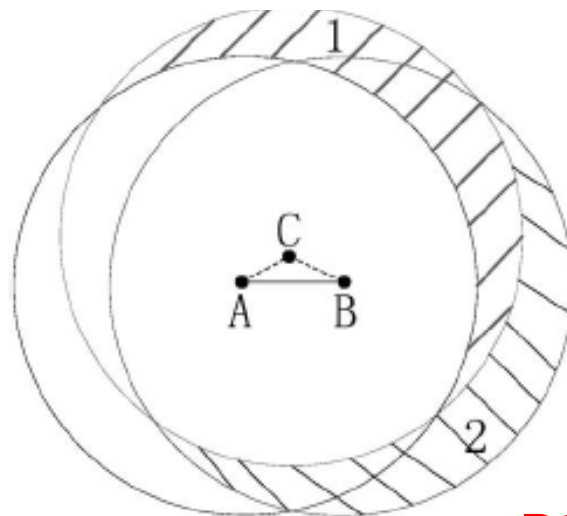
Case 2



# Carrier Sensing Zone Analysis

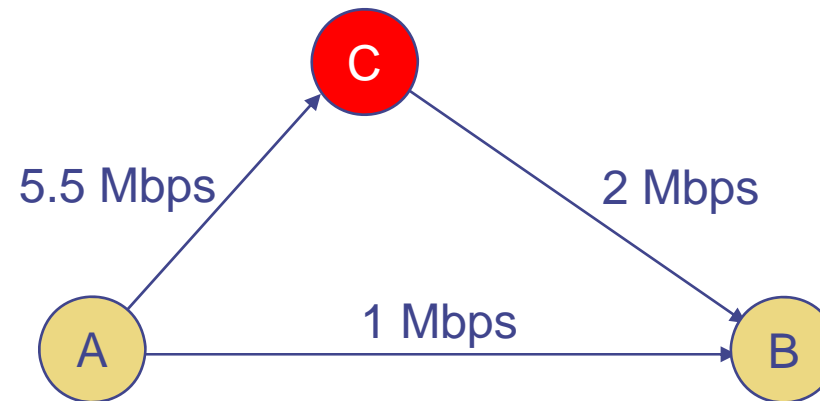
$a_1 < a$  and  $a_2 < a$  because  $d_{AC} < d_{AB}$  and  $d_{CB} < d_{AB}$

$$t_1 + t_2 < t \quad p_1 = e^{-a_1 \lambda t_1} \times e^{-a_2 \lambda t_2} > p_2 = e^{-a \lambda t}$$



# Summary

- According to the channel condition, data can be transmitted with different data rate modulation.
- Multi-rate transmission vs. single-rate transmission
  - Increasing overall throughput
  - Decreasing transmission time
- Data also may be delivered faster through a relay node than through the direct link if the direct link has low quality and low data rate.



## Homework #5:

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1. What's relay-based multi-rate MAC protocol ?
2. What's the difference between rDCF and RAMA protocols ?