MAC Protocols

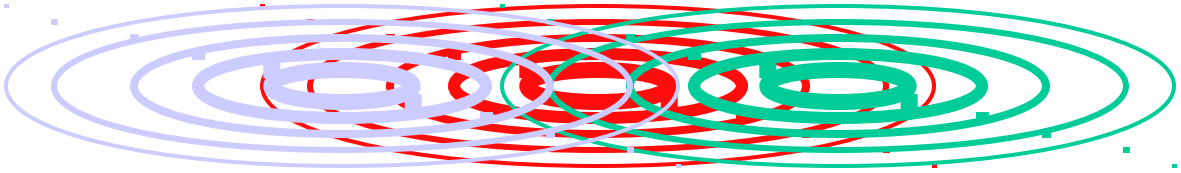
ISSUES in Wireless MAC

- Bandwidth Efficiency
  - BW available is very limited
  - MAC should be designed such that the scarce bandwidth is utilized in an efficient manner
- Hidden and Exposed Node Problem
- Collision-prone shared channel
  - Multiple nodes may contend for the medium leading to collision
  - MAC should make sure that collision is minimized

ISSUES in Wireless MAC

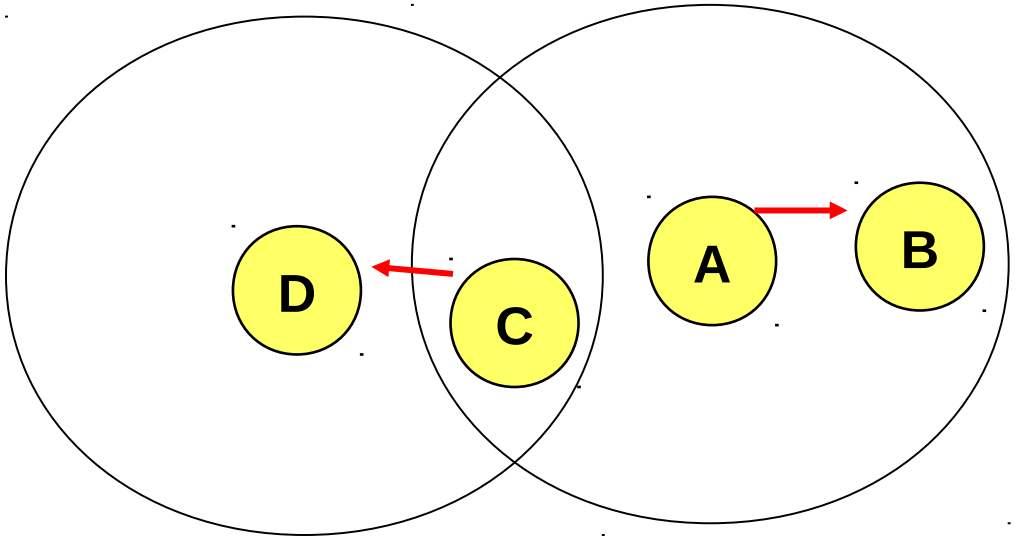
- Mobility of Nodes
  - Control information exchanged may become useless due to mobility
  - MAC performance should be satisfactory when nodes are mobile
- Power consumption
- QoS support
  - Criticial for real time applications

Hidden Terminal Problem



- A and C cannot hear each other.
- A sends to B, C cannot receive A.
- C wants to send to B, C senses a “free” medium (CS fails)
- Collision occurs at B.
- A cannot receive the collision (CD fails).
- A is “hidden” for C.

Exposed Terminal Problem



- A starts sending to B.
- C senses carrier, finds medium in use and has to wait for A->B to end.
- D is outside the range of A, therefore waiting is not necessary.

Design Goals

- Available bandwidth should be utilized efficiently
- Fair allocation of bandwidth
- Control overhead should be kept low
- Should minimize the effect of hidden and exposed node
- Should be scalable to large network
- Should have power control mechanisms to manage energy consumption of the nodes

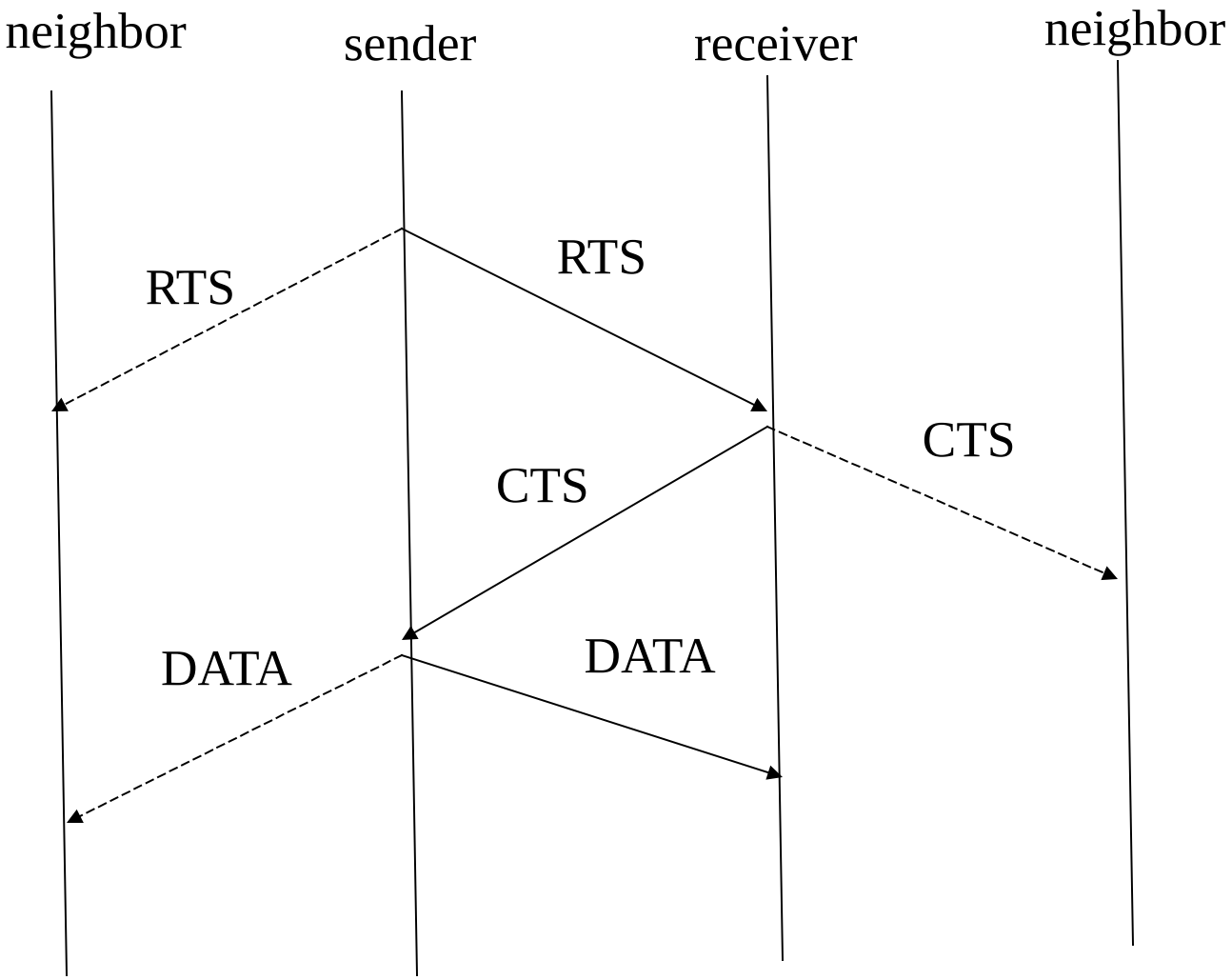
Classification of MAC protocols

- Contention-free
  - TDMA
  - FDMA
  - Polling
- Contention-based
  - MACA (Multiple Access Collision Avoidance)
  - MACAW

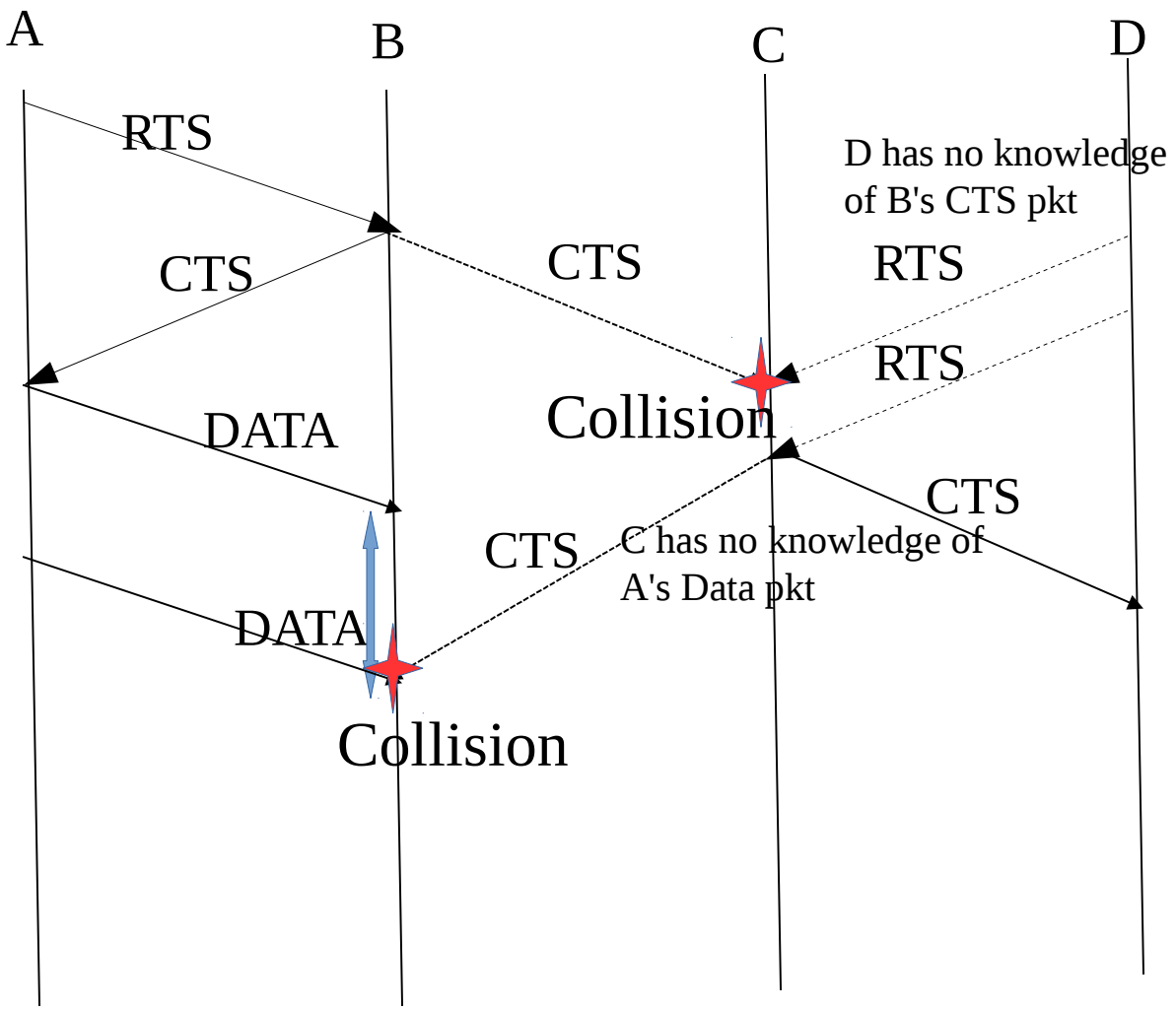
MACA

- Proposed as an alternative to the traditional CSMA
- CSMA senses the state of the channel only at the transmitter
  - Leads to hidden node problem
- Does not use carrier sensing
  - Nodes start transmitting after a random backoff
- MACA uses RTS and CTS to overcome hidden node problem and exposed node problem
  - Node which only hears CTS (but no RTS), stops from transmitting (hidden node)
  - Node which only hears RTS (but no CTS), is free to transmit (exposed node)
  - RTS and CTS carry the expected duration of data transmission
- When there is a collision, it uses binary exponential backoff (BEB) before retrying

Packet Transmission in MACA



Failure of RTS-CTS in solving Hidden and Exposed terminal problems in MACA

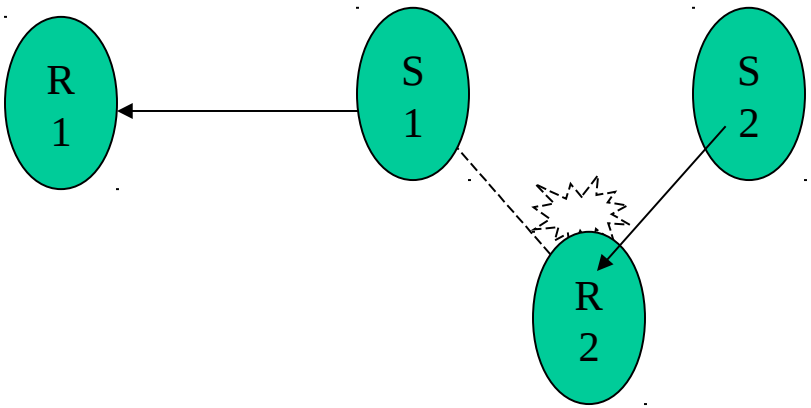


Weakness of MACA

- It does not provide any acknowledgement of pkt at the data link layer
- If a transmission fails for any reason retransmission has to be initiated by the transport layer
- It delays in transmission of data

MACAW

- The binary exponential back off can starve the flows
- S1 and S2 have data to send
- Let us say S1 captures the channel
- S2 keeps sending RTS, but it gets collided. S2 increases backoff window. Gets blocked from transmitting longer period of time after every collision.



Back off change in MACAW

- Send Back off counter value in the packet. Nodes receiving the packet use the backoff counter carried in the packet instead of that used in MACA
  - This mechanism make the Bandwidth allocation fair
- BEB (Binary Exponential Backoff) adjusts the back off counter very rapidly
  - After a successful Tx, the BO (Backoff counter) is reset to minimum
  - MACAW introduced multiplicative increase and Linear Decrease (MILD)
    - Upon collision BO multiplied by 1.5
    - Upon successful transmission it is decreased by 1

ACK packet in MACAW

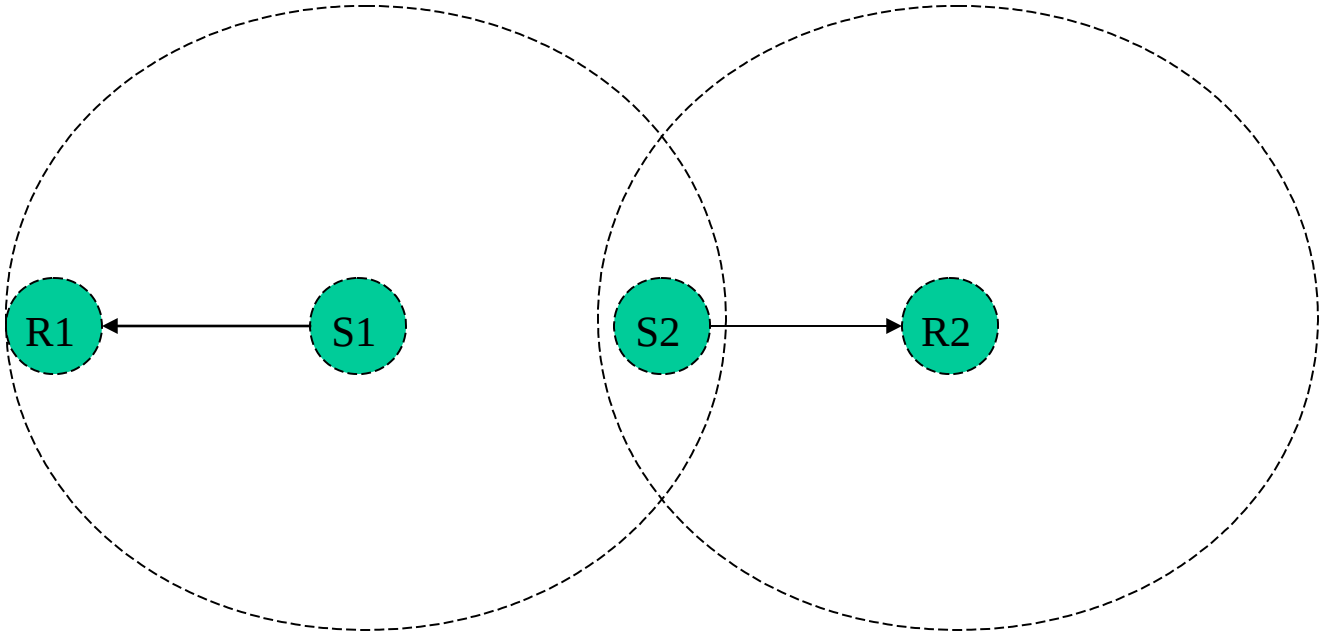
- In MACA, there was no reliability at DLL, it was left to the higher layer to provide reliability
- MACAW introduced ACK packet for every Data packet
  - If ACK is not received, the sender reschedules the Data packet for transmission.
    - Sender would send RTS
    - Rcvr would send CTS (if Data pkt was lost)
      - Would send ACK if ACK was lost

DS packet in MACAW

- In MACA, an exposed node is free to transmit simultaneously when the source node is transmitting packets.
  - But RTS transmission by exposed node is useless, since the CTS reception will end in collision
  - So the source node sends a DS (Data Sending) msg which contains the duration of data transmission
    - tells the exposed node that an RTS-CTS was successful, hence need to wait until DATA-ACK is done

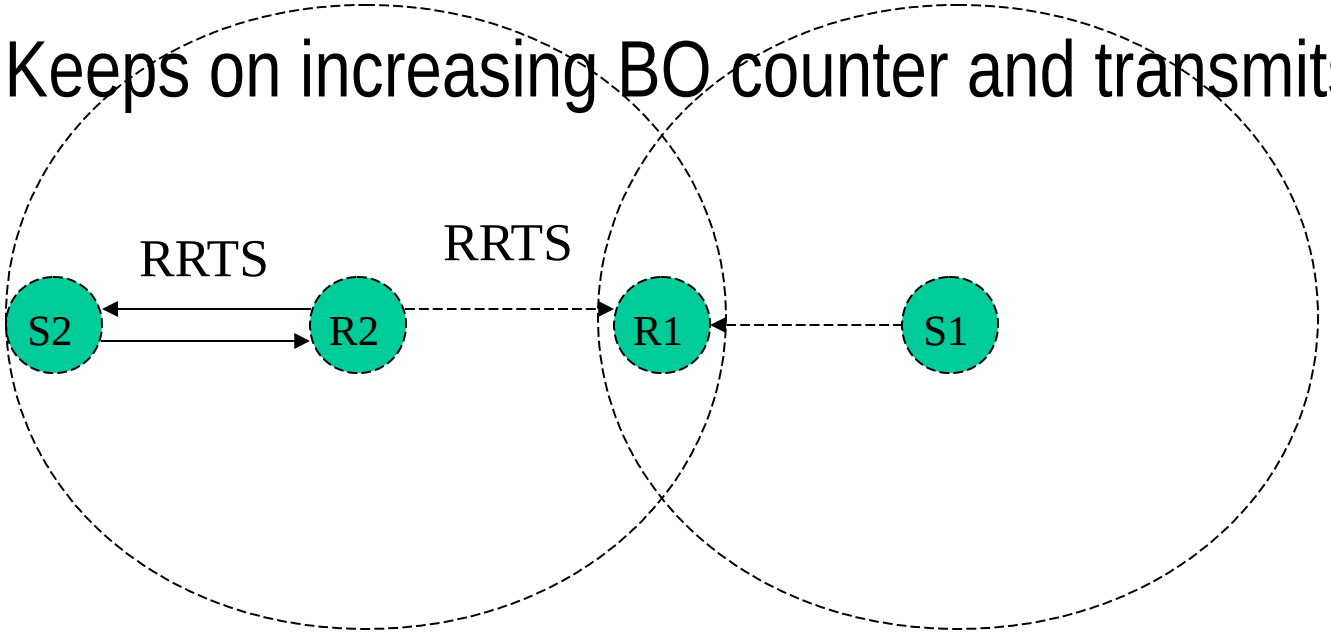
DS packet in MACAW

- S1 is already sending data packets to R1
- S2 sends RTS to R2, but when R2 sends CTS, it collides with data packet from S1



RRTS Packet in MACAW

- S1 is already sending Data
- S2 sends RTS, but R2 does not respond with CTS, since it is a hidden node to S1
- S2 does not know the duration of the Data transmission
  - Keeps on increasing BO counter and transmits RTS



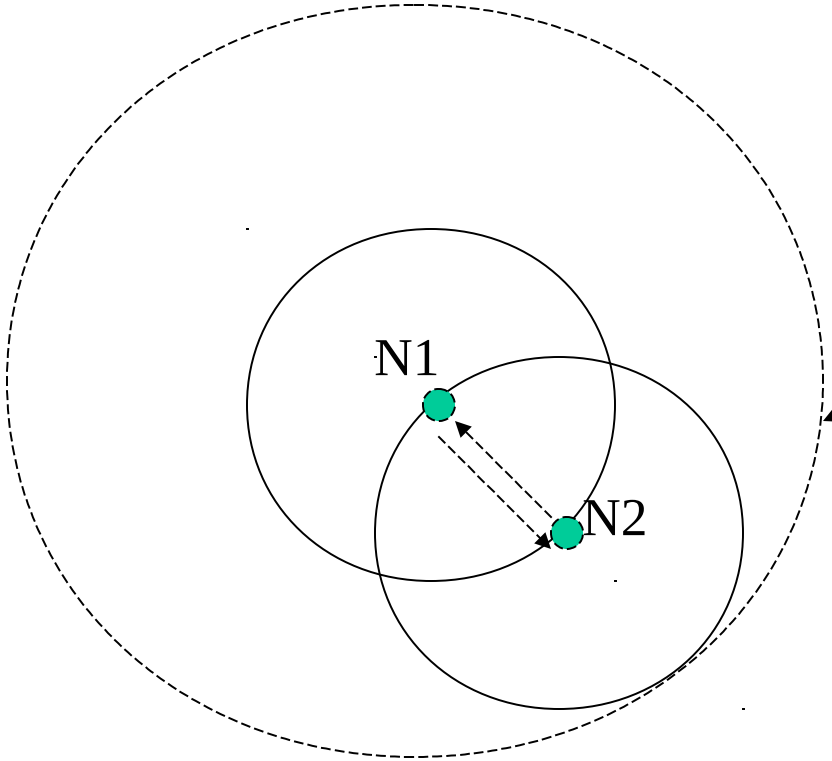
RRTS Packet in MACAW

- R2 contends for the medium on behalf of S2
  - If it had received RTS from S2, then it waits for the next contention period and transmits RRTS
  - Node S2 on receiving RRTS, sends RTS to R2 and normal RTS-CTS-Data-Ack takes place

Busy Tone Multiple Access Protocols (BTMA)

- There are two transmission channels
  - A data channel and a control channel
- When a node is ready for transmission, it checks if the busy tone is active
  - If not, it turns on the busy tone and starts data transmission
  - Otherwise, it reschedules the packet after some random delay
  - Any other node which senses the carrier on the channel also transmits the busy signal
  - When a node is transmitting data, no node in the 2-hop neighborhood is permitted to transmit

BTMA



Region in which
Simultaneous transmissions
are not possible when
N1 is transmitting data

Busy tone

BTMA

- Probability of Collision is very low
- But bandwidth utilization is very poor

References

- P. Karn, “MACA – A New Channel Access Method for Packet Radio”, Proc. Of ARRL/CRRL Amateur Radio Networking Conference, 1990, pp. 134-140, September 1990.
- V. Bharghavan, A. Demers, S. Shenker, L. Zhang, “MACAW: A Media Access Protocol for Wireless LANs”, Proc. Of ACM SIGCOMM 1994, pp. 212-225, August 1994.
- F. A. Tobagi and L. Kleinrock, “Packet Switching in Radio Channels: Part II – The Hidden Terminal Problem in Carrier Sense Multiple Access and Busy Tone Solution”, IEEE Transactions on Communications, vol. 23, no. 12, pp. 1417-1433, December 1975.

References

- F. Talucci and M. Gerla, “MACA-BI (MACA by Invitation) : A Wireless MAC Protocol for High Speed Ad Hoc Networking”, Proc. Of IEEE ICUPC 1997, vol. 2, pp. 913-917, October 1997.
- S. Jiang, J. Rao, D. He, and C. C. Ko, “A Simple Distributed PRMA for MANETs”, IEEE Transactions on Vehicular Technology, vol. 51, no. 2, pp. 293-305, March 2002.
- Z. Tang and J. J. Garcia-Luna-Aceves, “A Protocol for Topology-Dependent Transmission Scheduling in Wireless Networks”, Proc. Of IEEE WCNC 1999, vol. 3, no. 1, pp. 1333-1337, September 1999.