Computer Networks COE 549
Random Access

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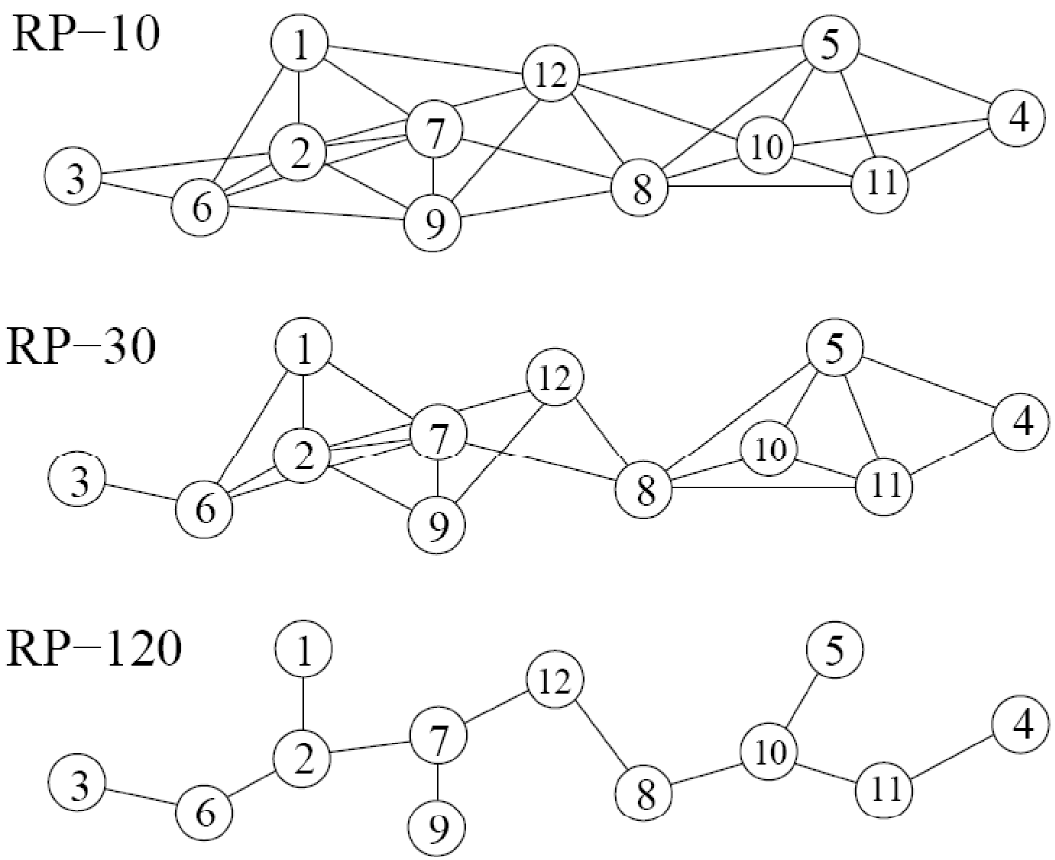
Outline

- Progressive backoff algorithm
- Progressive ramp up algorithm
- Some simulation results

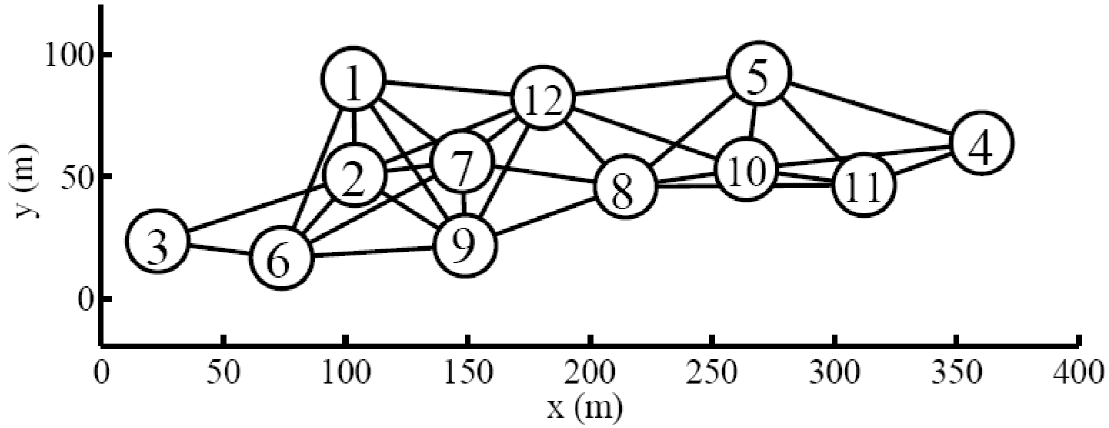
Three Routing Protocols: RP-10, RP-30, RP-120

- Discard weak links.
  - S/N in the absence of interference is below 10 (for RP-10), 30 (for RP-30), or 120 (for RP-120)
  - RP-10, RP-30, RP-120 are routing protocols that avoid links with SNR < 10, 30 and 120dB respectively
- Keep the rest of the links.
  - Use them to construct minimum hop routes
- Different tradeoffs:
  - RP-10 needs few hops.
  - RP-120 is robust to interference.
  - RP-30 is balanced.

Routing Tables



An example network

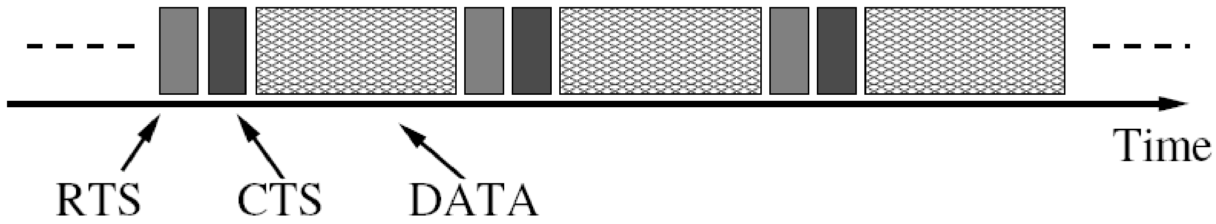


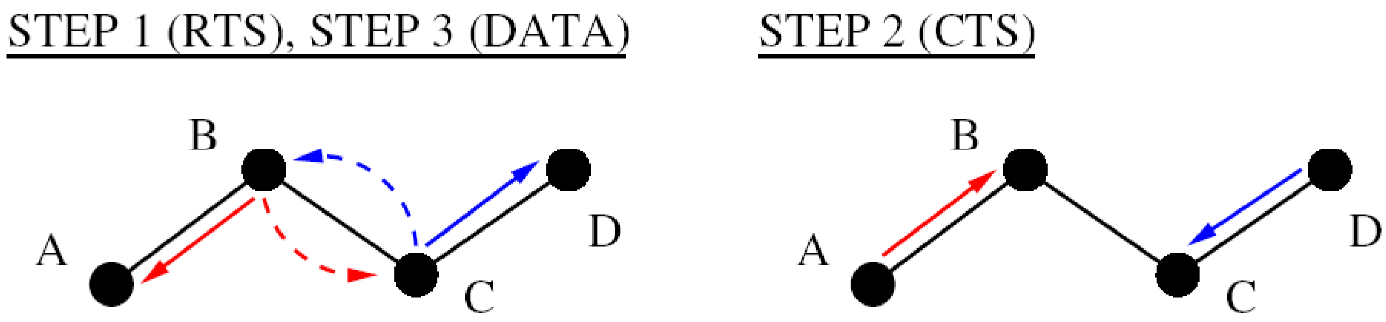
- Reception is successful as long as the SINR is greater than a threshold $\gamma_T = 10$ dB.
- All transmitters transmit with rate $R = 1$ Mbps.
- Maximum transmitter power is $P_{\max} = 0.3$ W.
- Power gains decay exponentially with distance, with decay exponent $\alpha = 4$, and there is no fading:

$$G_{ij} = K d_{ij}^{-\alpha}.$$

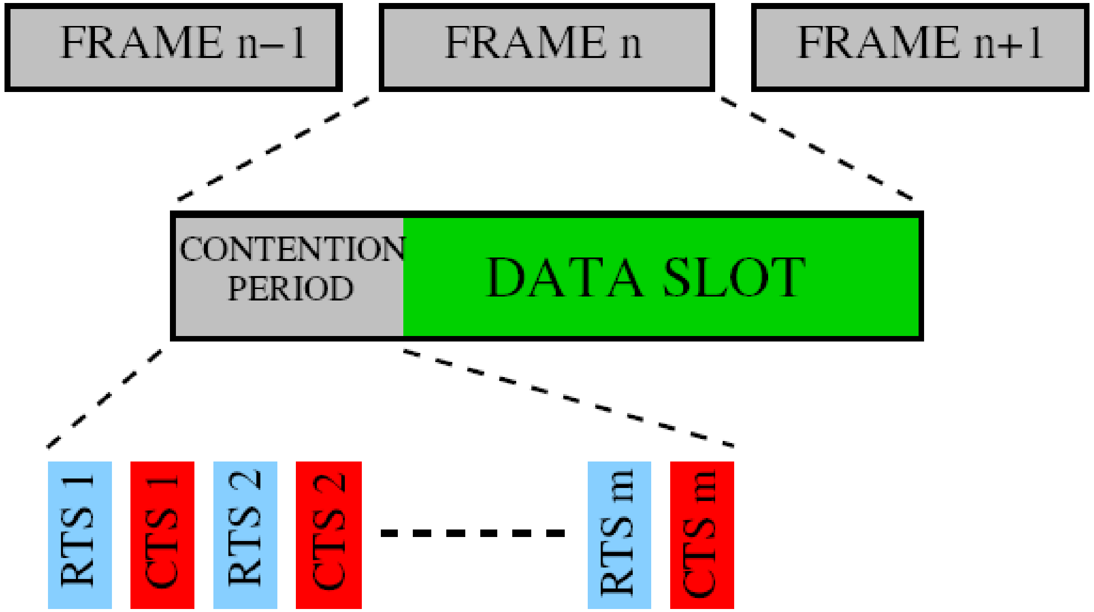
- Nodes that can communicate directly **in the absence of interference** are connected by a line in the figure.

An Improvement: Slotted Time (Tang '99, [13])





Even better: Multiple Minislot Pairs (Toumpis '03 [14])



- Many designs possible:
  - Progressive Backoff Algorithm.
  - Progressive Ramp Up Algorithm.

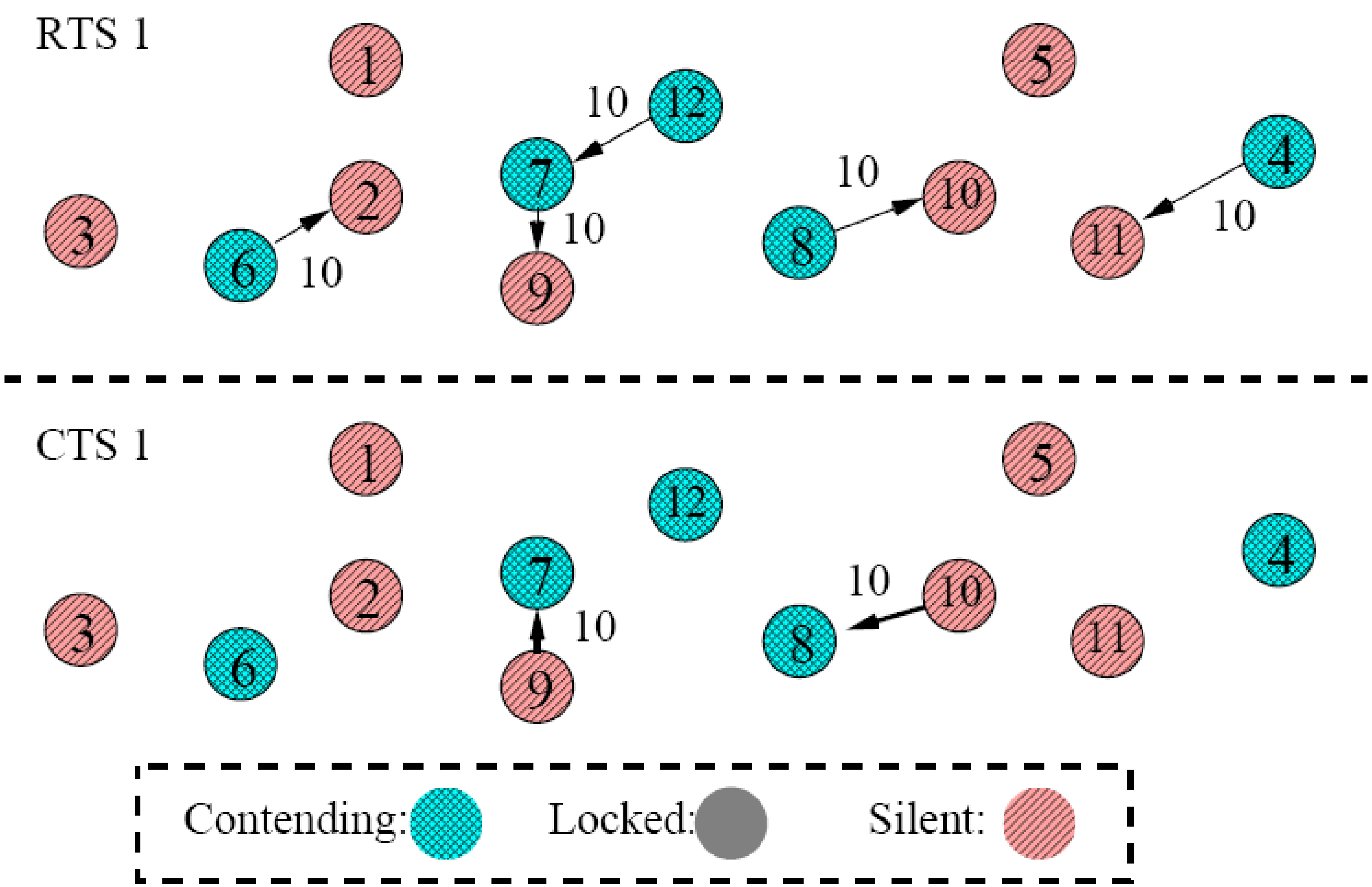
Progressive Backoff Algorithm: Overview

- Initially, all nodes with packets contend
- Nodes that are being unsuccessful:
  - Either backoff (so others will have a better chance)
  - Or remain in contention, but pick a new destination (if such exists)
- Nodes that succeed, use the rest of the slots for power control:
  - Energy is conserved
  - Interference is reduced for the rest

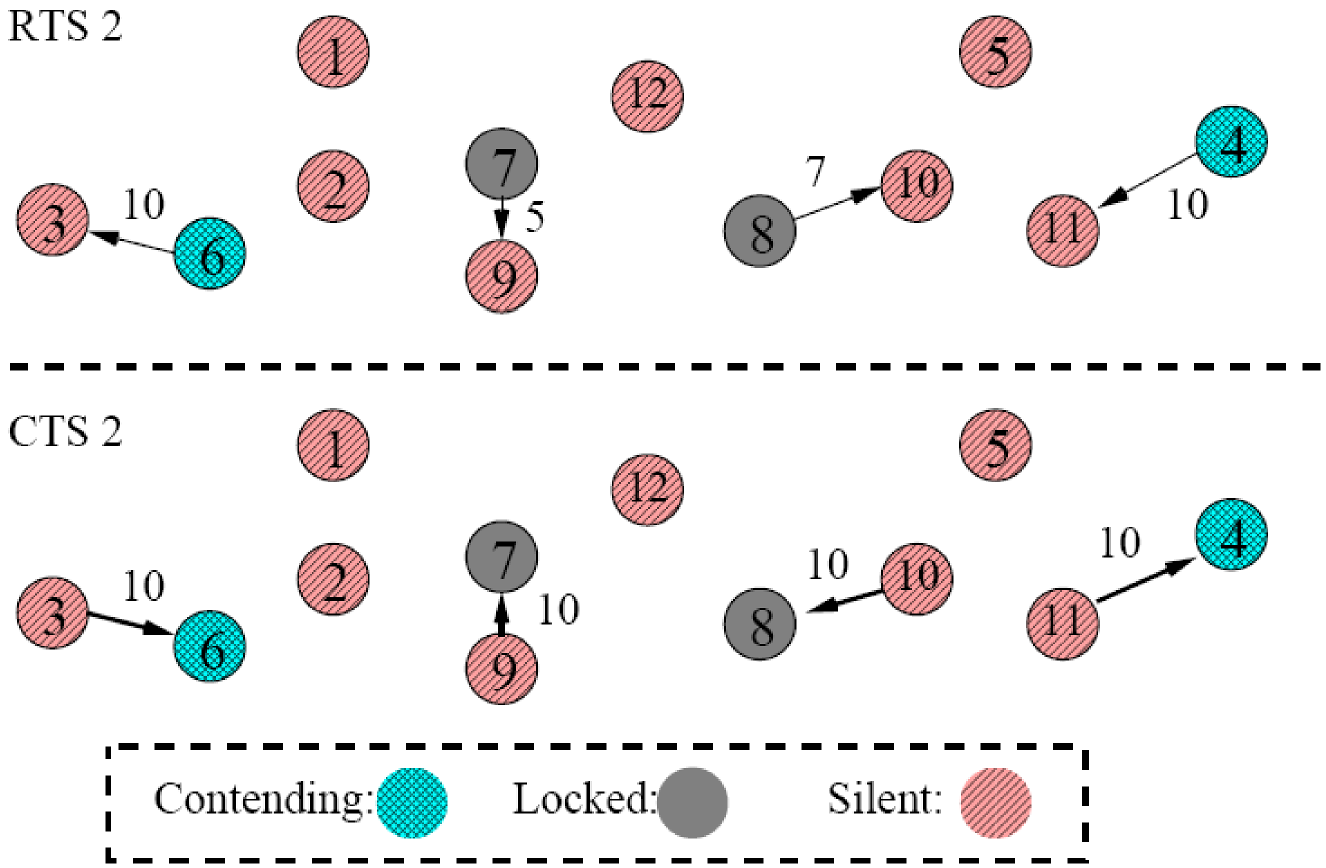
Progressive Backoff Algorithm: The Rules

- Nodes are divided in three groups: Contending, locked, silent.
- At the beginning of the first RTS minislot, nodes with packets form the contending group, the rest form the silent group.
- At the beginning of the i-th RTS minislot:
  - Silent nodes listen to the channel.
  - Contending nodes transmit to potential destination with maximum power.
  - Locked nodes transmit to destination (with power specified at previous slot).
- At the beginning of the i-th CTS minislot:
  - Contending and locked nodes remain silent.
  - Silent nodes that received an RTS packet from a contending node in the previous minislot transmit a CTS packet, specifying new power for the transmitter.
  - Silent nodes that received an RTS packet from a locked node transmit a CTS packet only if S/N was greater than $(1 + \Delta)\gamma_T$.
- At the end of the i-th CTS minislot:
  - Contending nodes that received a CTS become locked.
  - Contending nodes that did not receive a CTS:
    - With probability p remain contending, but select new destination.
    - With probability 1 – p become silent.

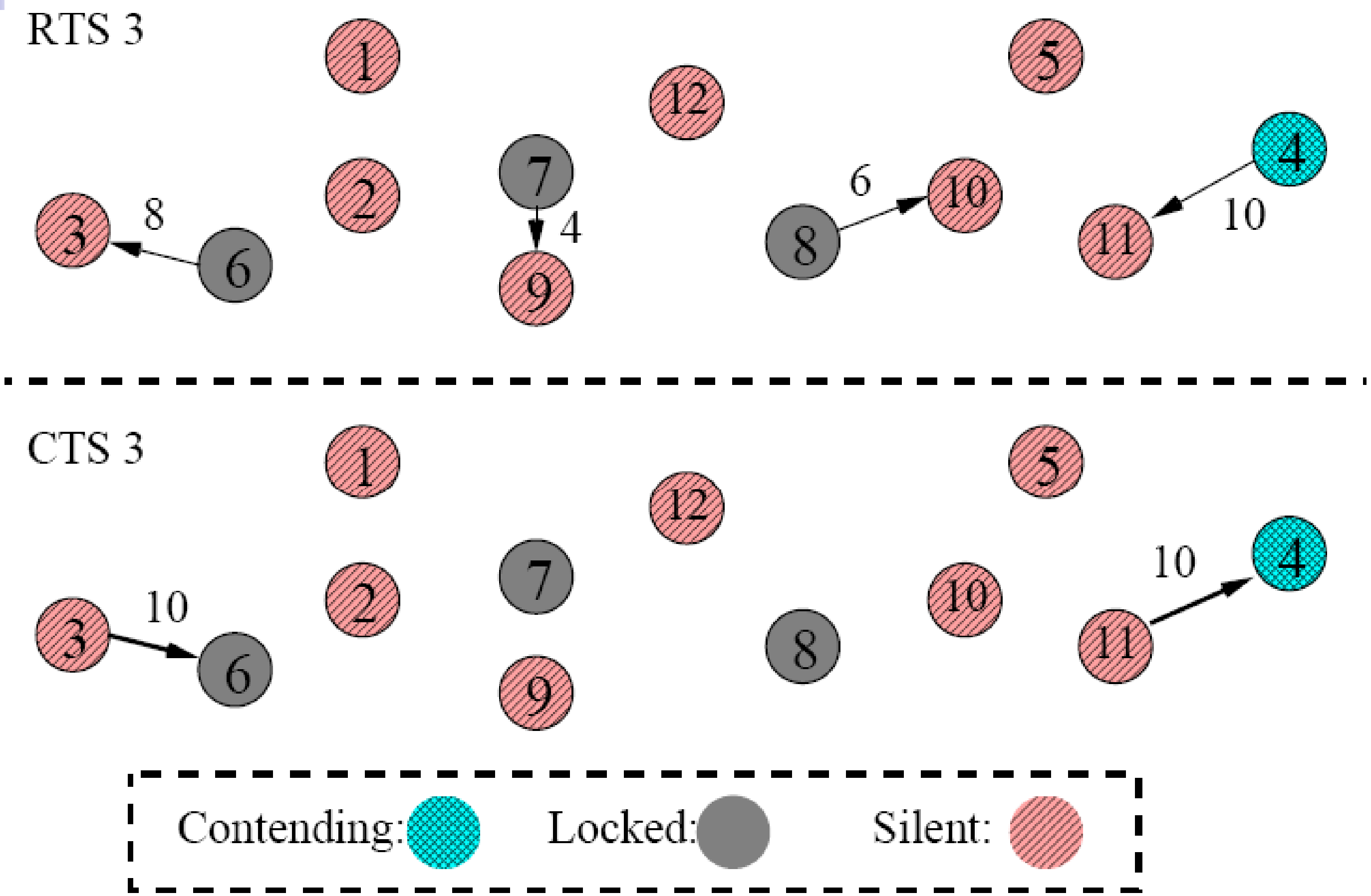
Operation of PBOA under RP-120 (RTS1-CTS1)



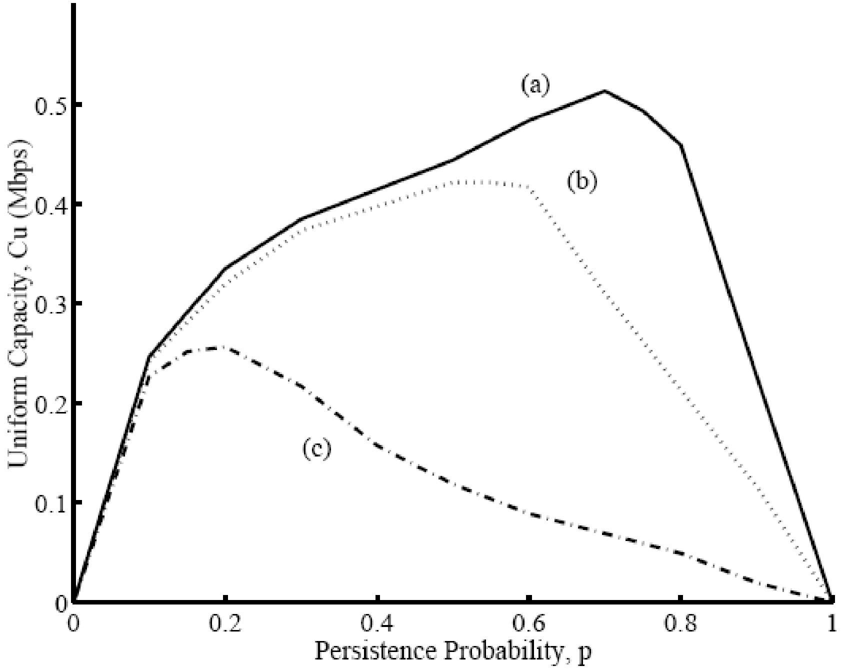
Operation of PBOA under RP-120 (RTS2-CTS2)



Operation of PBOA under RP-120 (RTS3-CTS3)



Parameter Selection: Throughput versus persistence probability p



(a) PBOA with 10 slots.
(b) PBOA with 5 slots.
(c) PBOA with 2 slots.

- With more slots, nodes should be more persistent.
- Intuition: Backingoff should be progressive over all slots.

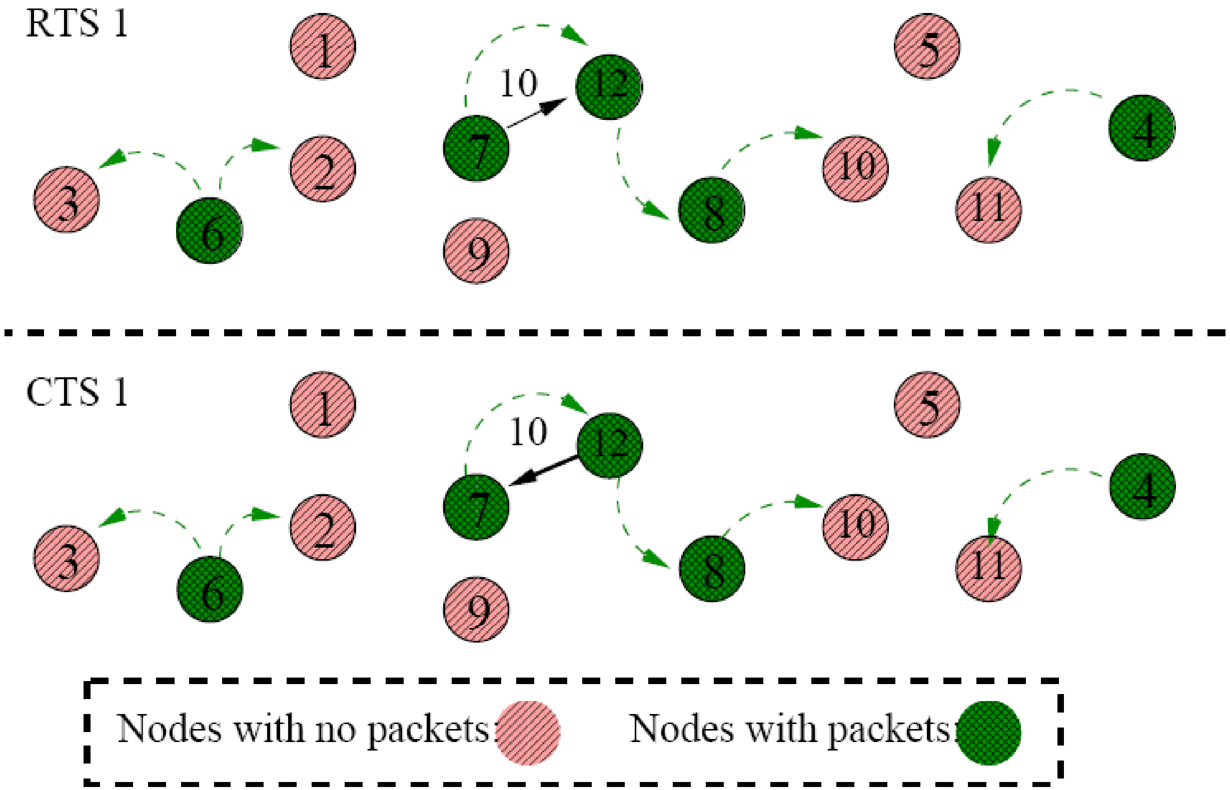
Progressive Ramp Up Algorithm: Overview

- PRUA works in the opposite way from PBOA.
- At the beginning of the contention period, nobody transmits.
- As the contention period progresses, every now and then a node will try to grab the channel.
- Successful nodes persist, unsuccessful ones may try again later.
- Nodes that do not transmit, monitor the channel to gain information about the competition and make educated decisions.
- Nodes pick destinations for which the conditions appear to be most favorable.
- A transmission schedule is slowly being built.

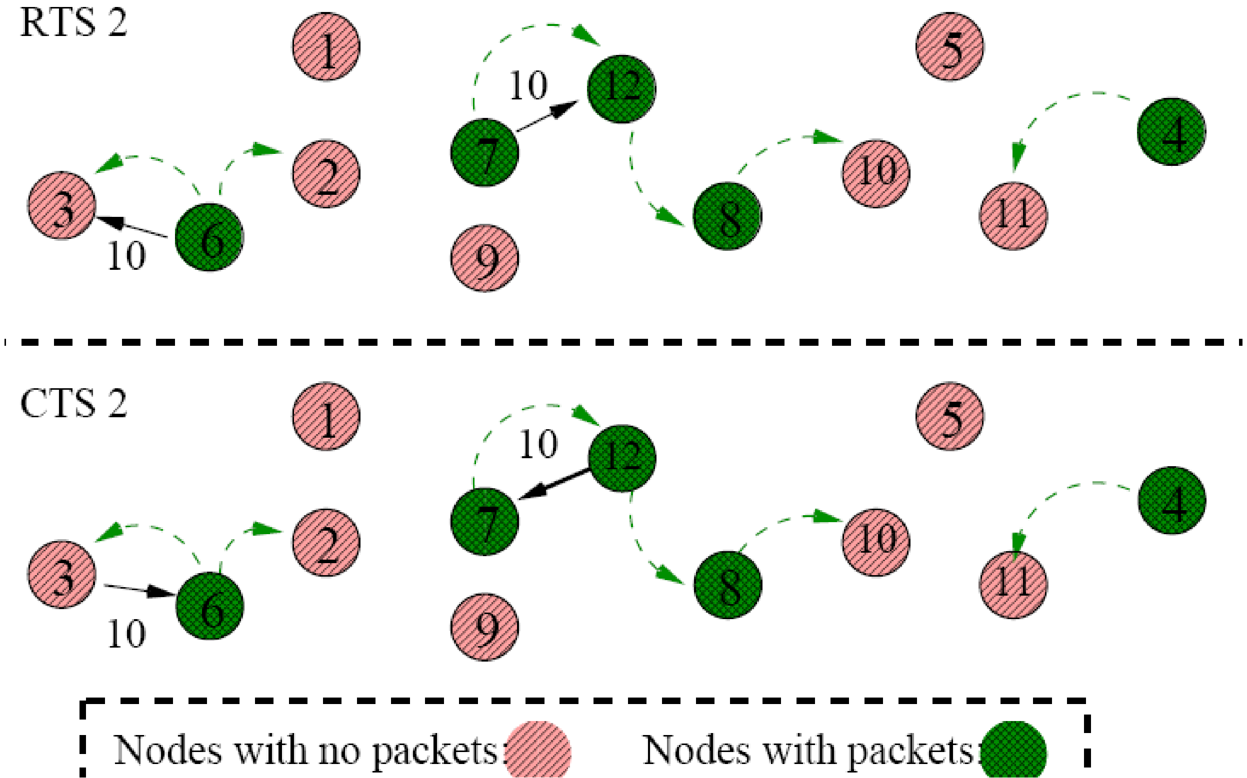
Progressive Ramp Up Algorithm: The Rules

- At the beginning of the i-th RTS minislot a node A will transmit an RTS packet:
  - If it transmitted an RTS in the previous RTS minislot and heard a CTS packet in reply.
  - Or all of the following conditions are satisfied:
    - *A* did not transmit a CTS packet in the previous minislot pair (i.e. is not awaiting a packet from another node)
    - The received power in the previous CTS minislot did not exceed a threshold P_T (otherwise it may interfere with other transmissions)
    - If *A* has not decoded an RTS in the previous RTS minislot, it must have a non-empty queue.
    - If *A* has correctly decoded an RTS packet in the previous RTS minislot from some node C, then node A will need to have a packet in the queue (otherwise it makes no sense to try to transmit), and in addition this packet must be intended for some node B, such that B is able to decode the packet from node A in the presence of interference from node C, and no other source of interference..
    - *A* must perform a biased coin toss, with probability p, and succeed.
- At the beginning of the i-th CTS minislot, whoever received an RTS packet addressed to him, replies with a CTS packet.
- At the beginning of the data slot, whoever received a CTS packet at the last CTS minislot transmits a data packet.

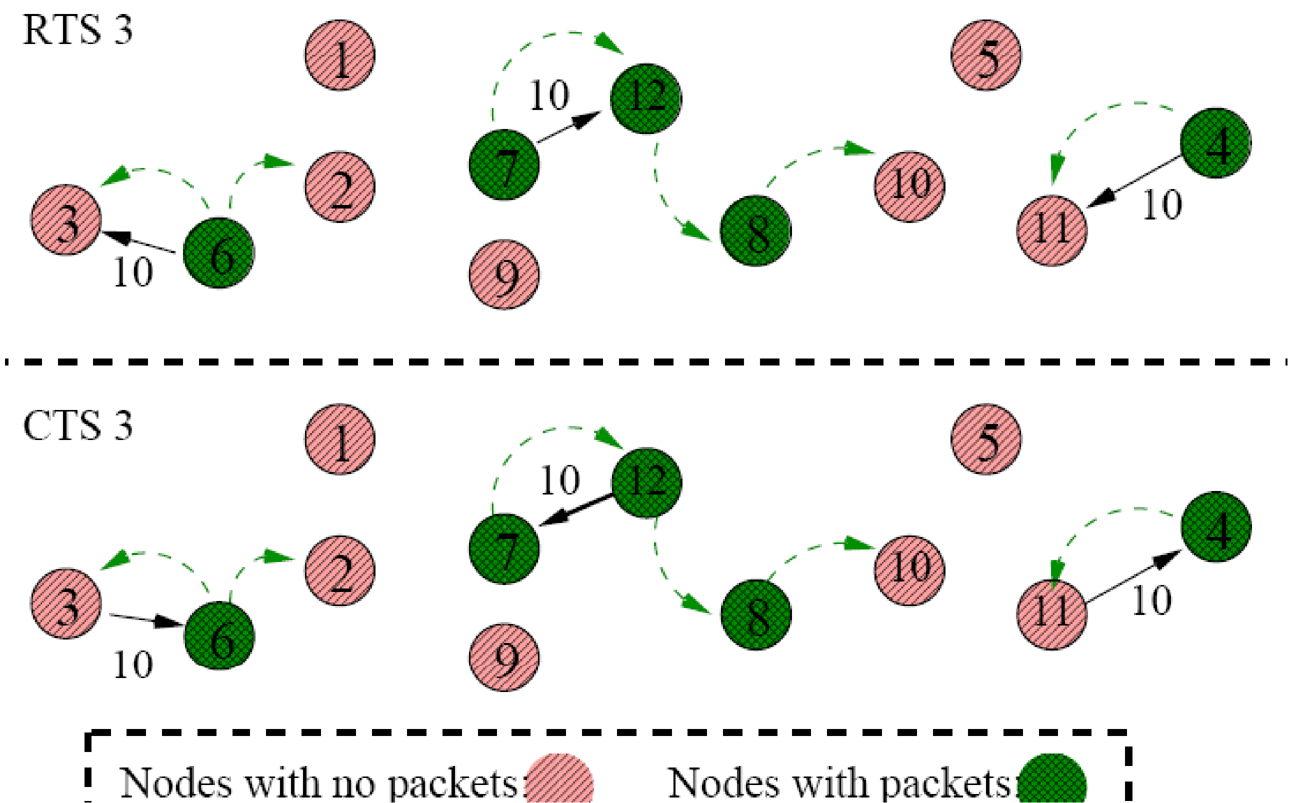
Operation of PRUA under RP-120 (RTS1-CTS1)



Operation of PRUA under RP-120 (RTS2-CTS2)



Operation of PRUA under RP-120 (RTS3-CTS3)



The Performance of PBOA, PRUA

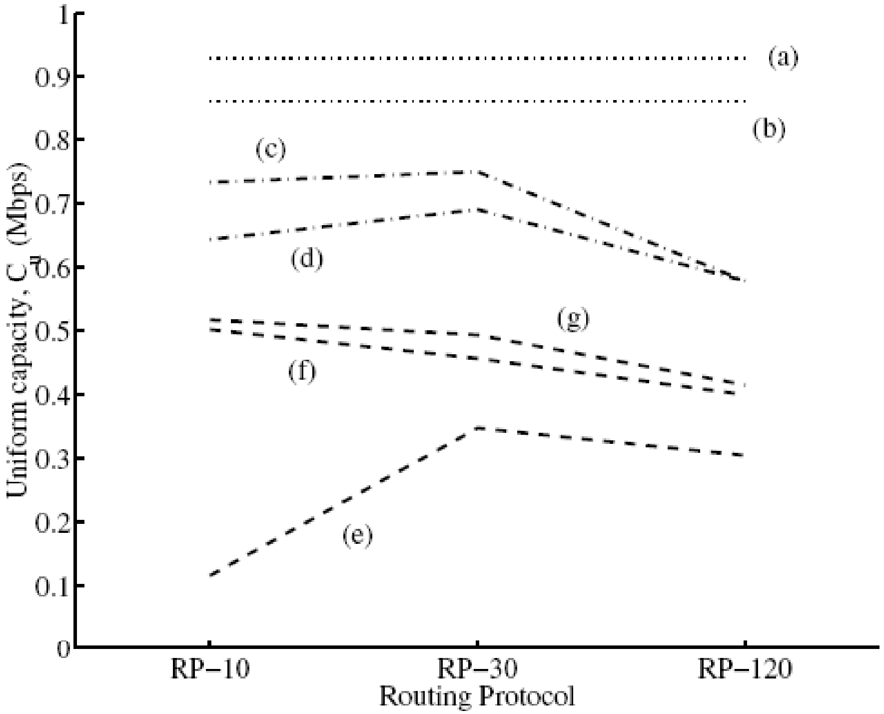
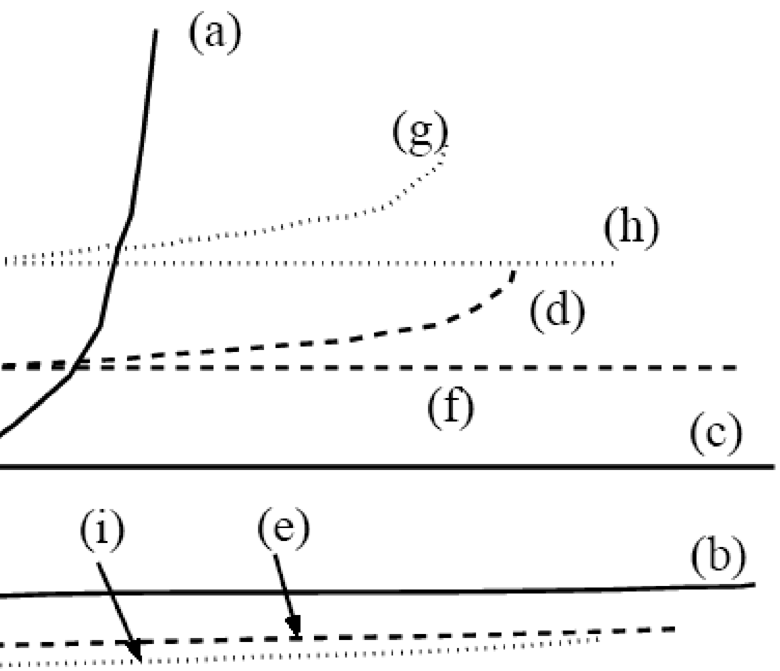


Fig. 3. Uniform capacities versus the routing protocol for the example net-

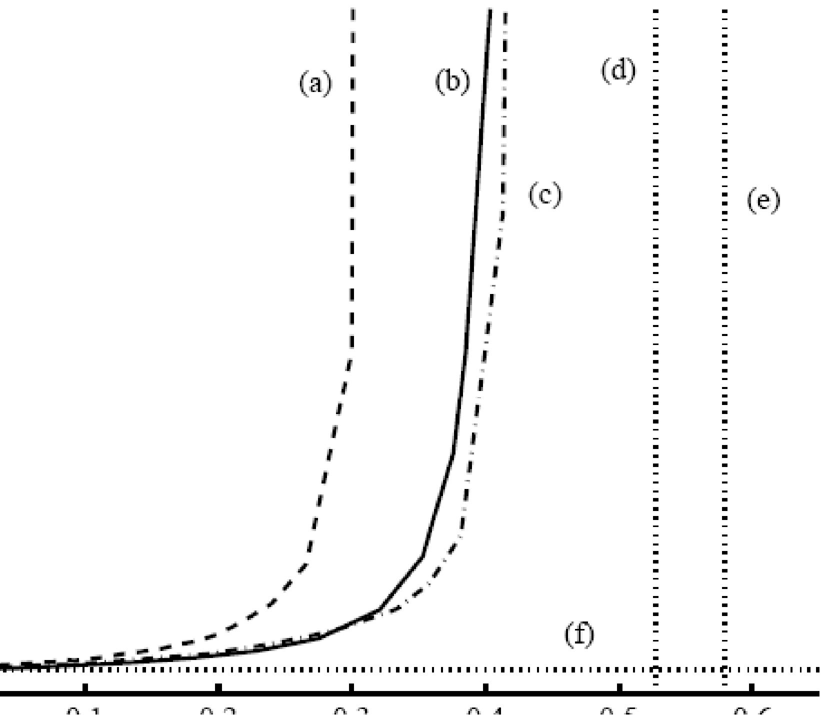
m=# of minislots
p= probability of transmission

Energy Efficient



(a) IEEE 802.11, RP-10.
(b) PBOA, RP-10.
(c) PRUA, RP-10.
(d) IEEE 802.11, RP-30.
(e) PBOA, RP-30.
(f) PRUA, RP-30.
(g) IEEE 802.11, RP-120.
(h) PBOA, RP-120.
(i) PRUA, RP-120.

Throughput-Delay Curves (with RP-120)



(a) IEEE 802.11.

(b) PBOA.

(c) PRUA.

(d) Uniform capacity, ON/OFF power control.

(e) Uniform capacity, Optimal power control.

(f) Bound on delay due to packetizing of data.

Discussion

- RUA learns from the surroundings and hence achieves gher throughput than PBOA
- 3OA uses power control → Energy efficient
- oth PRUA and PBOA achieve better throughput and delay erformance than CSMA/CA
- ו PRUA, nodes transmit at maximum power and ansmissions are always successful
  - Thus energy needed does not change with throughput
- outing protocols that use stronger links result in lower

Discussion..

PBOA/PRUA both need time synchronization across all users, where as CSMA does not

CSMA performs poorly when weak links are not discarded during route discovery

- On weak links, some of the nodes do not even receive the CTS messages correctly. This leads to increased collisions and performance penalty

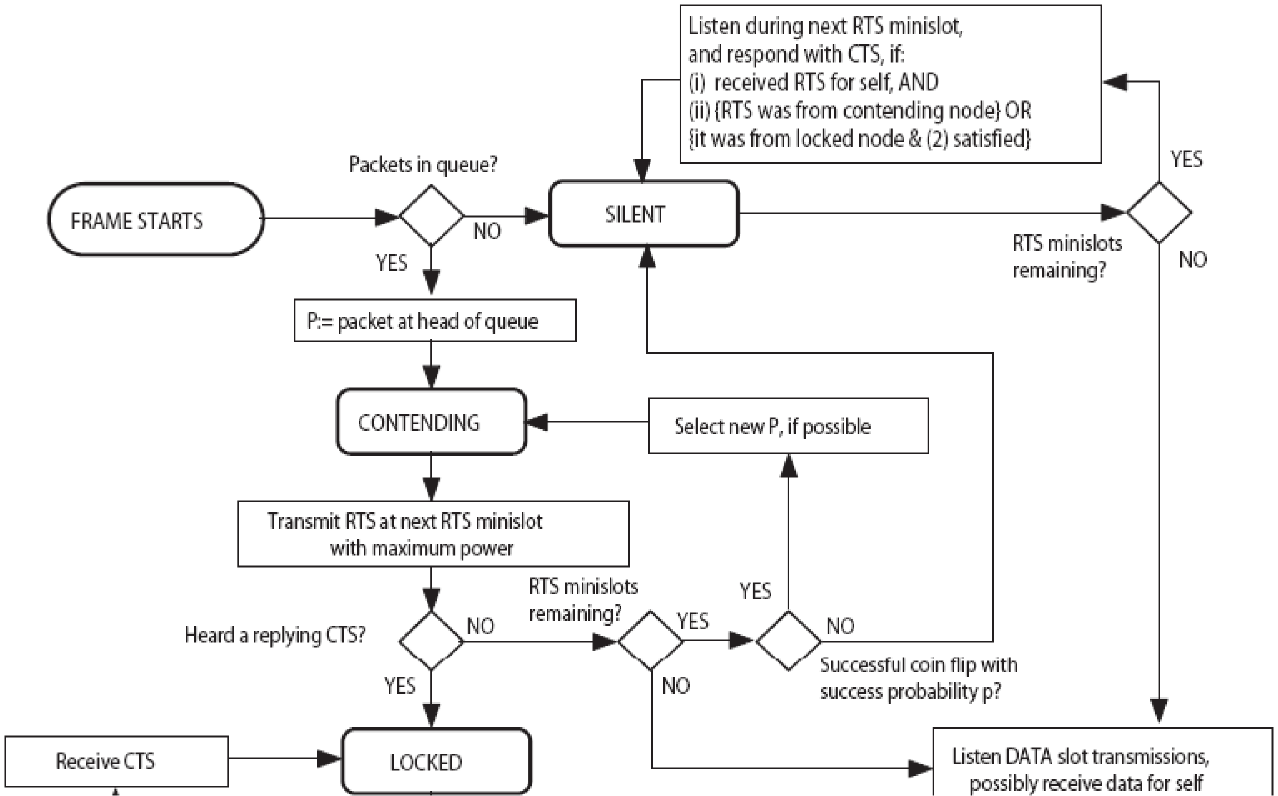
A large performance gap still exists between optimal and PBOA/PRUA methods

- Optimal schemes require co-ordination between nodes that are arbitrarily spaced apart
- Impossible to achieve such co-ordination using distributed protocols

References

ros Toumpis and Andrea J. Goldsmith, "NEW MEDIA ACCESS PROTOCOLS FOR WIRELESS AD HOC WORKS BASED ON CROSS-LAYER PRINCIPLES," IEEE TRANSACTIONS ON WIRELESS IMUNICATIONS, VOL. 5, NO. 8, AUGUST 2006

Flowchart of PBOA



Flowchart of PRUA