Random Access MAC for Efficient Broadcast Support in Ad Hoc Networks

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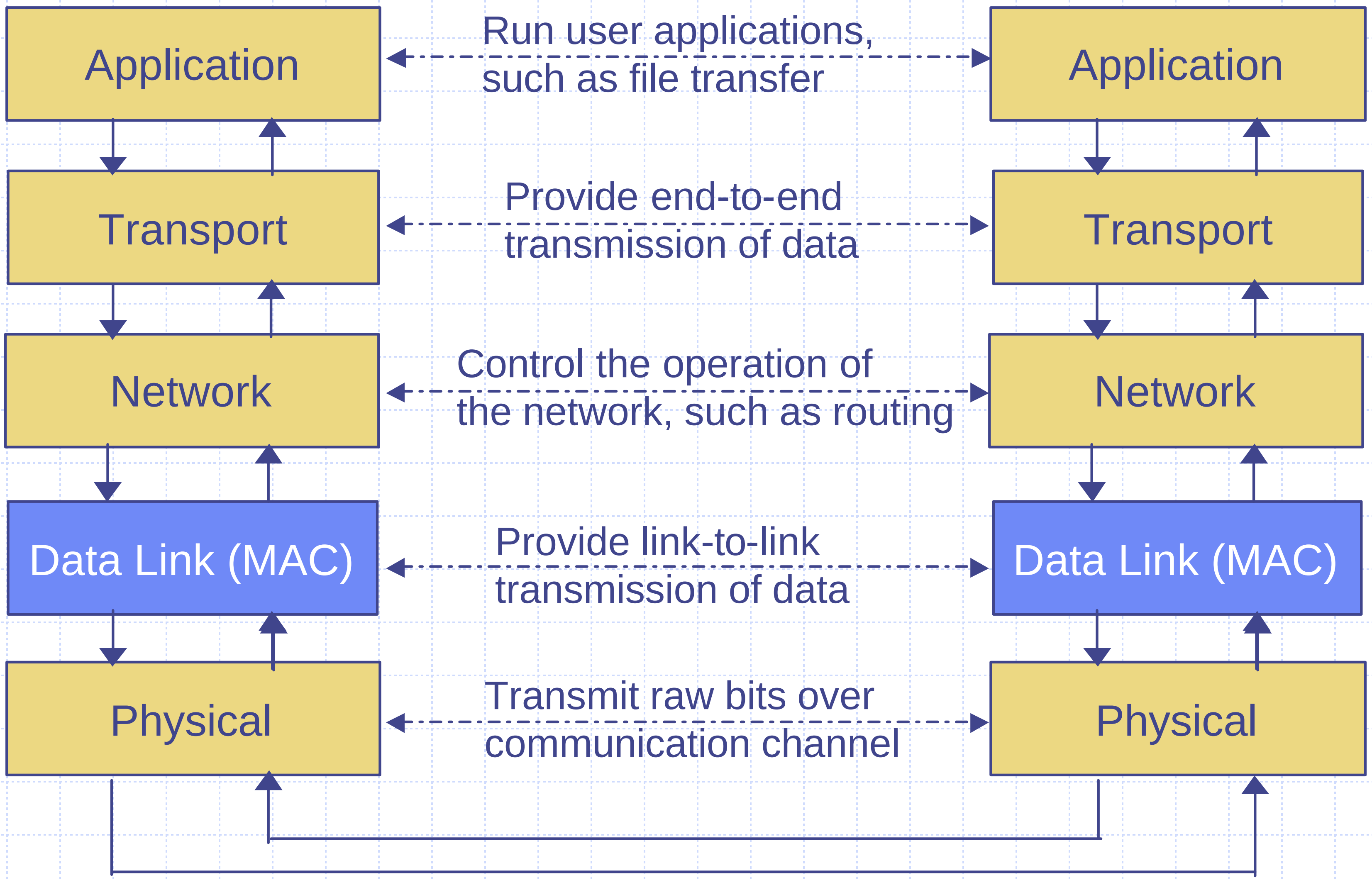
Overview

- Introduction to ad hoc networks
- Motivation
- Broadcast Support Medium Access (BSMA) protocol
- Simulation experiments
- Conclusion

The Ad Hoc Network Protocol Stack



The Medium Access Control (MAC) Layer in Ad Hoc Networks

- Schedules/coordinates nodes' access to the wireless channel
- Without channel access coordination, chaos would result from multiple nodes trying to access the shared channel at the same time
- Critical to the efficiency and performance of ad hoc networks

Motivation

- Ad hoc random access MAC protocols (eg 802.11) treat unicast and broadcast packets differently
  - Unicast packets are preceded by MAC layer control frames (eg, RTS, CTS)
  - Broadcast packets, on the other hand, are sent blindly without any control frames that can assure the availability of the destinations
  - Note: The procedure here outlined will work also for multicast (in a dense multicast tree/mesh it is preferable to use MAC broadcast rather than unicast)

Broadcast Support Multiple Access (BSMA) Protocol

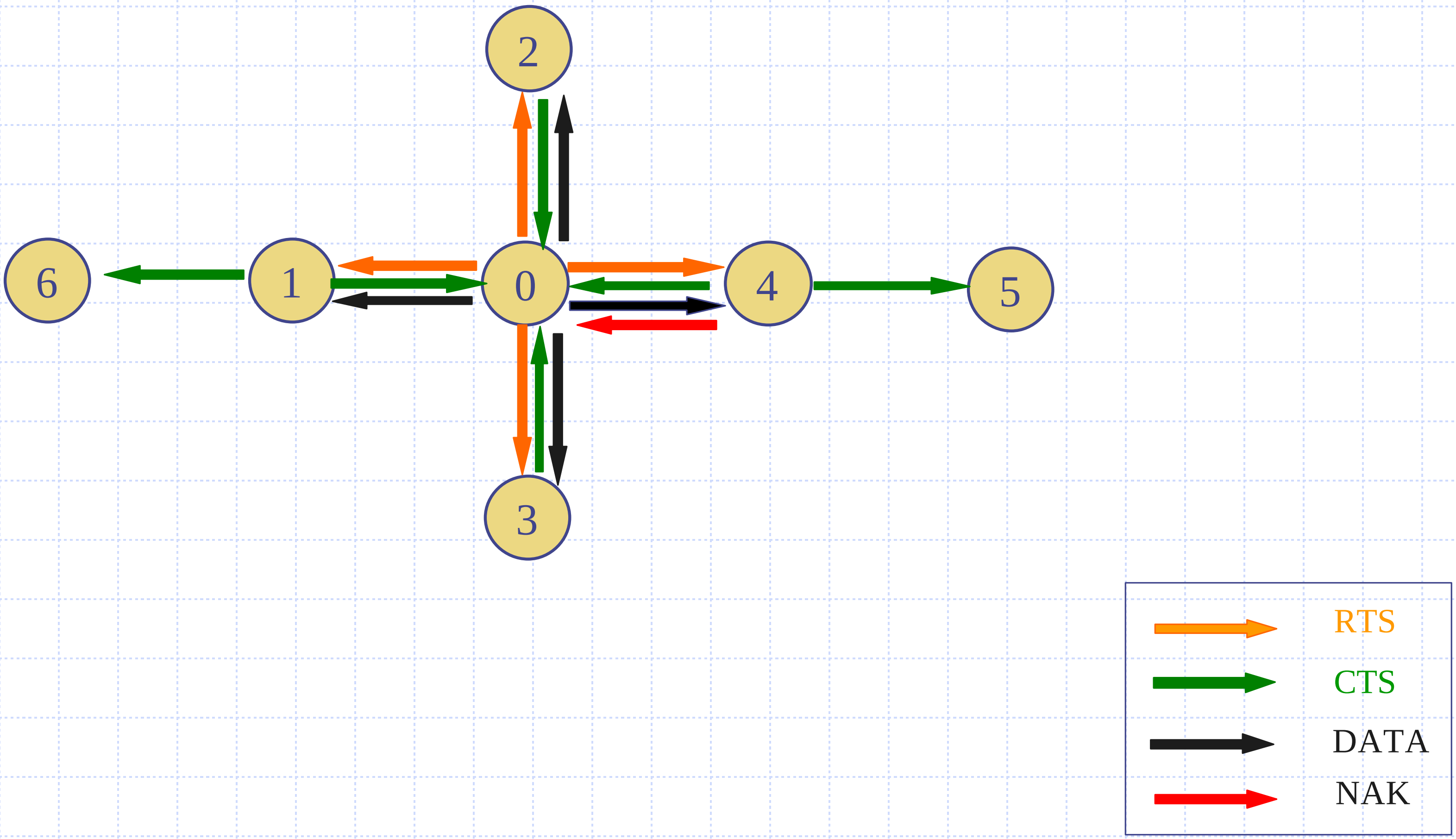
- Improves upon IEEE 802.11's broadcast feature
- Utilizes RTS/CTS control frames and negative acknowledgements (NAKs)
- Assumes radio has DS (direct sequence) capture ability

Broadcast Support Multiple Access (BSMA) Protocol (cont'd)

Steps:

1. Step 1: Collision avoidance phase
2. Source sends RTS to all neighbors and sets timer to WAIT_FOR_CTS
3. Neighbors of source, upon receiving RTS, send CTS if not in YIELD state and set timer to WAIT_FOR_DATA
4. If source receives CTS, send DATA and set timer to WAIT_FOR_NAK. Else, if no CTS and WAIT_FOR_CTS timer expires, back off and go to step 1. Nodes that are not involved in the broadcast exchange, upon receiving CTS, set their state to YIELD and set their timer long enough to allow for the broadcast exchange to complete
5. Neighbors send NAK if WAIT_FOR_DATA timer expires and DATA has not been received
6. If source receives NAK before WAIT_FOR_NAK timer expires, back off and go to step 1. Else, if no NAK and WAIT_FOR_NAK timer expires, the broadcast is complete. Go to step 1 and get ready to transmit new DATA

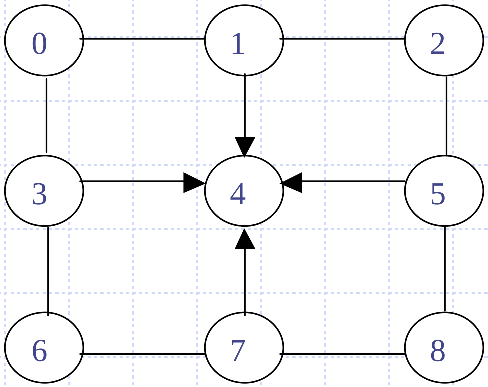
Broadcast Support Multiple Access (BSMA) Protocol Example

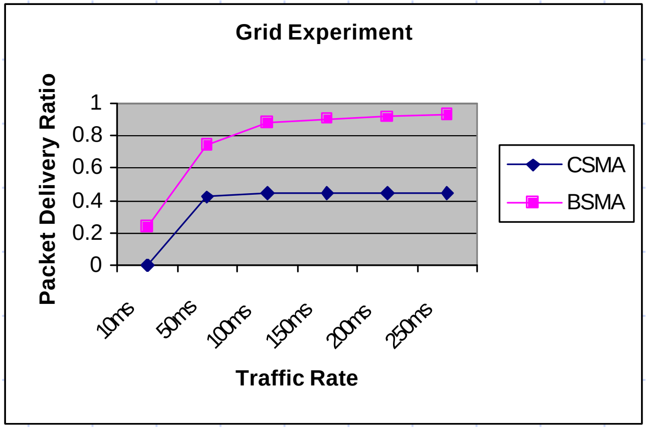


Simulation Configurations

- GloMoSim simulator (Parsec based library)
- Application: CBR traffic
- Transport: UDP (no congestion/rate control)
- Routing: On-Demand Multicast Routing Protocol (ODMRP)
  - Mesh topology
  - Forwarding group concept
  - On-demand approach
  - Soft state
- MAC: BSMA and CSMA (802.11's broadcast approach)
- Radio: Capture (threshold based)
- Channel: 2Mbps, free space propagation model

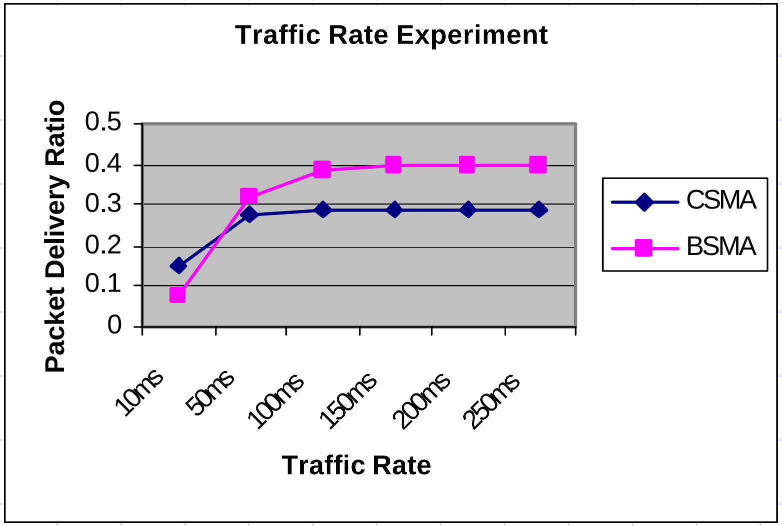
Grid Experiment





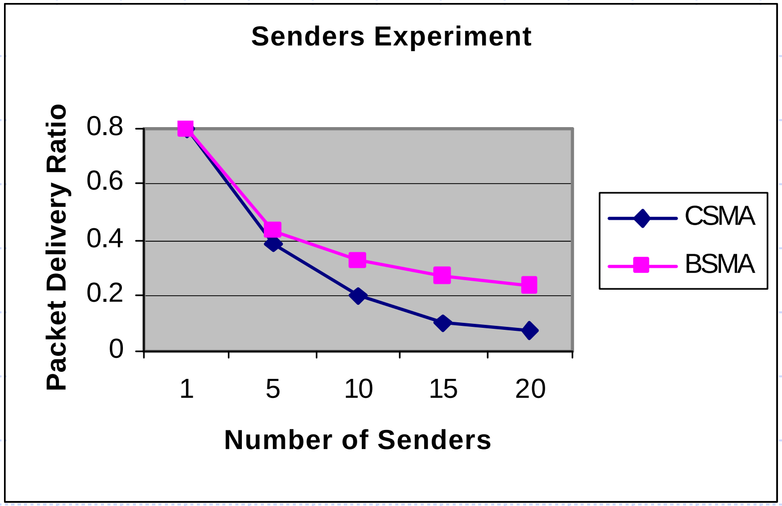
- Nodes 1, 3, 5 and 7 are transmitting data to node 4 at the same time
- Orchestrated to evaluate the performance of CSMA and BSMA in situations where hidden terminals exist (worst case situation)
- At high rates, CSMA collapses. BSMA still able to achieve 23%
- At lower traffic rates, the RTS/CTS/NAK mechanism of BSMA is given time to combat loss due to hidden terminals
  - 92% for BSMA while CSMA tops at 45%
  - Recovery is not possible in CSMA once a packet is dropped

Traffic Rate Experiment



- 20 nodes that are uniformly placed in a 1000m x 1000m area, each with a radio power range of 250m
- Five multicast senders and five multicast receivers
- BSMA shows 33% improvement over CSMA
- RTS/CTS/NAK mechanism acts as a rudimentary flow control scheme

Senders Experiment



- 25 nodes are randomly placed in a 1000m by 1000m area, each with a radio power range of 250m.
- Five multicast receivers and the number of multicast senders ranges from 1 to 20
- Inter departure time of packets is 200ms (5 packets per second)
- With a single sender, the packet delivery ratio is high for both protocols (80%)
- As number of senders increases, BSMA (20%) quadruples the packet delivery ratio of CSMA (5%)

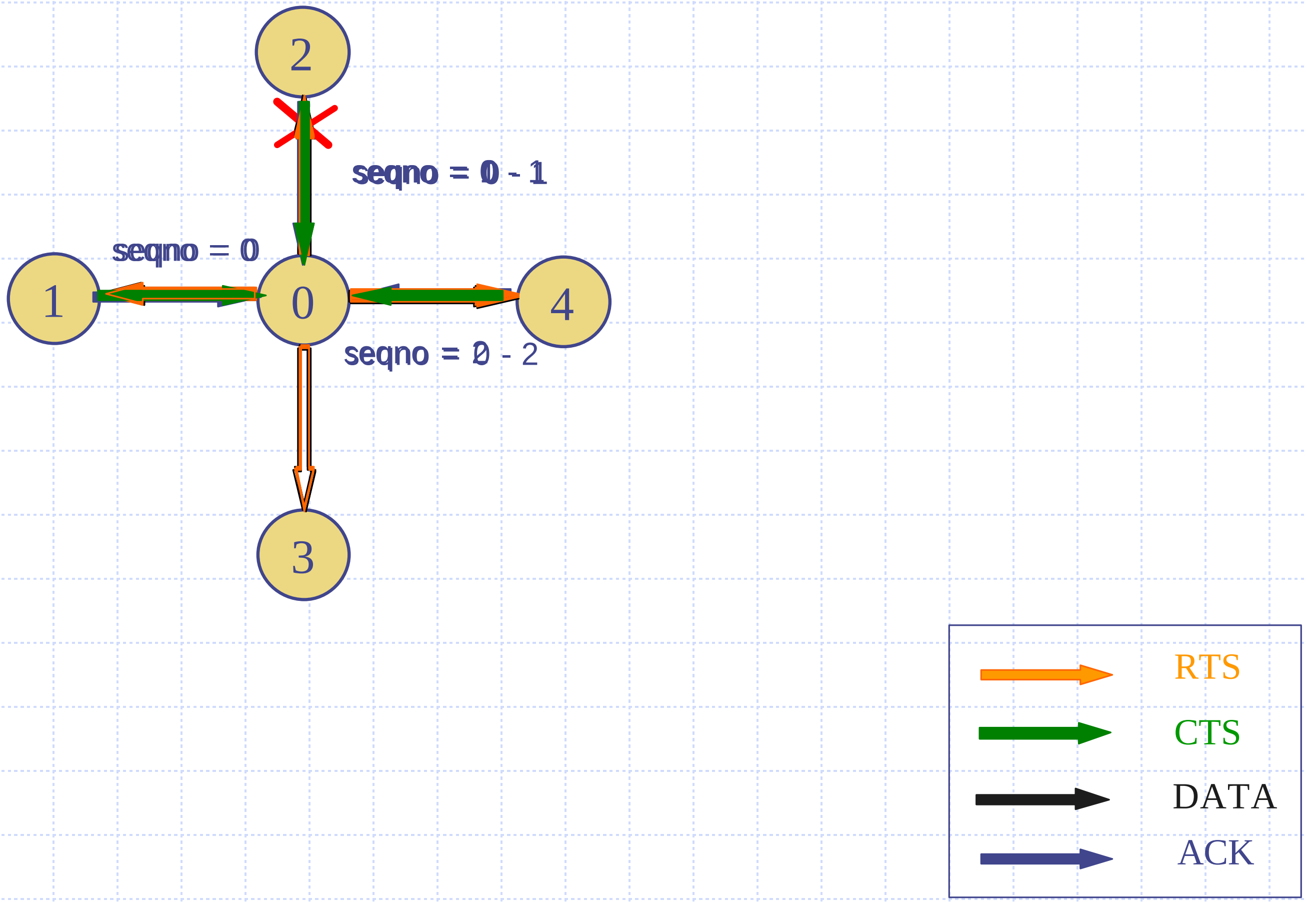
Broadcast Medium Window (BMW)

- Here is another scheme, Broadcast Medium Window (BMW) to provide robust (but not 100% reliable) MAC broadcasting

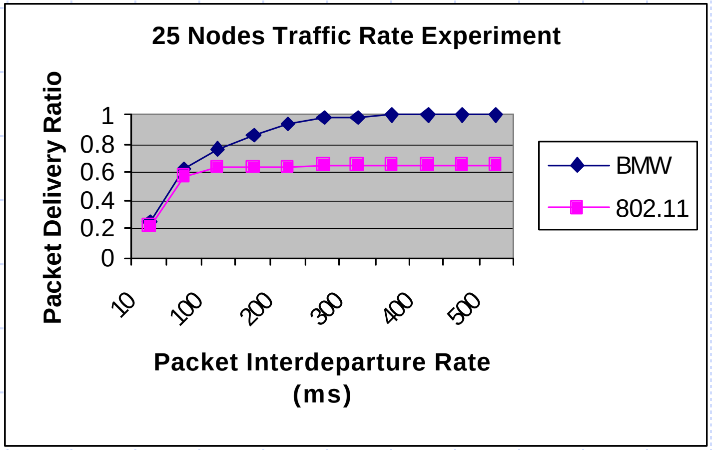
The Broadcast Medium Window

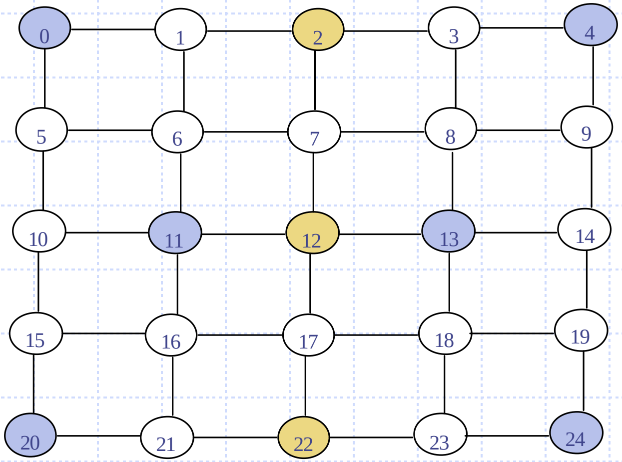
- Conventional window protocol (e.g., TCP) transmits packets in sequence to a single destination
- The “broadcast window” protocol transmits packets by increasing sequence numbers to ALL neighbors
- The window protocol “visits” each neighbor in Round Robin order to retransmit packets which the node missed in the broadcast transmission
- Note: we assume the node has a list with all its neighbors (this is a common assumption in MANETs)

Broadcast Medium Window (BMW) Protocol Example



Traffic Rate Experiment





- 25 nodes in grid topology, 3 sources and 6 members
- BMW outperforms 802.11
- Under high rate, BMW and 802.11 are comparable
  - BMW reverts to 802.11 unreliable broadcast

Conclusions

- Both BSMA and BMW performs well under low to medium transmission rate
- They do not guarantee the delivery of broadcast packets, but rather improve upon the delivery
- BMW easier to implement (can be implemented at the network level, above 802.11 unicast)
- To guarantee delivery one must enforce rate/congestion control