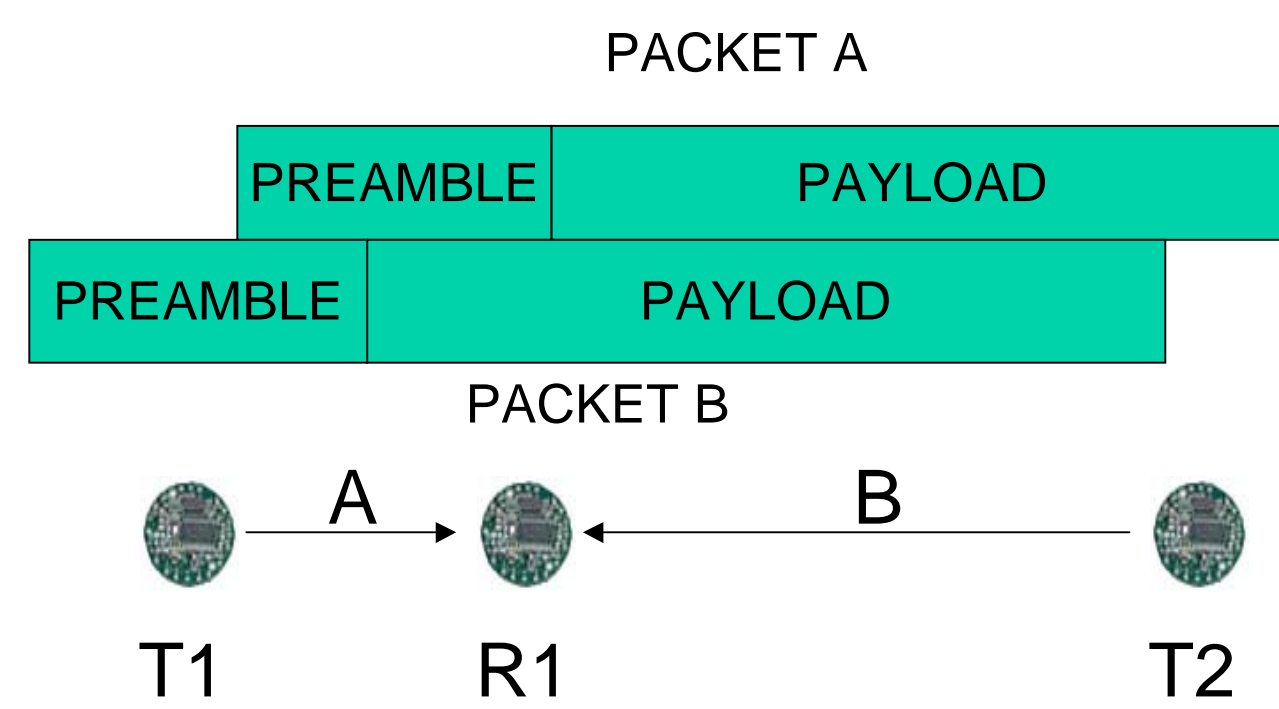
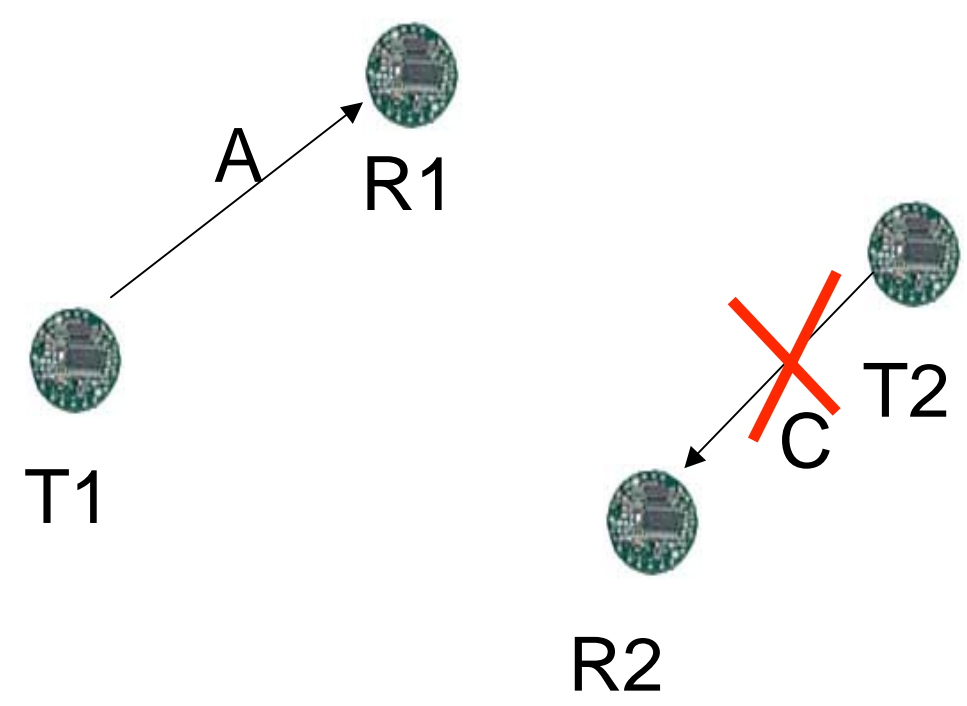


Motivation



- CSMA is the predominant sensor networks link level protocol
- CSMA sacrifices spatial reuse for less collision
- CSMA still has the hidden-terminal problem
- RTS/CTS reduces hidden-terminal (for unicast only) but incur overhead

- Most radios (including FSK radios used on motes) are able to recover the stronger packet (called Capture effect)
- Minor MAC modification allow us to recover node ID of both stronger and weaker transmitters
- Capture effect can aid us in designing better link layer protocols
- Have different benefit and tradeoffs under broadcast vs unicast

CAPTURE SENSING SIMULTANEOUS ACCESS

UNDER BROADCAST:

- Fast sequential flooding
- Safe concurrent transmissions
- Massive spatial reuse
- Optimization in the network layer

UNDER UNICAST:

- Spatial reuse
- Reduce hidden-terminal
- More precise backoff than CSMA
- Pipelining

TRADEOFFS BETWEEN:

- Spatial reuse
- Complexity
- Hidden-terminal
- Memory requirement
- Link vs Transport Layer

Related Work

- Exploiting the Capture Effect for Collision Detection and Recovery [Whitehouse, et al.]
 - A study of the Capture effect in simple 3 node scenarios
 - Shown that the capture effect is significant and can be fairly easily used
- Experimental Analysis of Concurrent Packet Transmissions in Low-Power Wireless Networks [Son, et al.]
 - A systematic study of the capture effect in terms of SINR, and also multiple interferences
 - Shown that RSSI correlates to packet reception ratio if $RSSI < -55dBm$
 - Shown that additivity of interference does not hold ($JRIS(m) \neq JRIS(e)$)
 - JRIS(m) follows the single strongest interferer if number of interferers not large; JRIS(m) approaches JRIS(e) as # of interferers becomes large**
 - THIS MEANS THAT MY SIMULATIONS IS LESS ACCURATE WHEN NEIGHBORHOOD BECOMES LARGE**

Simulation Setup and Assumptions

Assumptions:

- Symmetric radio links
- Unit disk model
- Capture works (but not always true as stated above)
- Gaussian backoff time
- Motes placement in network is uniform random
- Carrier sensing is simulated by mote checking if any neighbor is in transmit mode
- Does NOT simulate all possible hidden-terminal scenarios, but treat CSMA and CSSA equally

Setup:

- Capture table building in unicast scenarios
- Conservative setup:
 - Refrain from sending if anybody is in data section
 - Only listen to NACK when I want to transmit (no time-stamping)

Conclusions / Future Work

- Capture effect can be exploited to improve spatial reuse in both broadcasts and unicasts
- Capture often involve tradeoffs between simultaneity, hidden-terminal, and cost (preamble length, memory, energy)
- Plan to implement in MICA2 (CC1000) and possibly Telos (CC2420)

Protocols

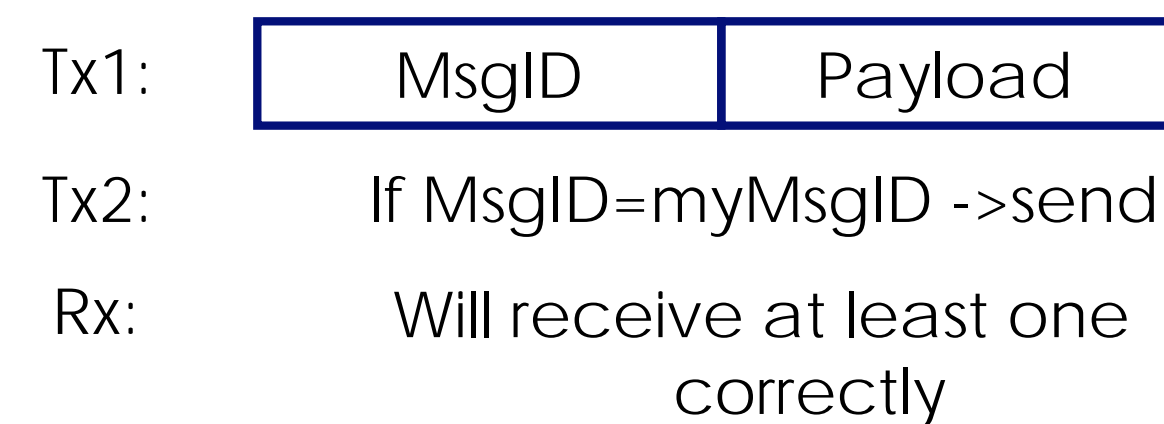
BROADCAST / FLOOD

Application

- Flooding / reprogramming / dissemination

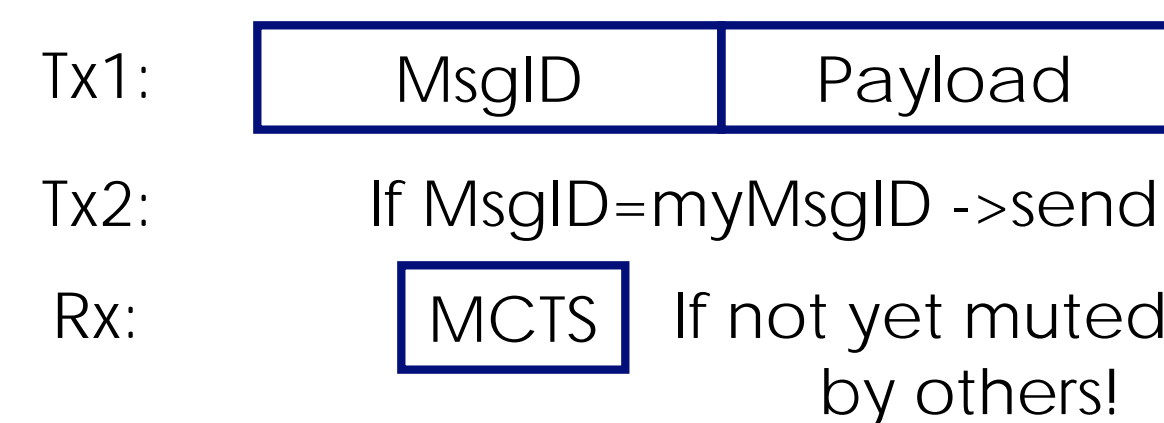
CSMA+MsgID (CSSA-B1)

- Fast sequential flooding
- Pipelining



MsgID+MCTS*(+TTS*)(+ACK) (CSSA-B2)

- CSSA-B1 +
- Reduce hidden-terminal



*MCTS: Message-Clear-to-Send

Receiver acks transmitter's message signature to avoid hidden-terminal from another transmitter

Nodes records all MCTS with expiration

MCTS is **MESSAGE-BASED ACKING**

*NCTS: Not-Clear-to-Send

Before TTS expires, receiver checks its Capture Table and NACKs nodes who are stronger than original transmitter

NCTS is **ID-BASED NACKING** and requires knowledge of the Capture Table

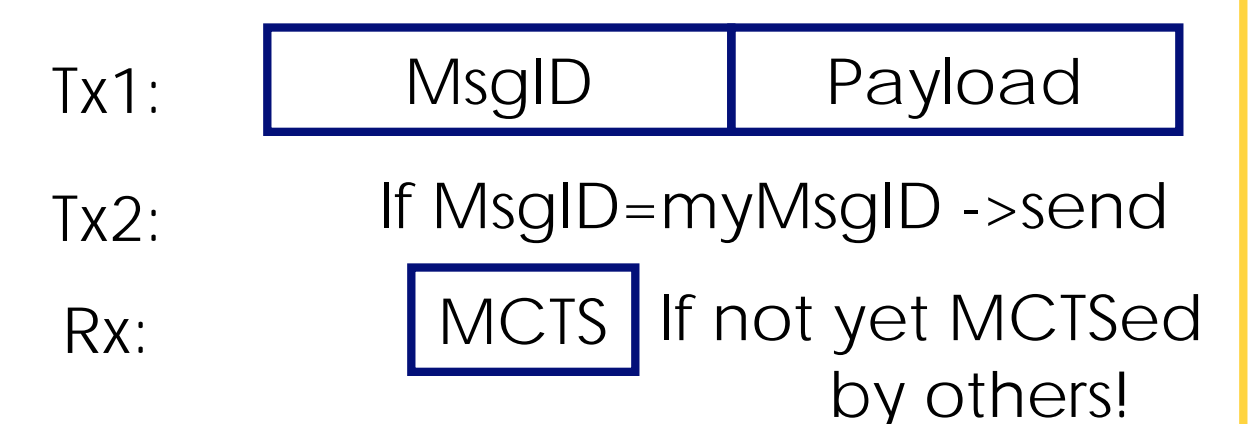
UNICAST

Application

- MintRoute / STRAW / Trickle / Drip&Drain / etc

MsgID+MCTS*(+TTS*)(+ACK) (CSSA-U1)

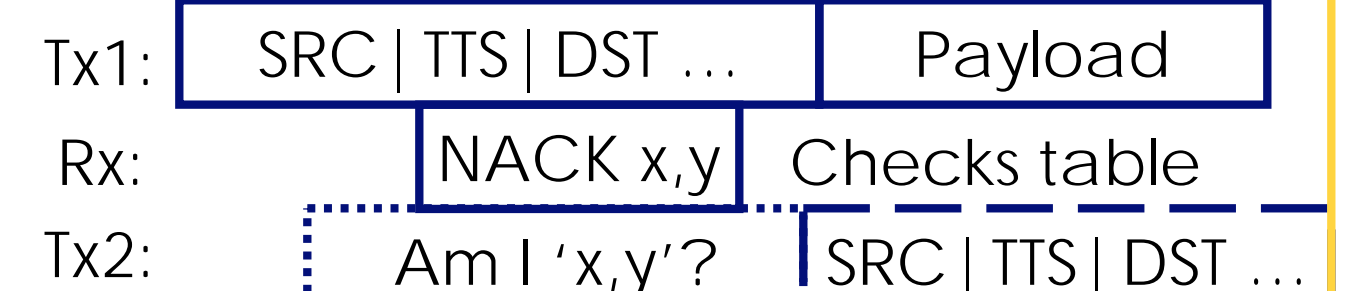
- CSSA-B2 for unicast
- Reduce hidden-terminal



2-lvl table+TTS+NCTS (CSSA-U2)

- Spatial reuse
- Reduce hidden-terminal
- Require setup phase for table construction

SETUP PHASE: For every node, 2 of its neighbors chirp at around same time, record winner and losers in a table. Repeat for all pairs of neighbors. This is the Capture Table

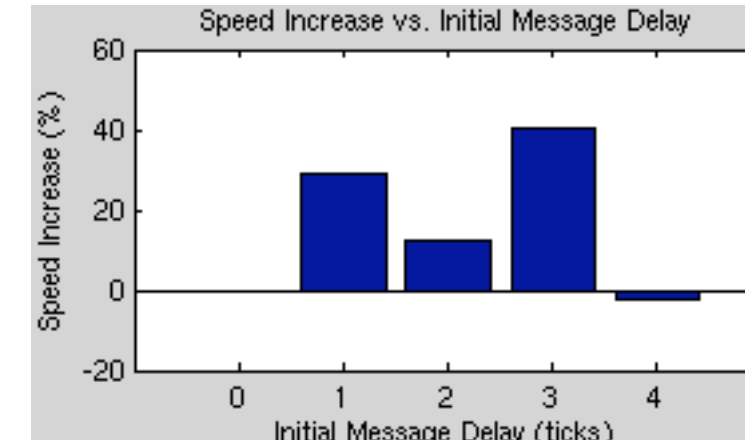
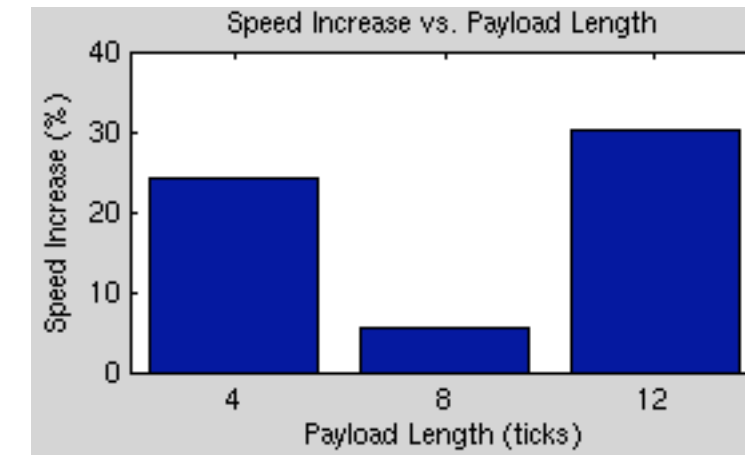
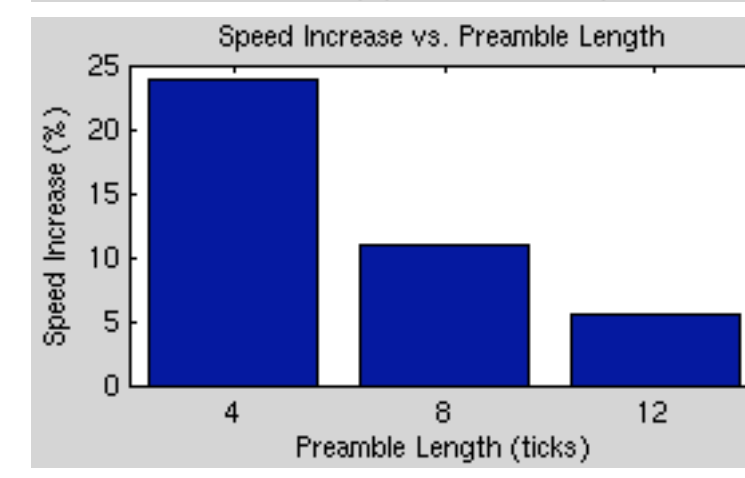
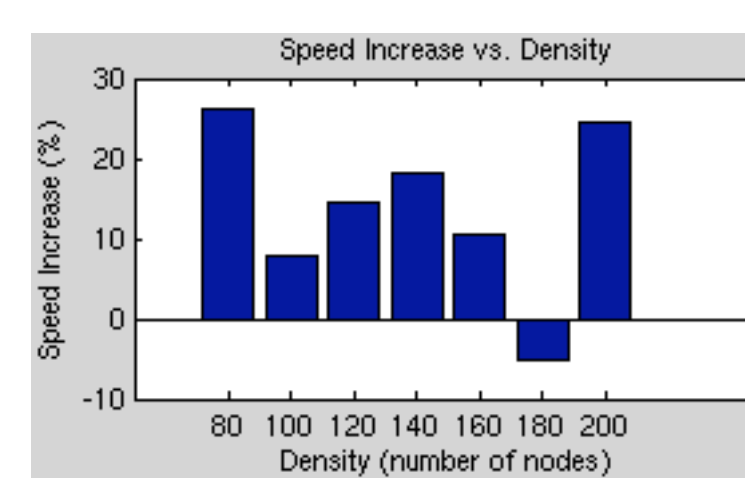


*TTS: Time-to-Send

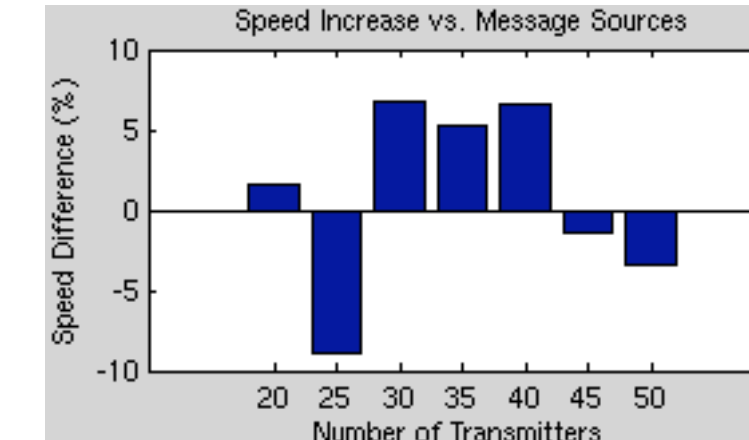
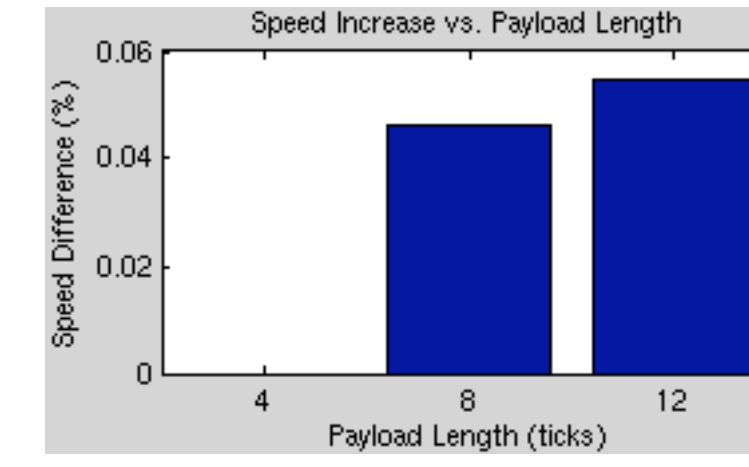
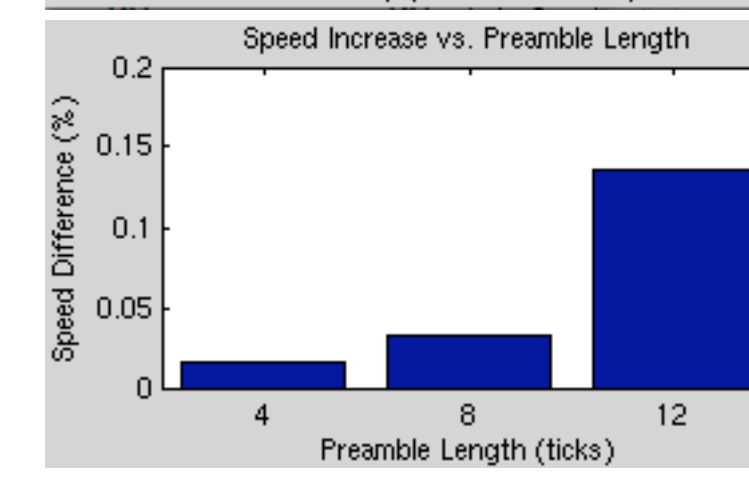
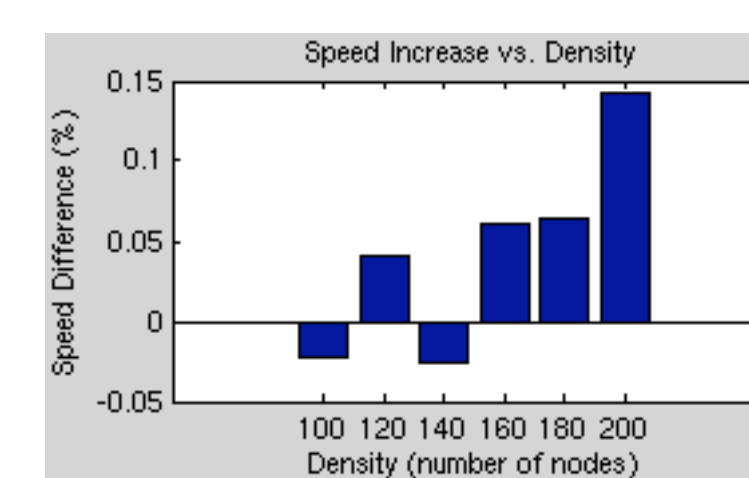
Transmitter encodes a countdown timer (TTS) in preamble as a window of time for other transmitters to receive NACK

Simulation

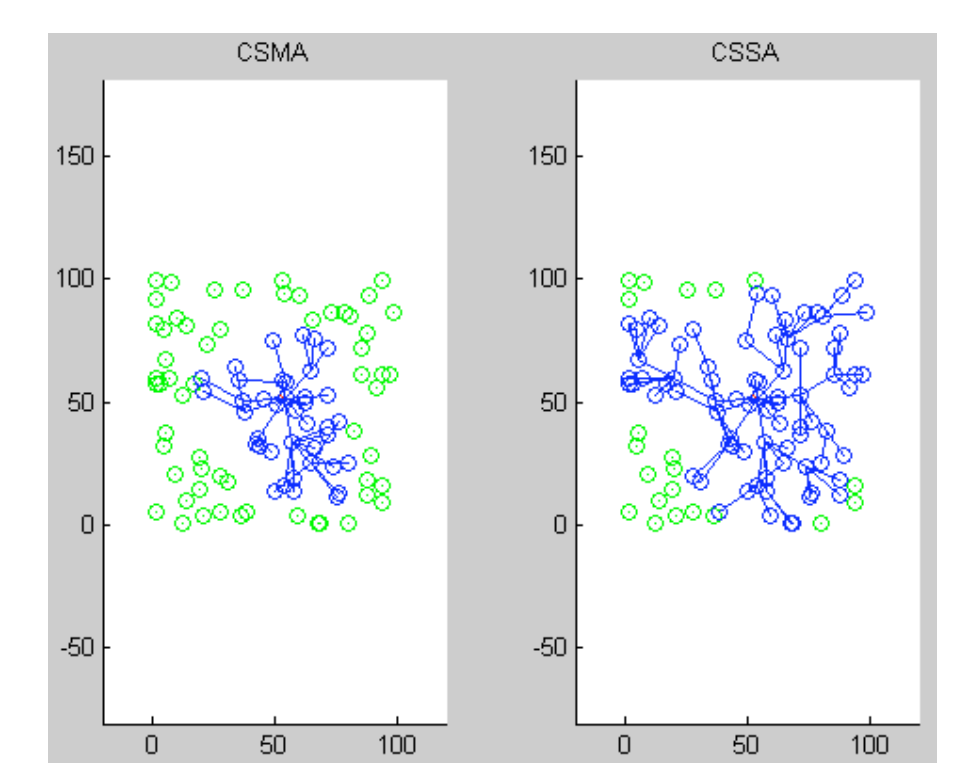
Multi-hop Flooding using CSSA-B1



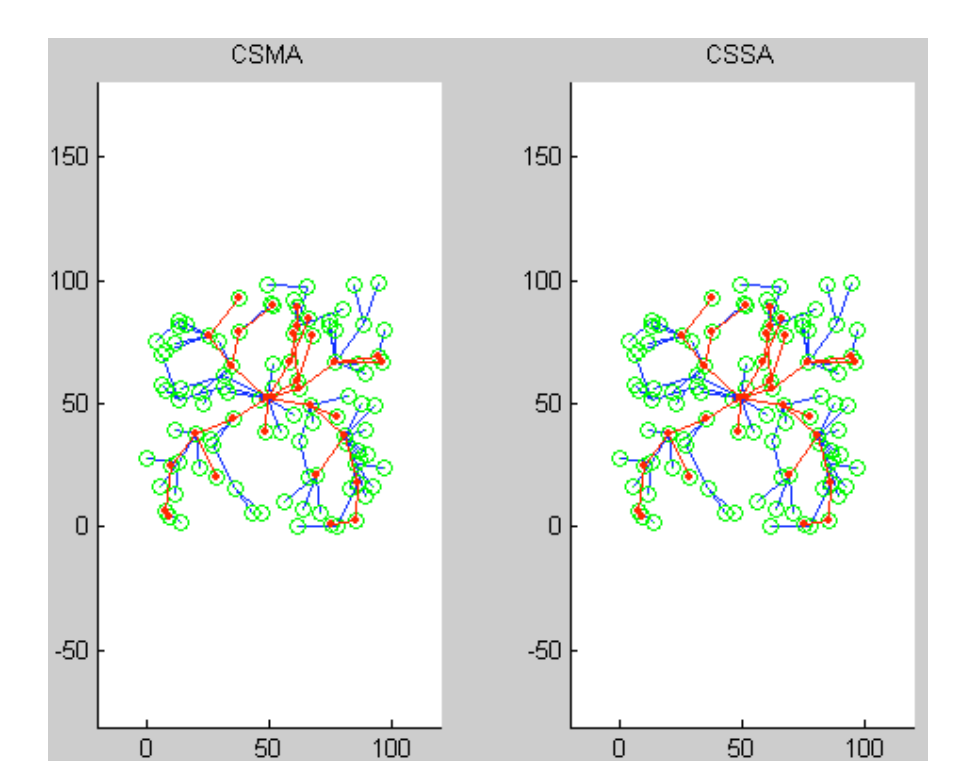
Multiple Unicasts using CSSA-U2



Multi-hop Flooding using CSSA-B1



Multiple Unicasts using CSSA-U2



Thanks

Kamin Whitehouse, Prabal Dutta, Dima Ryazanov, David Culler