RI-MAC: A Receiver-Initiated Asynchronous Duty Cycle MAC Protocol for Dynamic Traffic Loads in Wireless Sensor Networks

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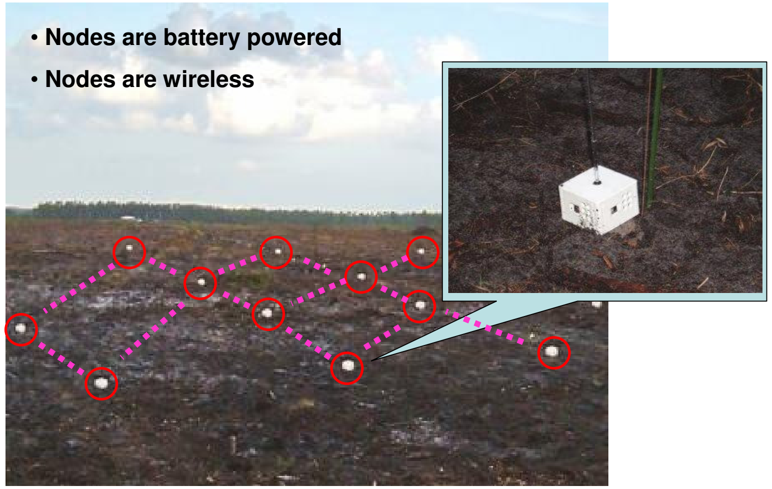
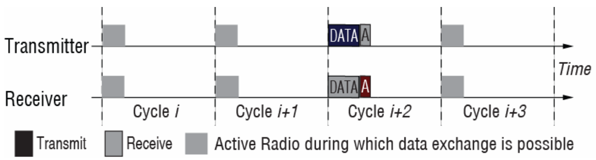
SenSys 2008

Multihop Wireless Sensor Networks

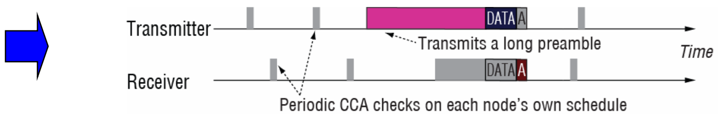


Duty Cycle MAC Protocols

- Synchronous protocols (e.g., S-MAC, T-MAC, DW-MAC)



- Asynchronous protocols (e.g., B-MAC and X-MAC)

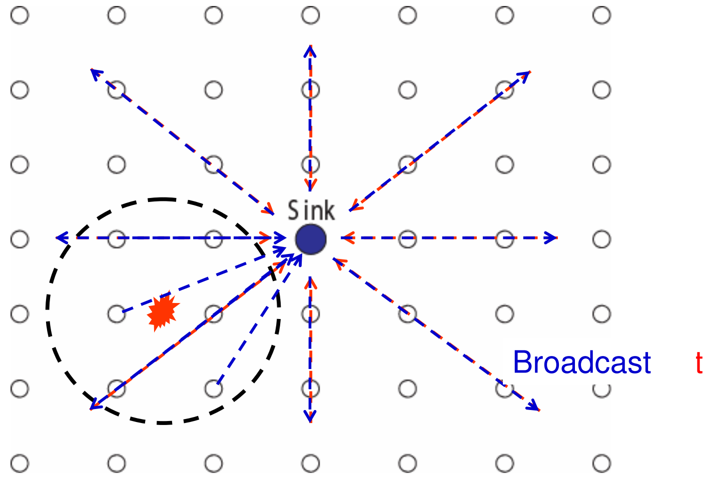


- Hybrid protocols (e.g., WiseMAC and SCP)

Objectives

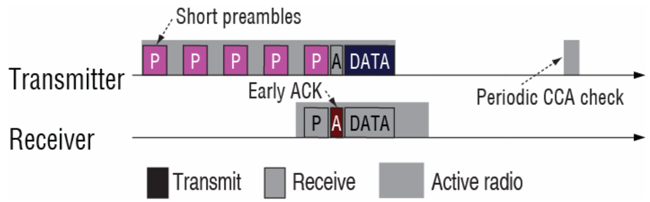
- Asynchronous duty cycle MAC protocol
- High power efficiency
- High packet delivery ratio
- Low packet delivery latency
- Efficient under a wide range of traffic patterns and loads

Dynamic Traffic in Wireless Sensor Networks

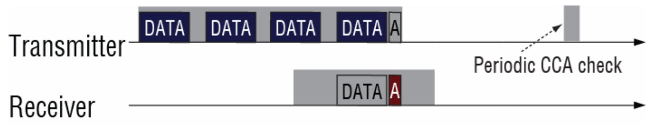


Related Work

- X-MAC, uses ***short preambles*** to find rendezvous time

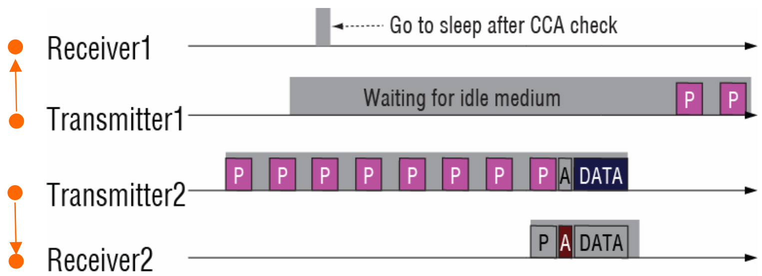


- X-MAC in TinyOS UPMA package (X-MAC-UPMA)



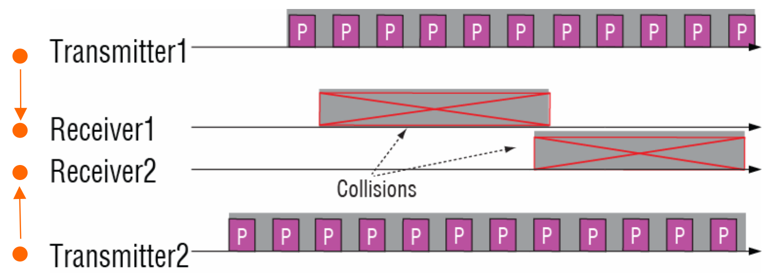
Problems

- This preamble occupies the medium for much longer than actual data
- Blocks transmissions from neighbors



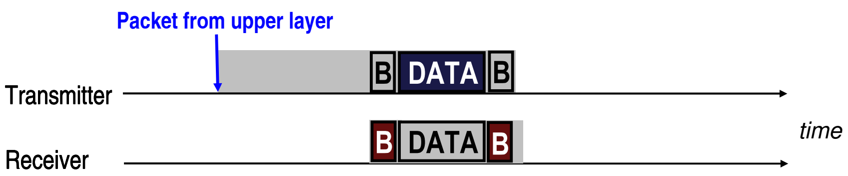
Problems

- Preambles from hidden nodes continue colliding for a long time
- Wastes time/energy, accomplishes nothing



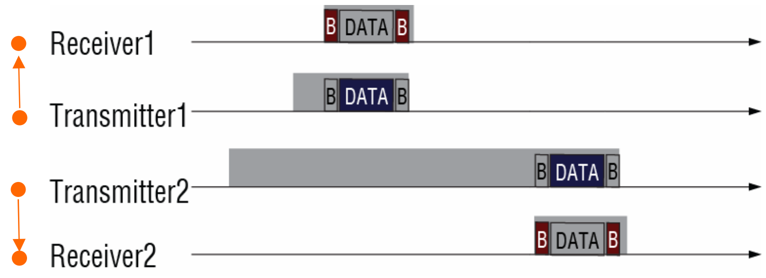
RI-MAC: Receiver-Initiated MAC

- Transmitter wakes up and waits for the intended receiver
- Each node periodically wakes up and broadcasts a beacon after sensing idle medium
  - Sleep intervals randomly chosen from [0.5×interval, 1.5×interval]
- Upon receiving a beacon from intended receiver, the transmitter starts DATA transmission
- Receiver acknowledges the DATA with another beacon



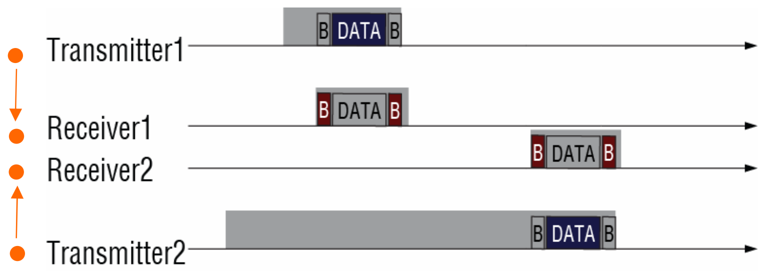
RI-MAC Solves Earlier Problems

- Improves channel utilization
  - Reduces the time a pair of nodes occupy the medium to reach a rendezvous time



RI-MAC Solves Earlier Problems

- Reduces collisions caused by hidden nodes

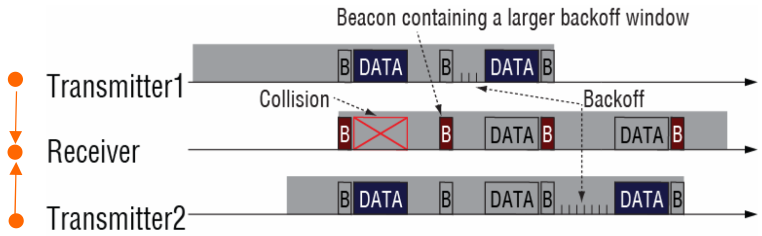


Receiver-Controlled Backoff Window

- Beacon specifies backoff window size to be used by a transmitter before DATA transmission
  - Transmitter picks backoff delay over this range
- Receiver increases the backoff window size in beacons using binary exponential backoff

Receiver-Controlled Backoff Window

- Reduces collision recovery cost
  - A receiver detects collisions quickly and controls retransmissions



RI-MAC Evaluation

- *ns-2* simulation-based evaluation:
  - Clique networks
  - Grid networks
  - Random networks
- TinyOS-based implementation and evaluation:
  - Clique networks
  - Networks with hidden nodes

Simulation Parameters

- Radio parameters

Bandwidth	250 Kbps	Size of Hardware Preamble	6 B
SIFS	192 μs	Size of ACK	5 B
Slot time	320 μs	CCA Check Delay	128 μs
Tx Range	250 m	Carrier Sensing Range	550 m

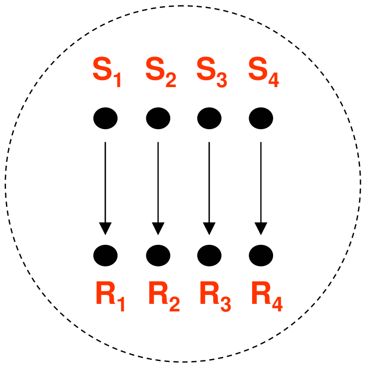
- MAC protocol parameters

	XMAC	XMAC-UPMA	RI-MAC
Backoff Window	32	32	0 – 255
Retry Limit	0 or 5	0 or 5	5
Special Frame	Short Preamble	—	Beacon
Special Frame Size	6 B	—	6 – 9 B
Dwell Time	10.5 ms	100 ms	Variable

- 1-second duty cycle interval; 28-byte DATA frames

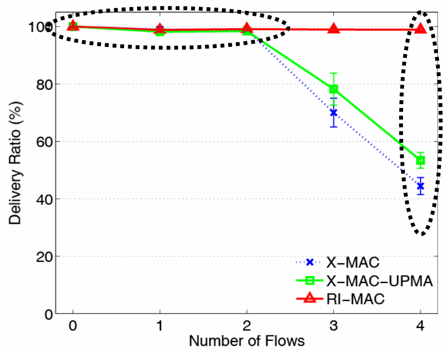
Clique Networks

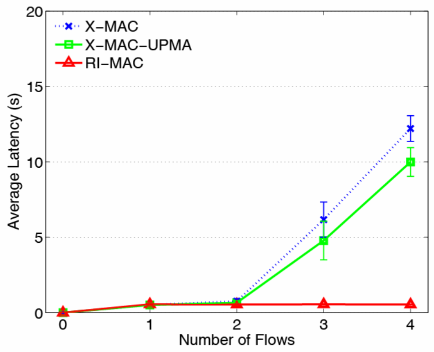
- Independent flows that do not share end nodes
- Packet generation interval is randomly chosen from [0.5, 1.5] seconds for each flow



Clique Networks: PDR and Latency

- Independent flows that do not share end nodes
- Packet generation interval is randomly chosen from [0.5, 1.5] seconds for each flow

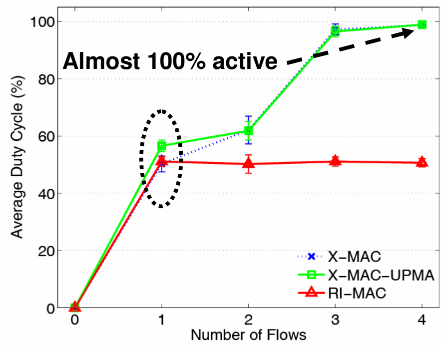




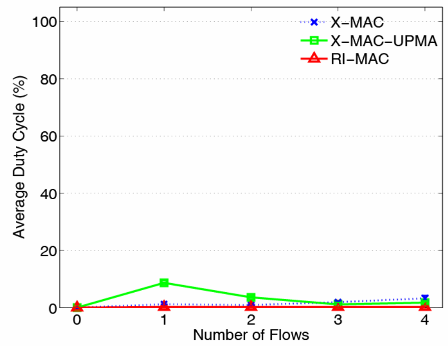
Clique Networks: Average Duty Cycle

Average Duty Cycle = Percentage of time a node is on

Senders



Receivers



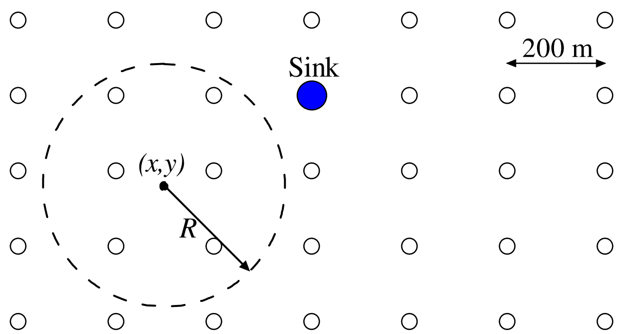
Grid Network

- 49 nodes in 7 × 7 grid
- Sink node is at center node
- 10 different simulation runs
- Random correlated-event traffic with event every 100 seconds

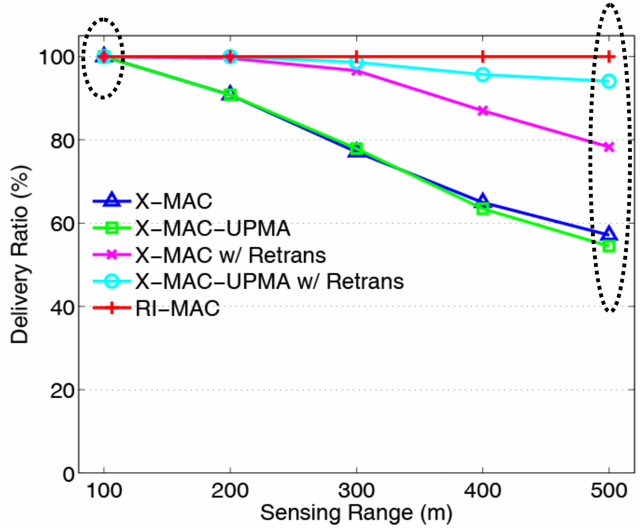
Random Correlated-Event Traffic

Average number of packets per event vs. sensing range (R):

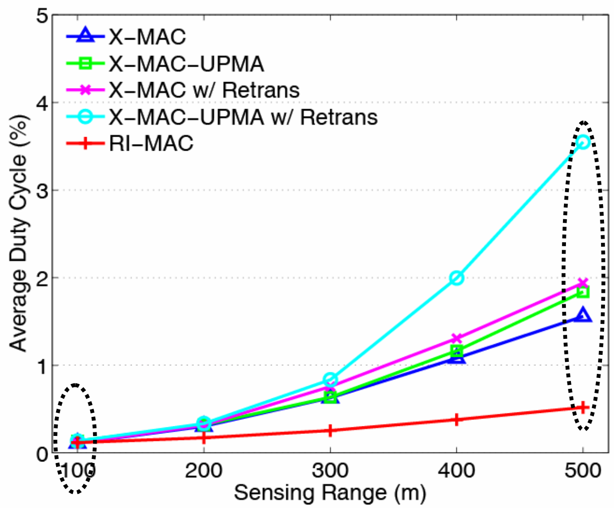
Range(m)	100	200	300	400	500
Packets	0.8	3.1	6.4	10.6	15.2



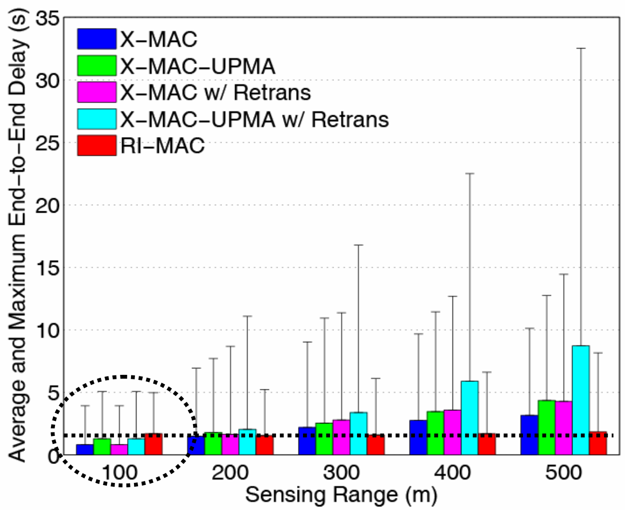
Grid Network: Packet Delivery Ratio



Grid Network: Average Duty Cycle



Grid Network: End-to-End Latency

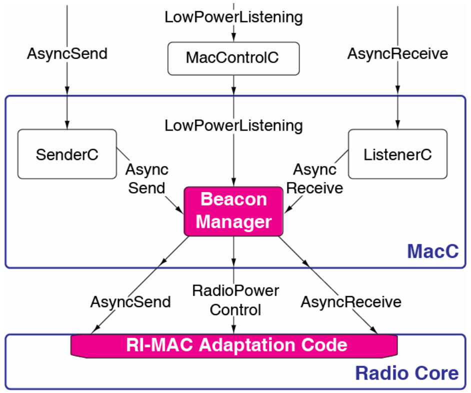


Random Networks

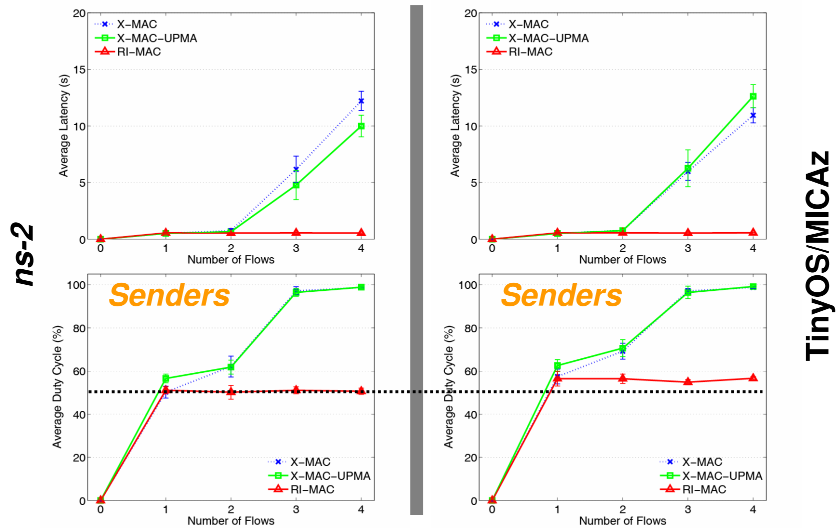
Results for random network show similar trends and are reported in the paper

RI-MAC Implementation in TinyOS on MICAz

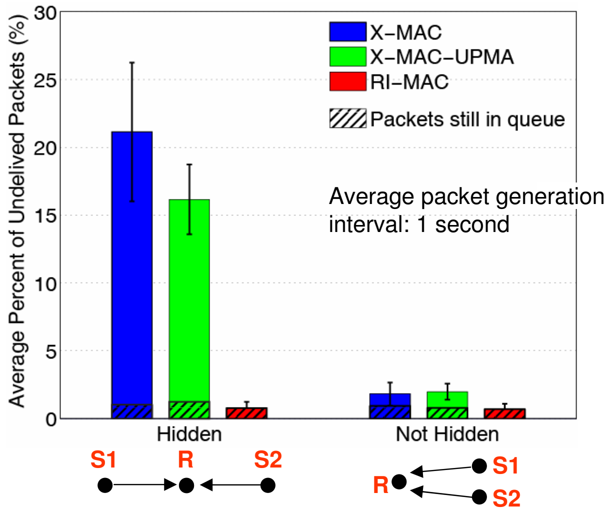
- Under the UPMA framework in TinyOS
- All beacons operations are in software



Clique Network: Simulation vs. Experimental



3-Node Network with Two Hidden Nodes



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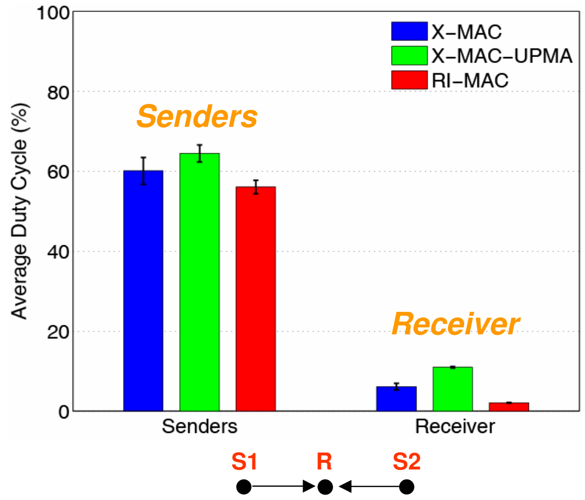

Conclusion

- RI-MAC is an asynchronous duty-cycle MAC
- Receiver-initiated transmissions and receiver controlled collision resolution
- Improved channel utilization
- Lower collision recovery cost
- Implemented in TinyOS
- Evaluated in *ns-2* and TinyOS/MICAz
- Performs much better than X-MAC and X-MAC-UPMA