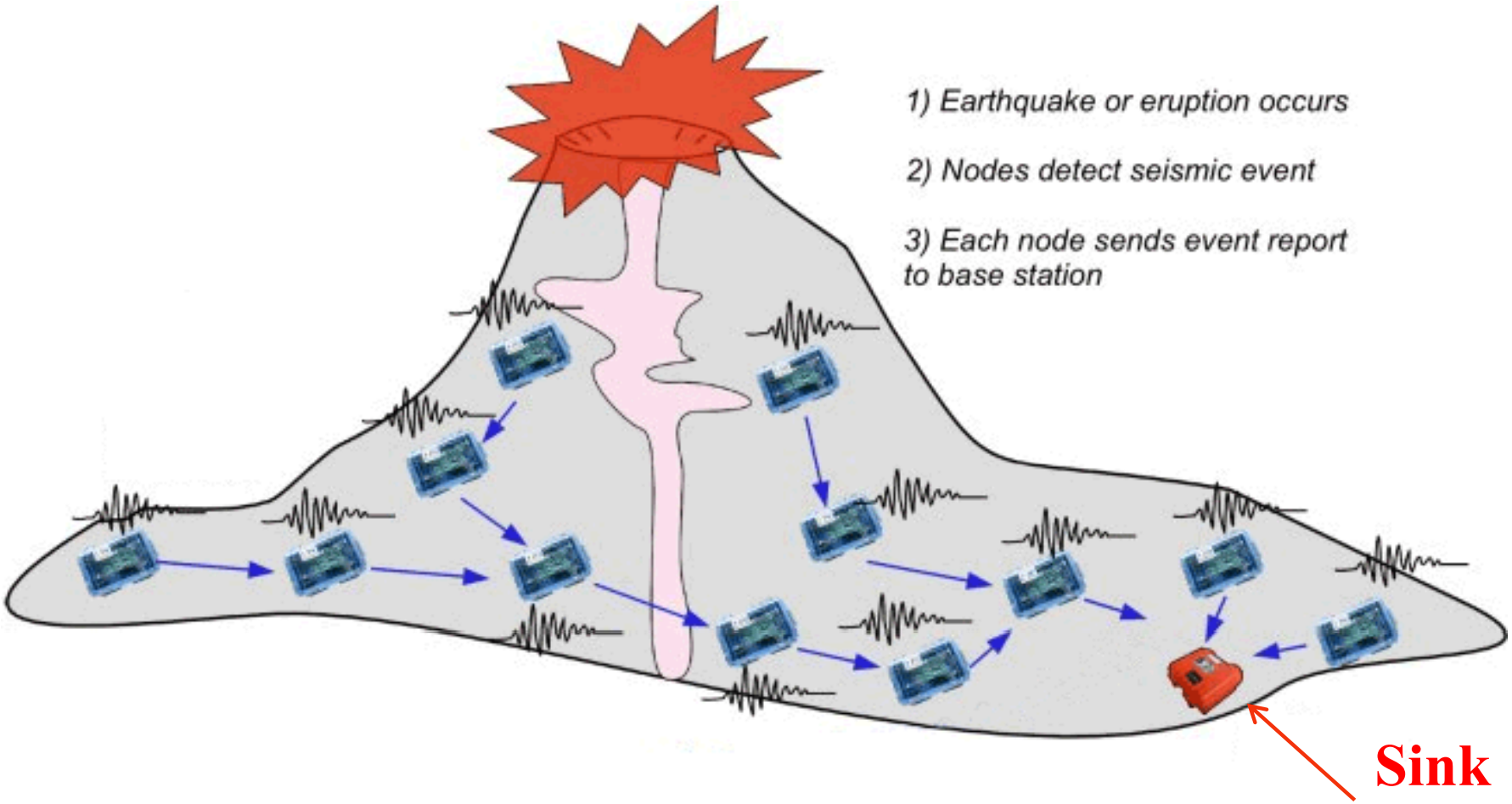
PW-MAC: A Predictive-Wakeup MAC Protocol for Wireless Sensor Networks

Lei Tang, Yanjun Sun, Omer Gurewitz,
and David B. Johnson

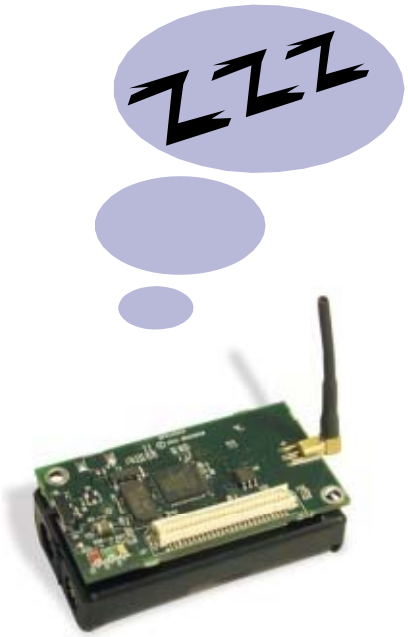
Multihop Wireless Sensor Network



- The traffic is multihop.
- To save energy, nodes use duty-cycling
  - ➢ Duty cycle metric = percentage of time awake

Picture adapted from http://fiji.eecs.harvard.edu/Volcano

PW-MAC Objective



Minimize energy consumption both at **senders** and at **receivers** while maintaining:

- High packet delivery ratio
- Low delivery latency

Outline

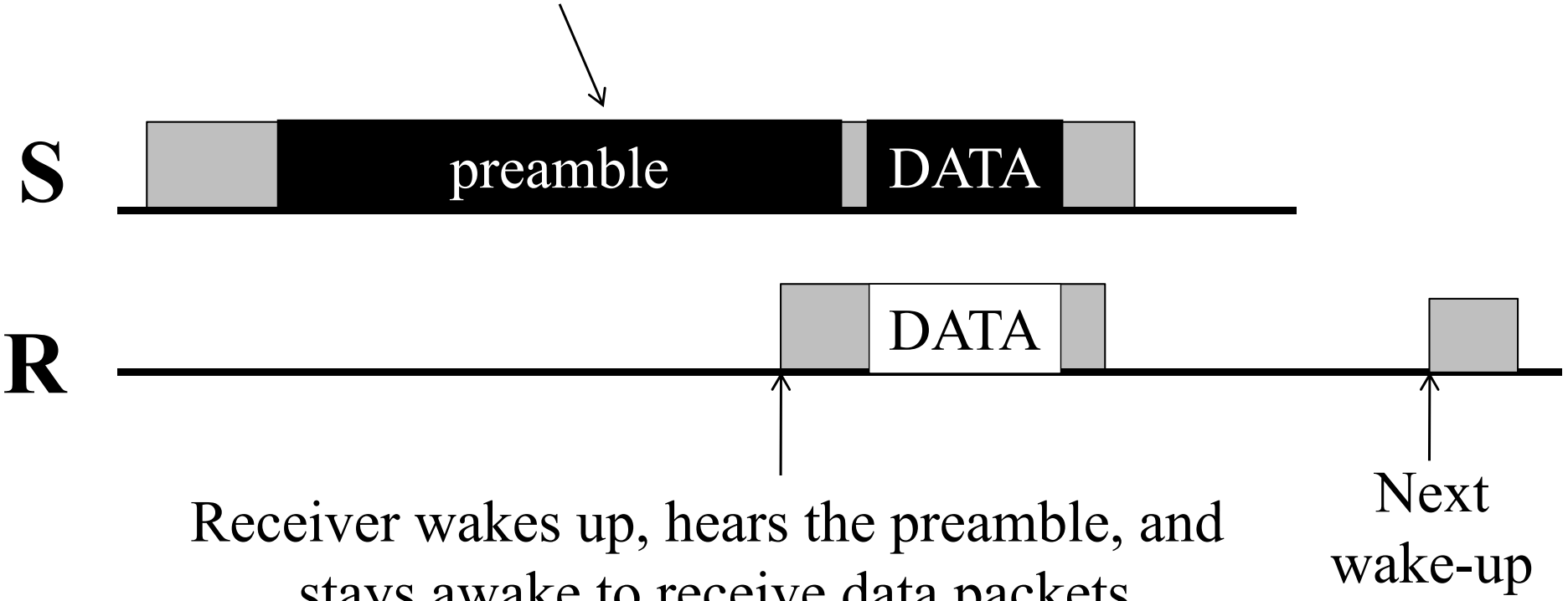
1. Introduction
2. Related Work

Related Work

- *Asynchronous* duty cycling MAC protocols can be categorized into:
  - Sender-initiated: e.g., B-MAC, X-MAC, WiseMAC.
  - Receiver-initiated: e.g., RI-MAC.

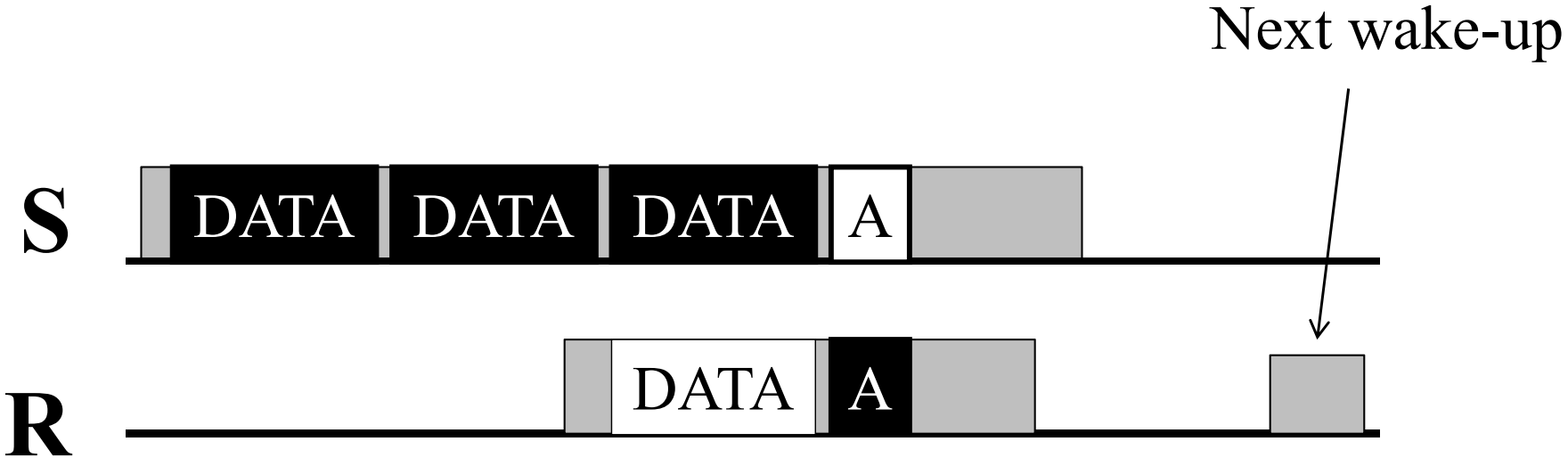
B-MAC (Sender-initiated)

Sender sends a preamble longer than the receiver wake-up interval to notify receiver the pending transmission.



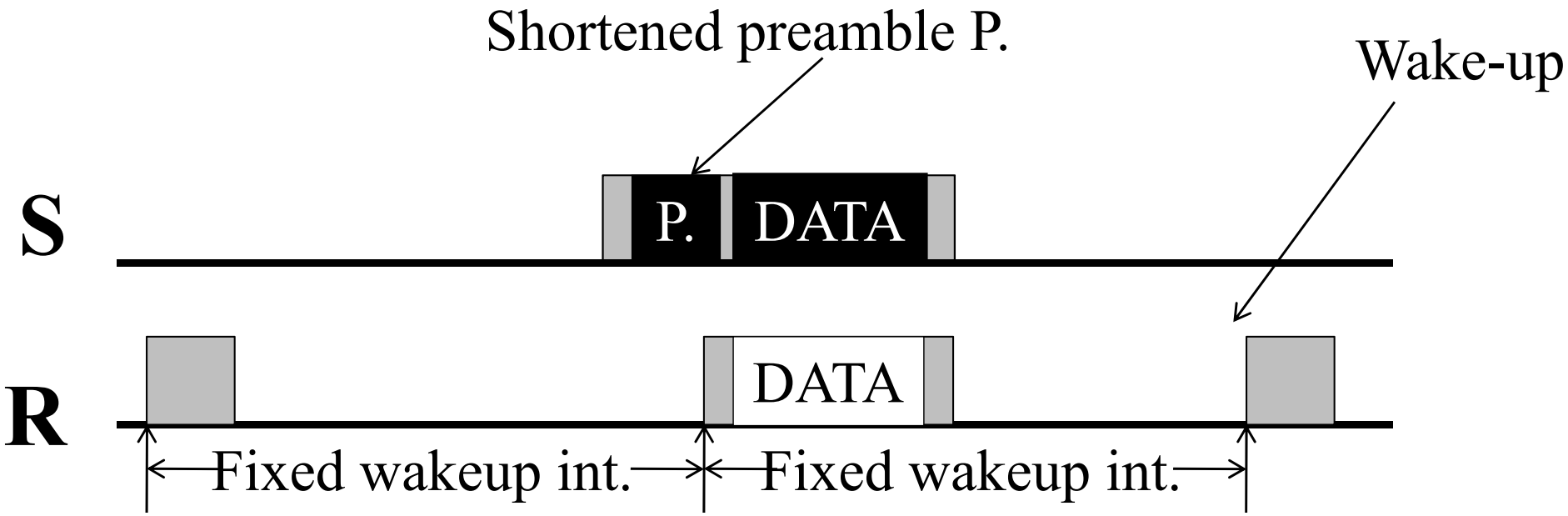
X-MAC (Sender-initiated)

The UPMA implementation of X-MAC:



- Sender preamble is replaced by shorter data packets.
- Receiver sends an ACK after receiving a data packet, without hearing the entire preamble.

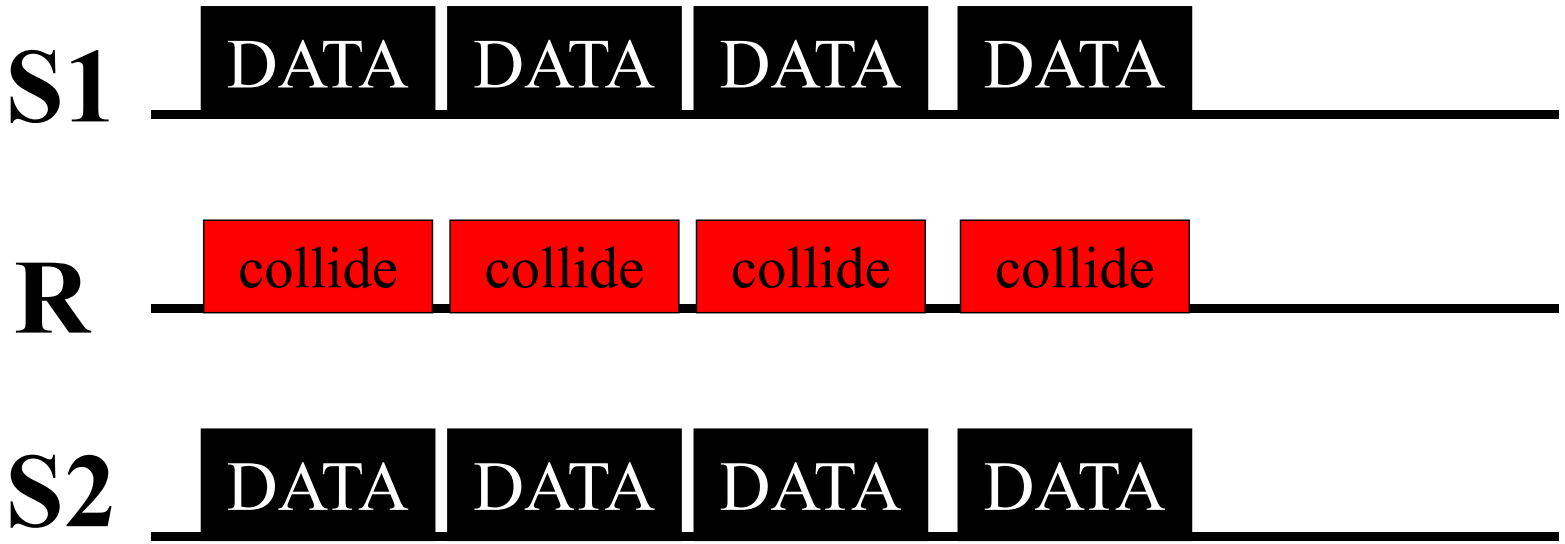
WiseMAC (Sender-initiated)



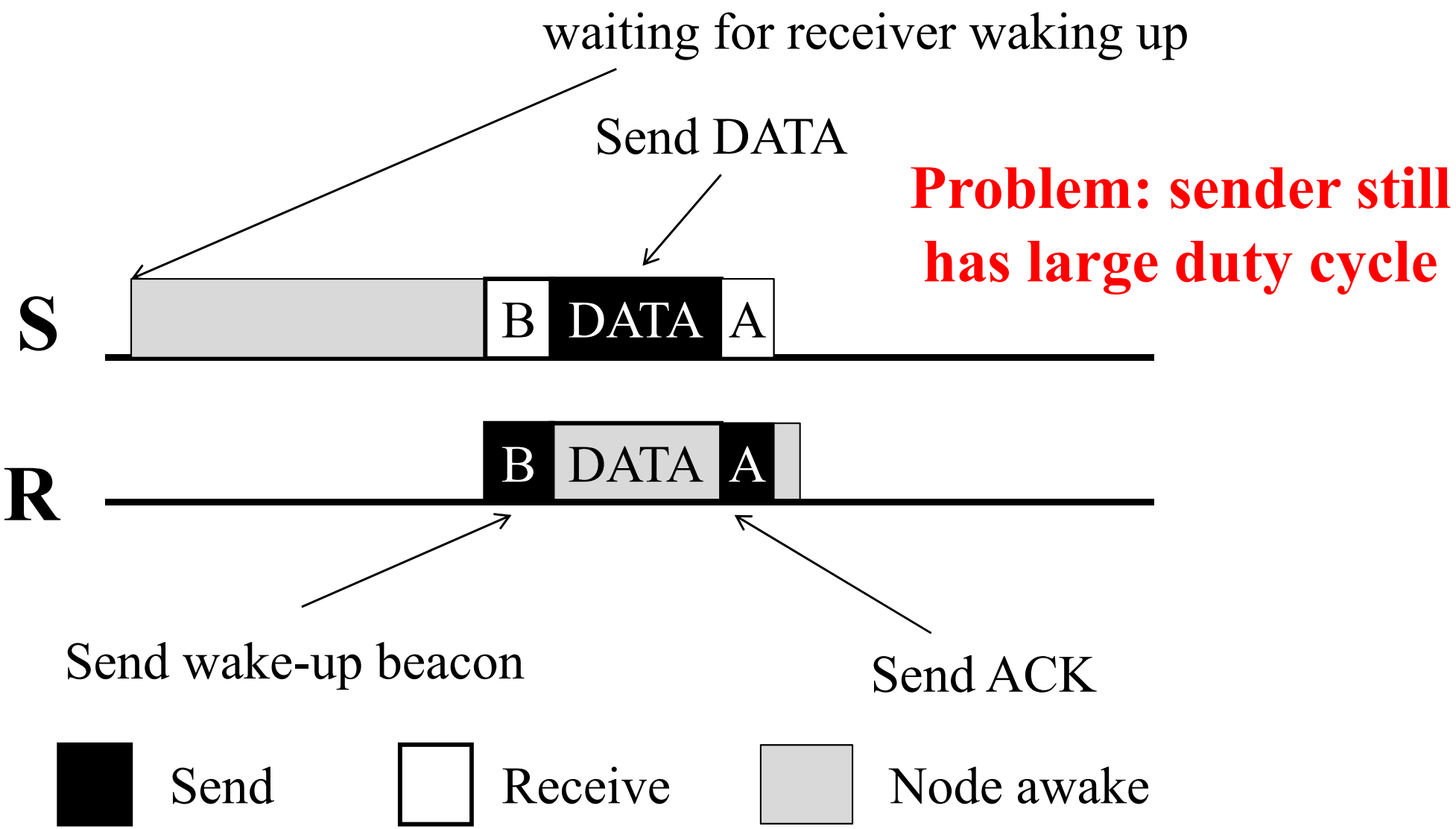
WiseMAC shortened the long preamble, taking advantage of fixed node wake-up interval to enable sender to predict the receiver wake-up times.

B-MAC, X-MAC, and WiseMAC

- B-MAC and X-MAC have large sender duty cycle.
- The fixed wakeup interval of WiseMAC can often causes collisions.
- Preambles often collide when there are multiple hidden transceivers.
- No efficient retransmission mechanism.



RI-MAC (Receiver-initiated)



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2. Related Work
3. Predictive Wake-up MAC (PW-MAC)

PW-MAC: Predictive Wake-up MAC

- Receiver-initiated protocol, no global clock synch.
- Independent pseudo-random wakeup scheduling to reduce collisions.
- Minimizes idle-listening and overhearing both at **senders** and at **receivers** by **predictive pseudorandom wakeup**.
- Also a **prediction-based retransmission mechanism** to achieve high energy efficiency even when collisions occur.
- Achieves high performance on real hardware by controlling the prediction error caused by hardware and OS latency and clock drift.

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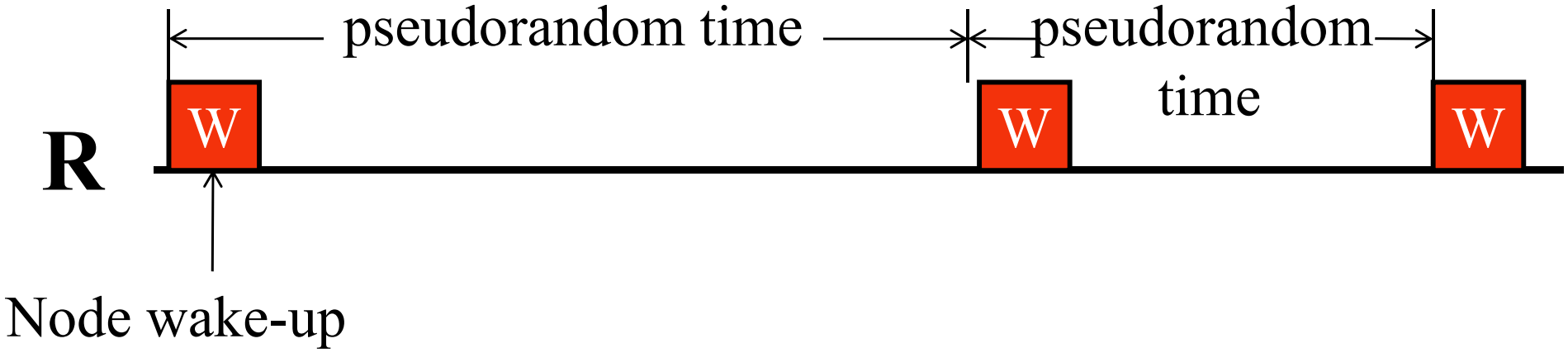
   - 3.1 Predictive Wake-up

Predictive Wake-up Mechanism of PW-MAC

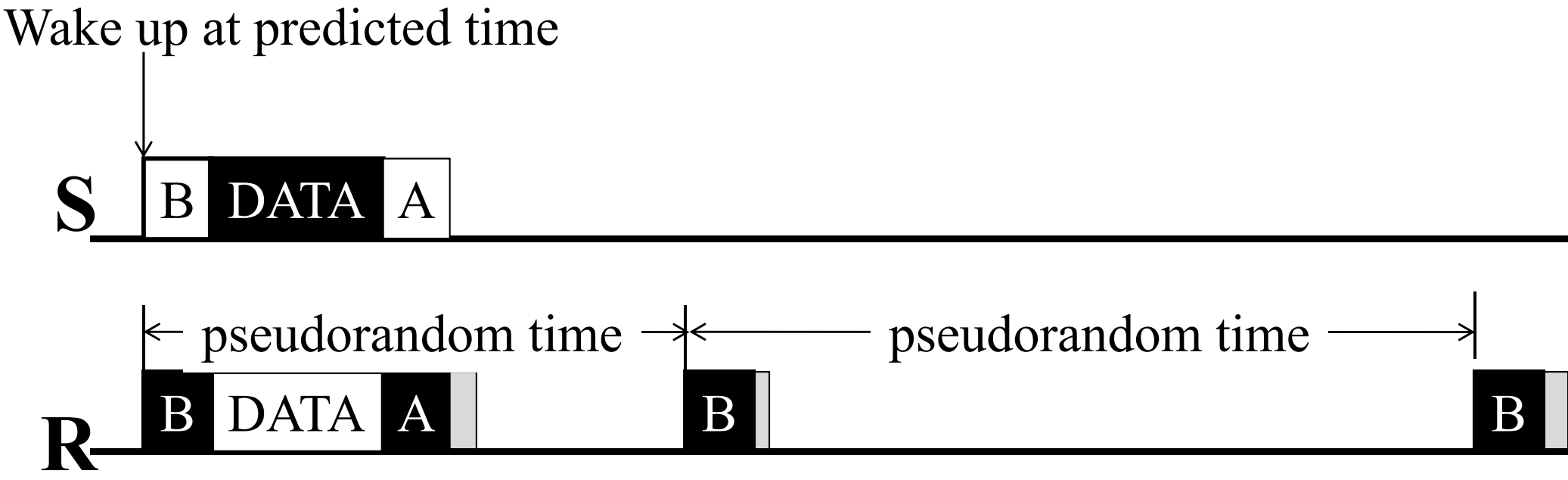


Prediction state obtained by a node S to predict a node R's wakeups includes:

- Pseudorandom number generator parameters and current seed of R.
- The time difference between S and R.

Predictive Wake-up Mechanism of PW-MAC

By waking up right before a receiver does, a sender minimizes its idle listening and overhearing.



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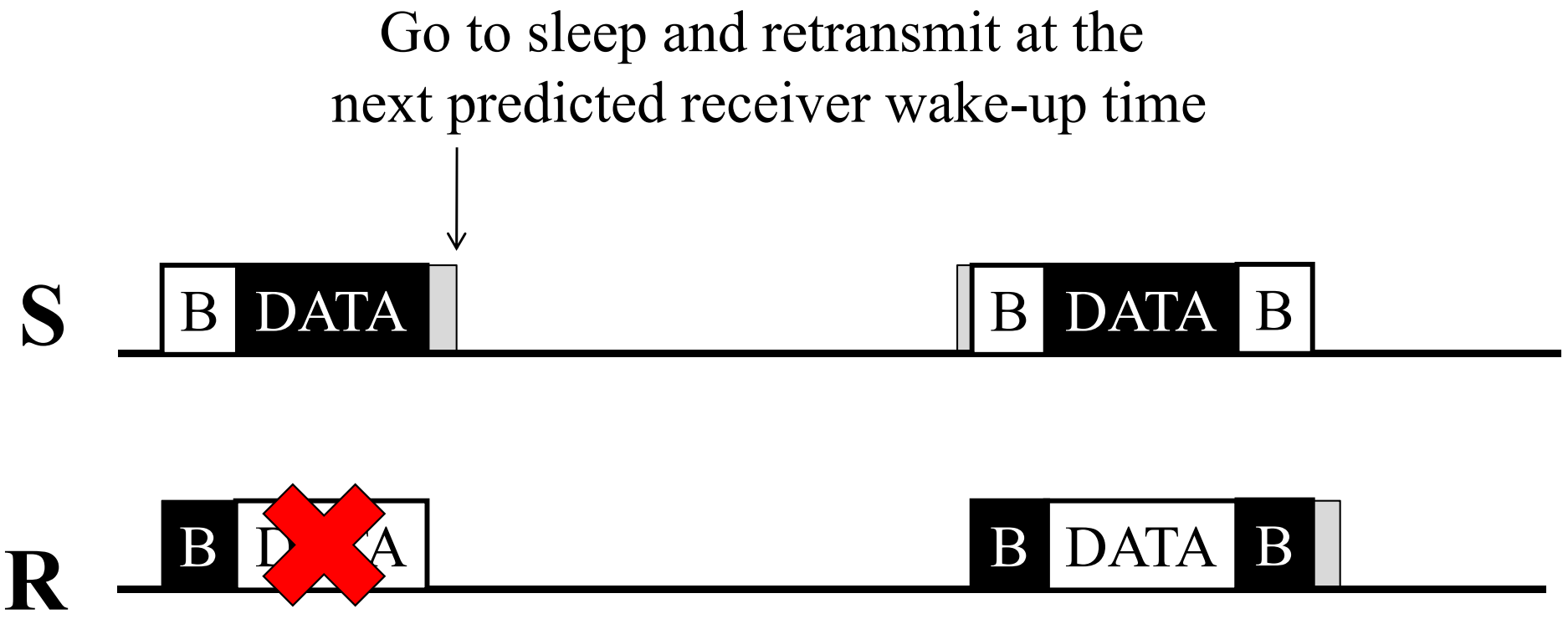
   - 3.1 Predictive Wake-up
   - 3.2 Prediction-based Retransmission

Prediction-based Retransmission



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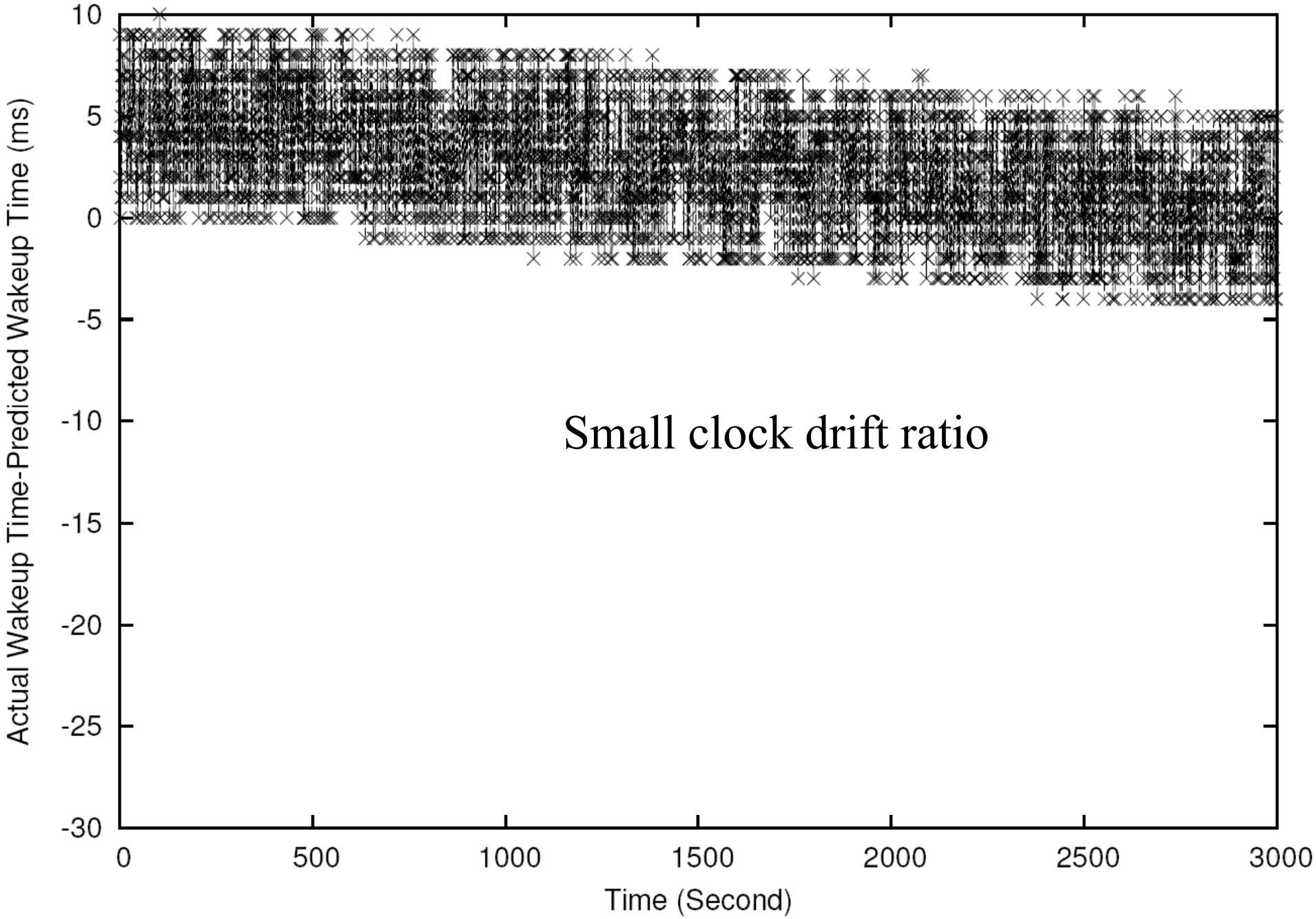
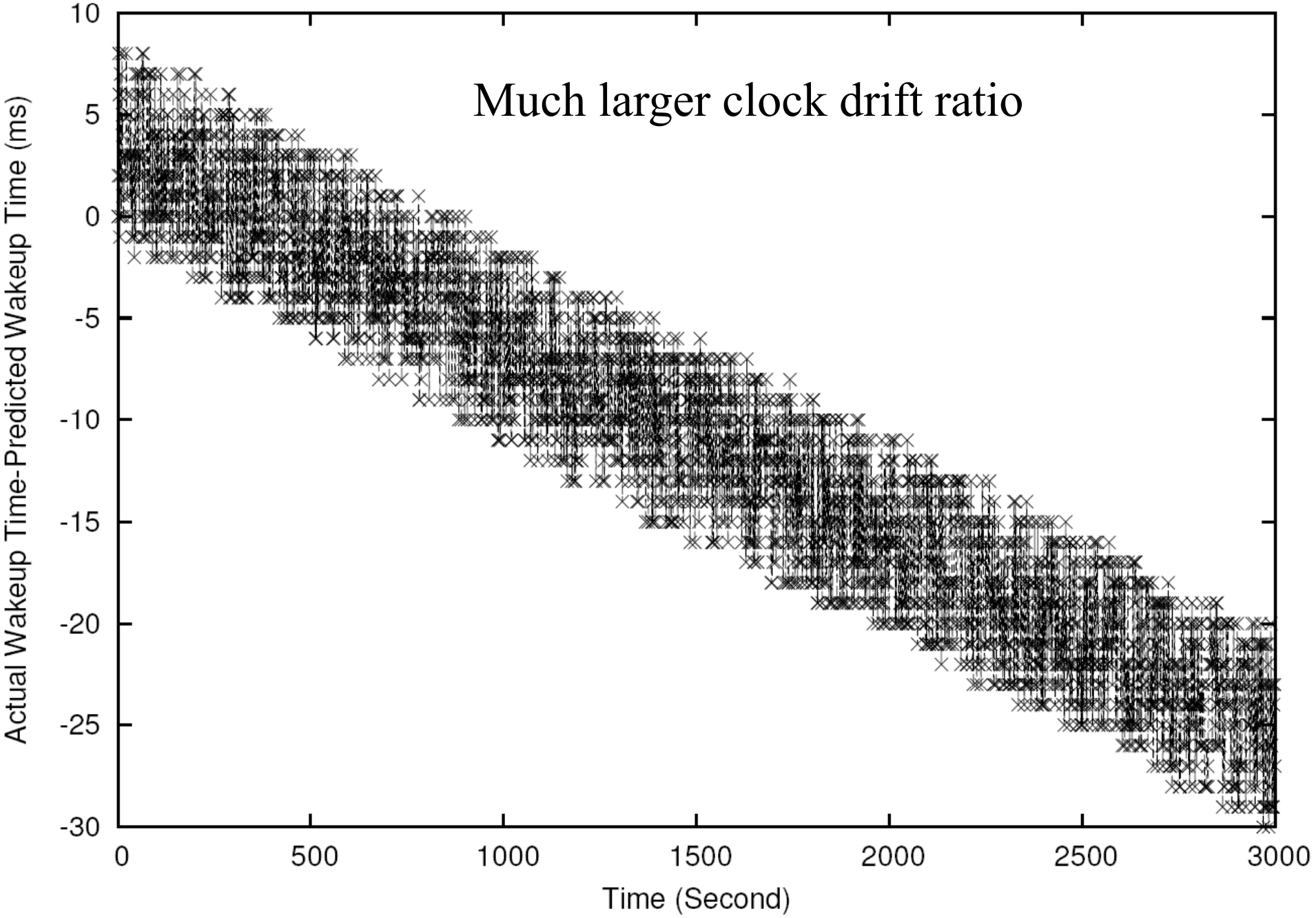
   - 3.1 Predictive Wake-up
   - 3.2 Prediction-based Retransmission
   - 3.3 Controling Prediction Error

Prediction Error on a Pair of MICAz Motes



Prediction Error on Another Pair of MICAz Motes

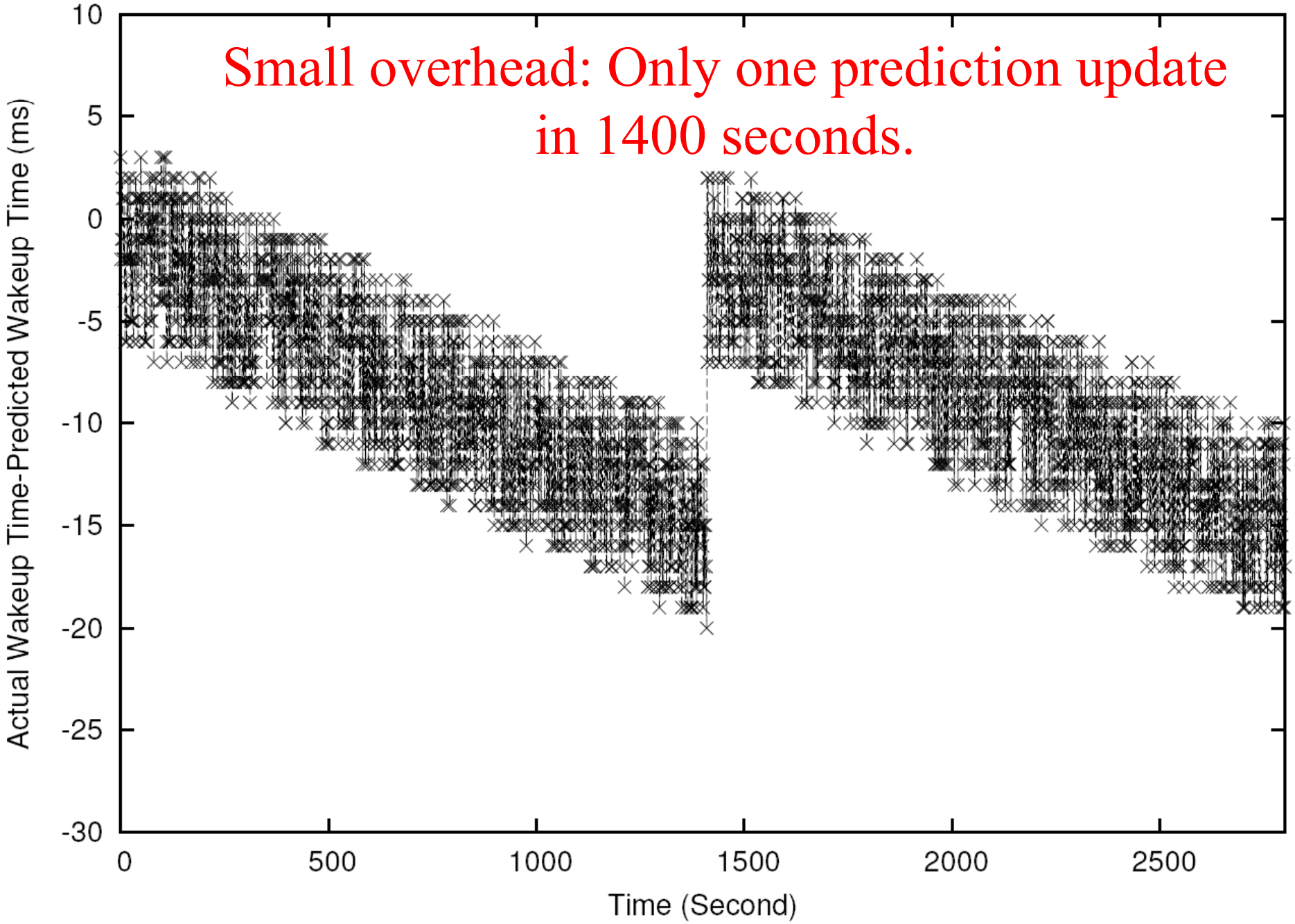


Controling Prediction Error

- To rendezvous a sender and a receiver, a MAC protocol must also take into hardware, OS latency, clock drift into consideration.

- No single clock drift ratio is suitable for all pairs of nodes. Clock drift ratio can also change over time (e.g., environment temperature).

PW-MAC effectively controls the prediction error to be ≤ wake-up-advance time



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3. Prediction Wake-up MAC (PW-MAC)
4. Evaluation on MICAz motes

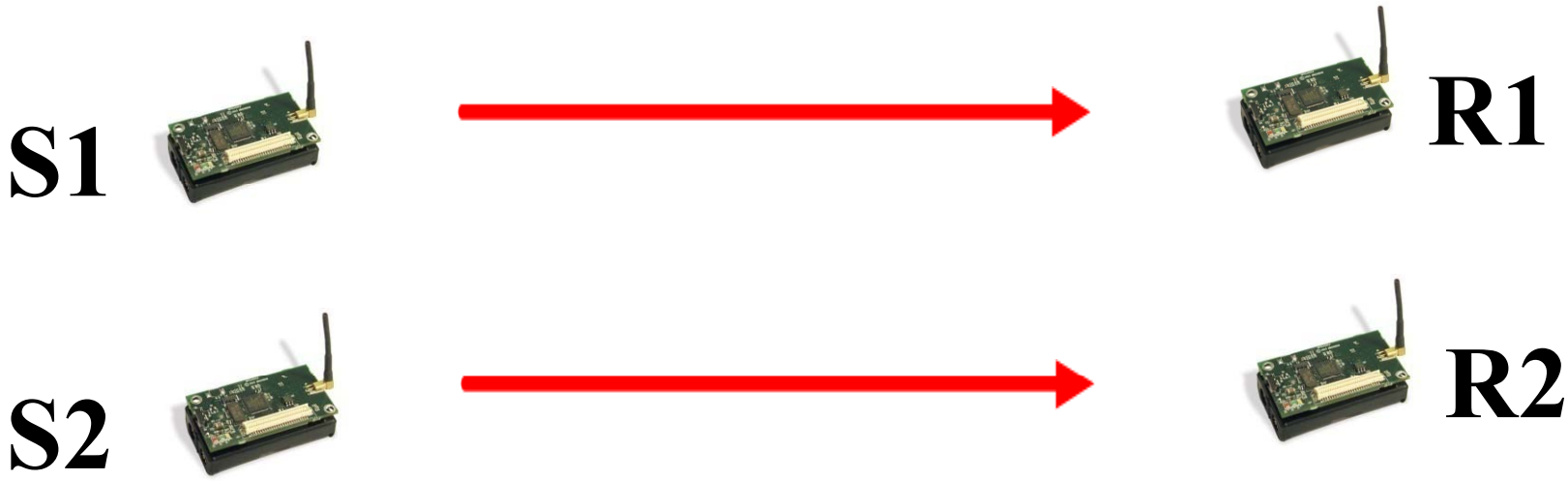
Hidden Terminal Experiment

Two senders are hidden to each other

	Sender Duty Cycle	Delivery Latency
PW-MAC	6.8%	670 ms
WiseMAC	81.6%	10905 ms

In hidden scenario, with WiseMAC, the two senders' repeated retransmissions cause persistent collisions.

Experiment of Wake-up Schedule Conflicts

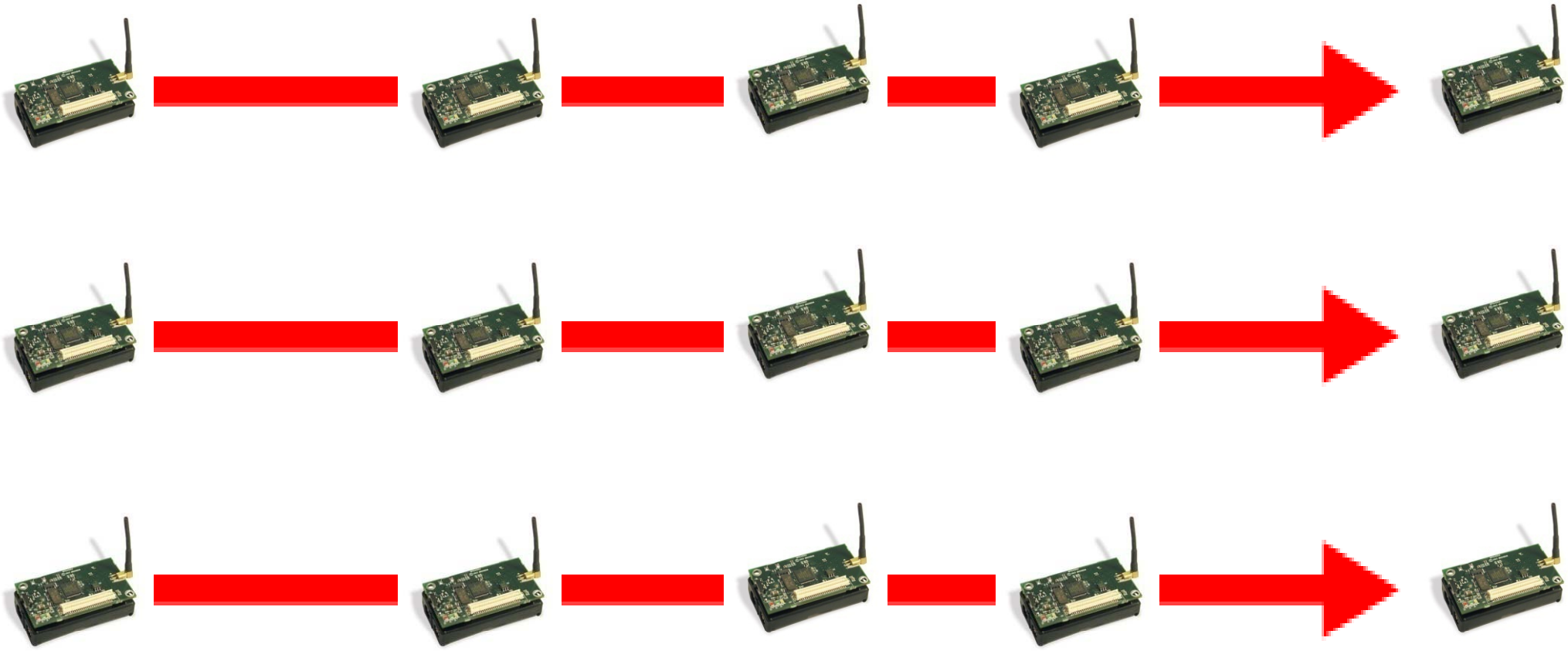


Two receivers have the same first wake-up time

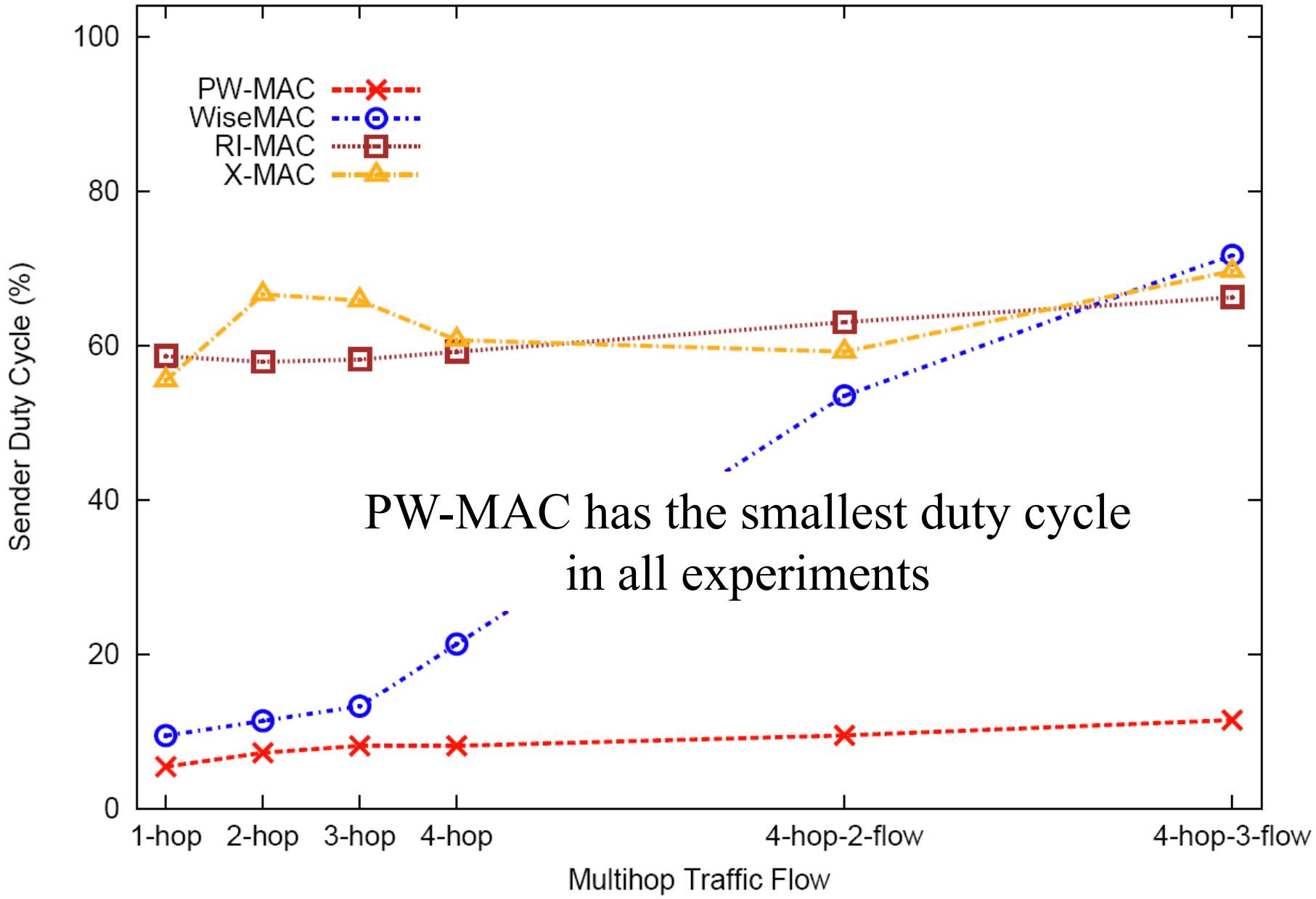
	Sender Duty Cycle	Delivery Latency
PW-MAC	5.5%	579 ms
WiseMAC	78.1%	17425 ms

Multihop Network Performance

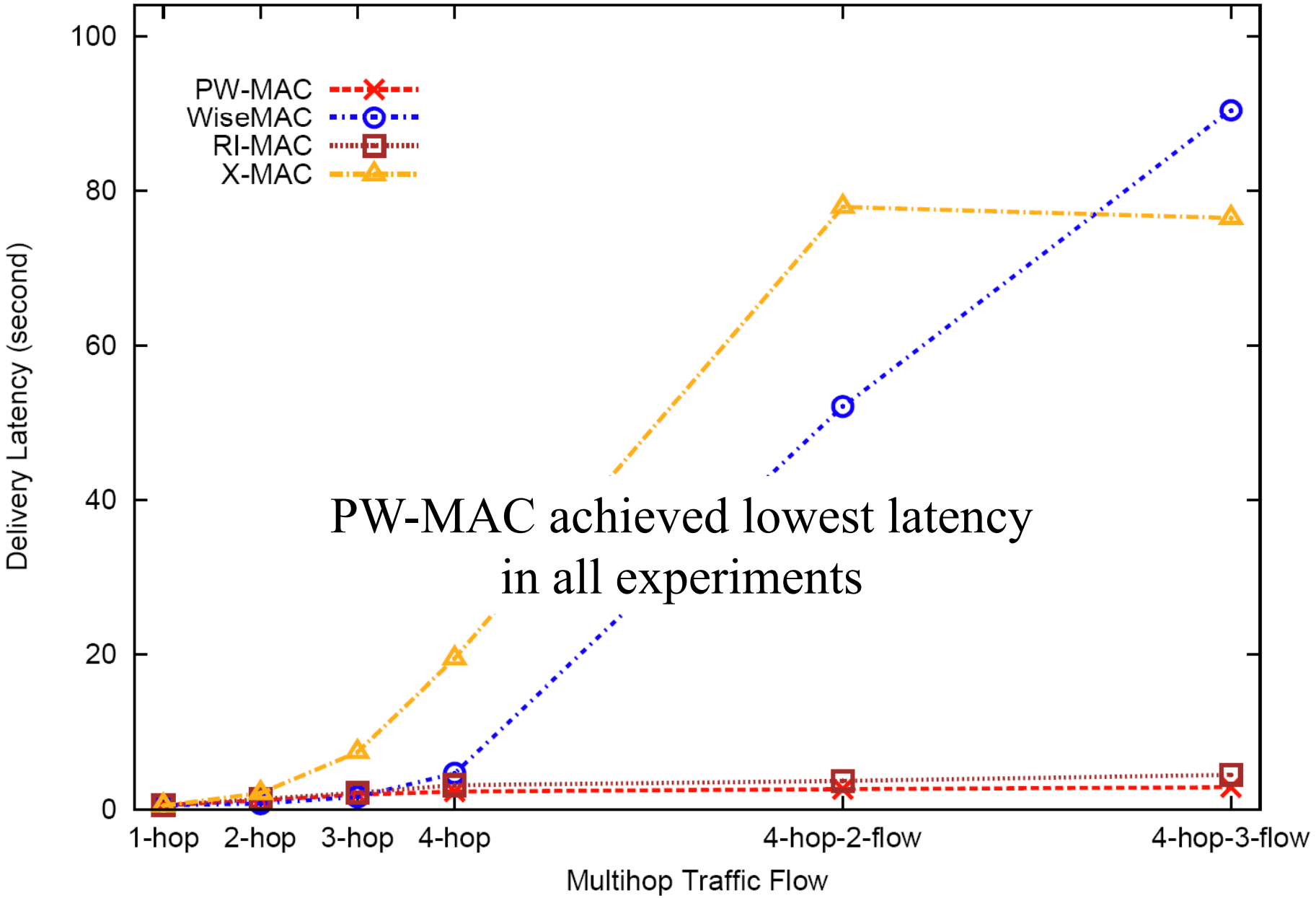
Up to 3 multihop traffic flows with hop-length from 1 to 4



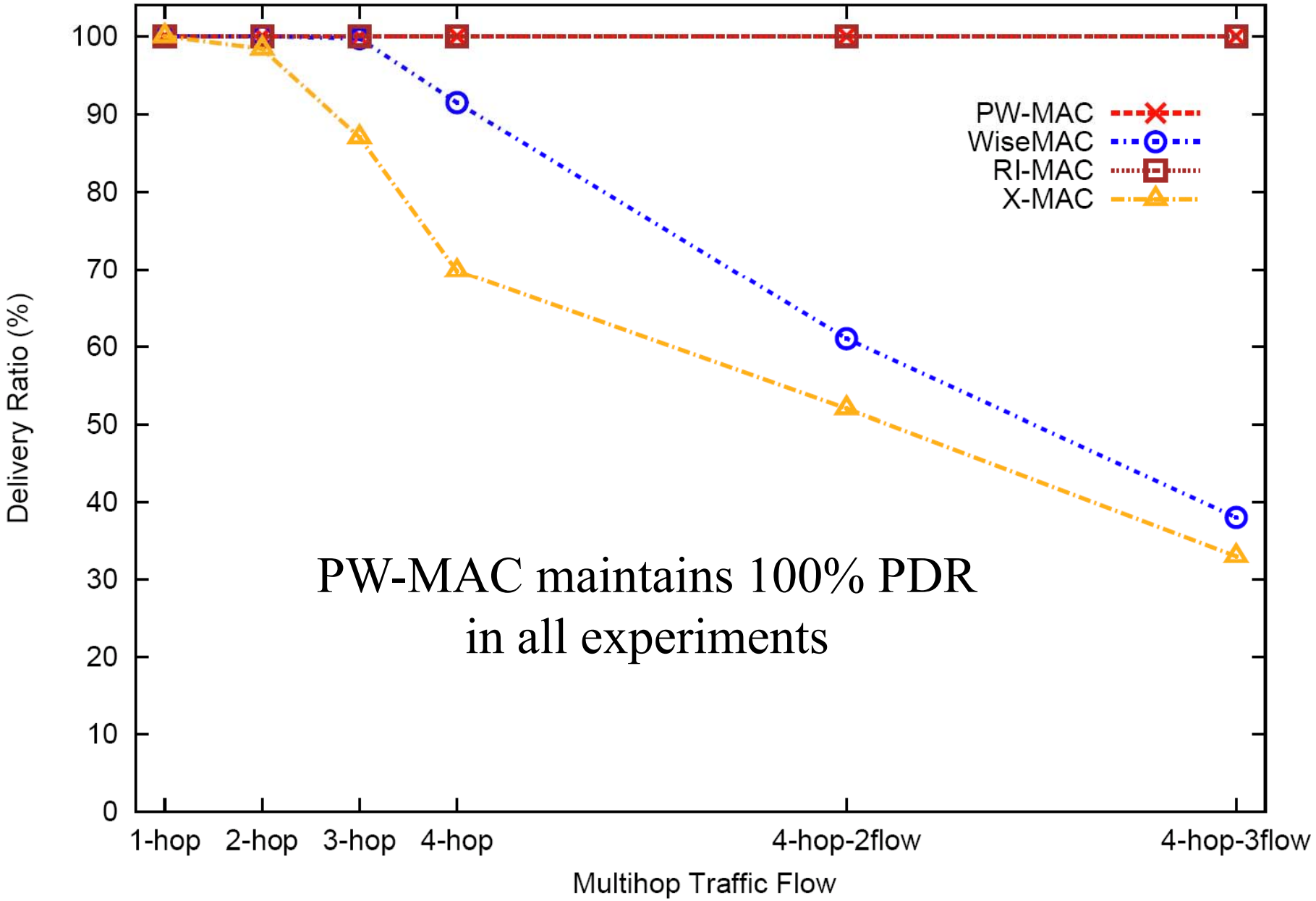
Sender Duty Cycle with Increasing Hop-Length and Num-Flows



Delivery Latency with Increasing Hop-Length and Num-Flows



Delivery Ratio with Increasing Hop-Length and Num-Flows



Conclusion

- PW-MAC achieves high energy efficiency both at senders and at receivers.
- Predictable pseudorandom wake-up schedules.
- Prediction-based retransmission mechanism maintains high energy efficiency even when collisions occur.
- PW-MAC outperformed other tested protocols under colliding-schedule, hidden-terminal, and multihop experiments on a testbed of MICAz motes.

Questions

Question?