



TR-MAC: An Energy-Efficient MAC Protocol for Wireless Sensor Networks exploiting Noise-based Transmitted Reference Modulation

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Outline

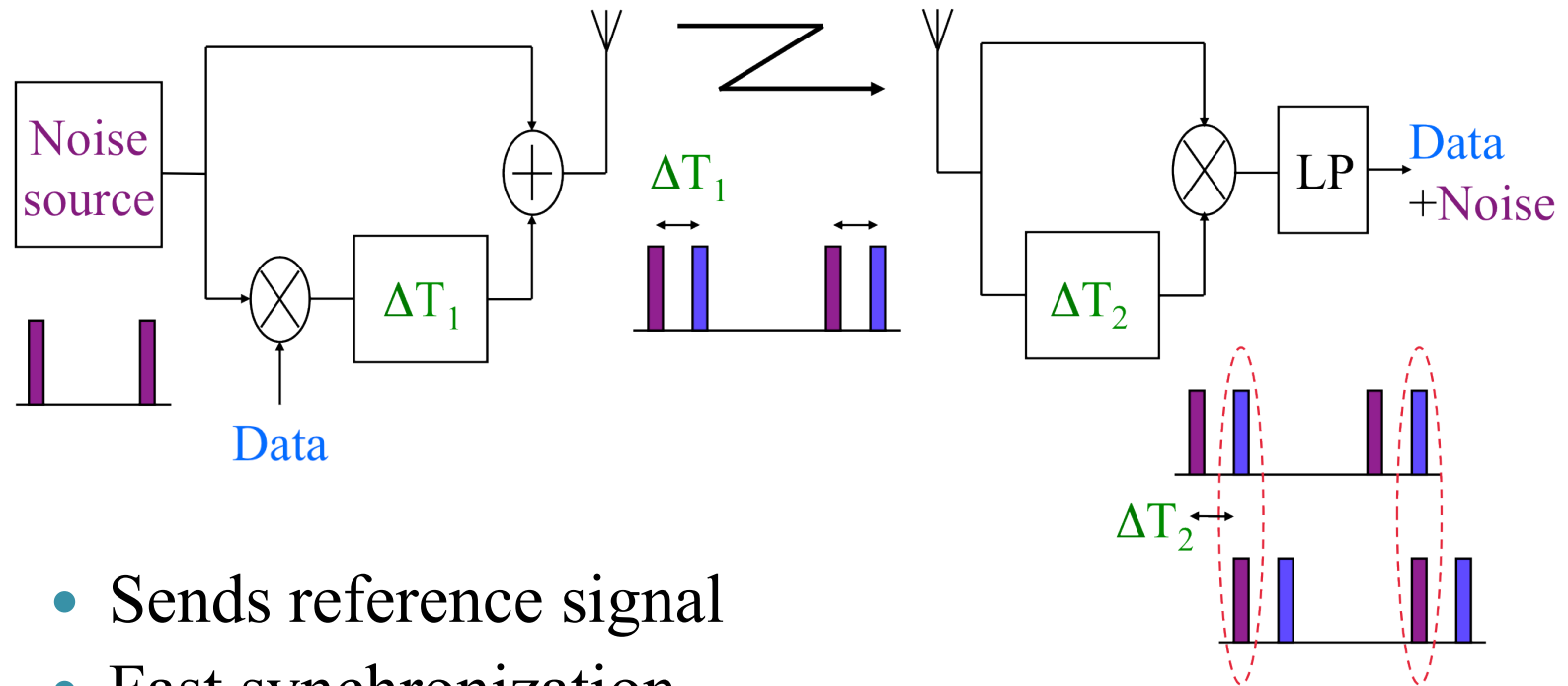
- Research motivation
- Background
- TR-MAC Protocol
- Analysis
- Conclusion



Research Motivation

- Why another new MAC protocol?
 - Exploit the advantages of Transmitted Reference (TR) modulation minimizing its drawbacks
 - Incorporating energy harvesting gives new requirement in wireless sensor networks
 - Need an efficient energy-driven protocol

Transmitted Reference Modulation



- Sends reference signal
- Fast synchronization
- Inherent multiplexing
- No power hungry stable oscillators
- **More transmission power for individual bits**

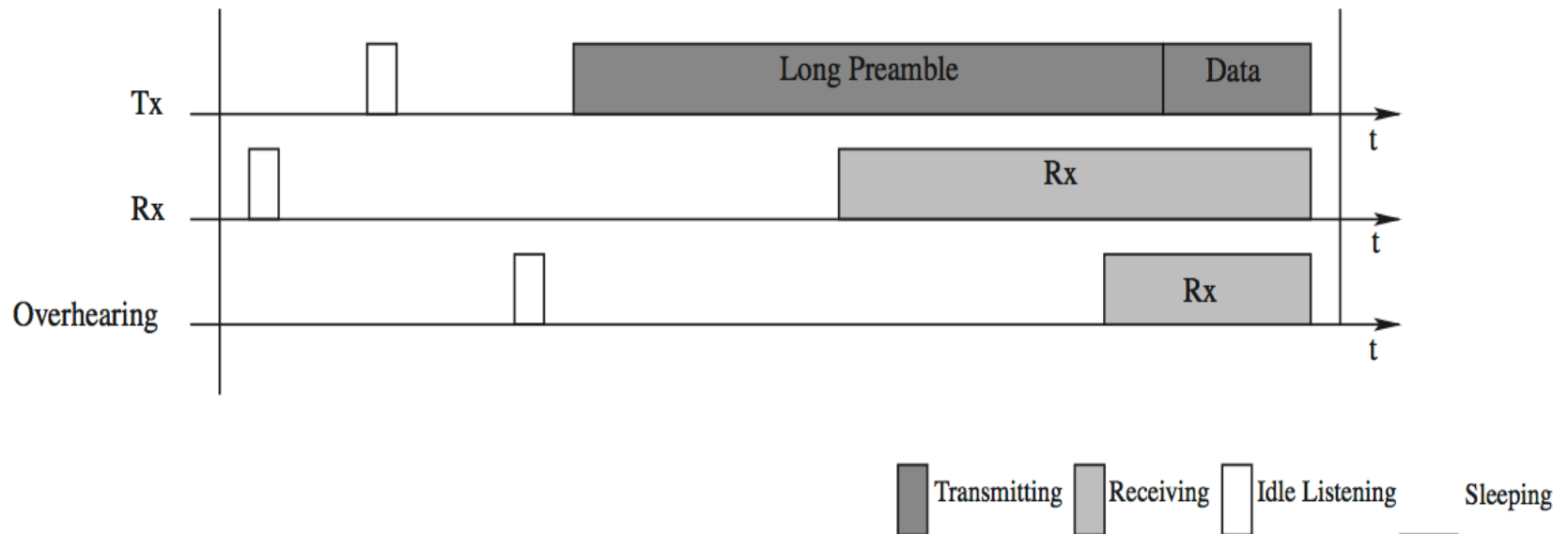


TR-MAC: Based on TR modulation

- Preamble can be very small
- Data might be sent right away with preamble
- Implicit identification of (possible simultaneous) transmissions based on offset between reference signal and data
- Mitigate transmit power penalty

Related work

- Preamble sampling protocols are most energy saving ones compared with
 - Reservation based protocols, e.g., TDMA
 - Protocols with common active periods, e.g., S-MAC



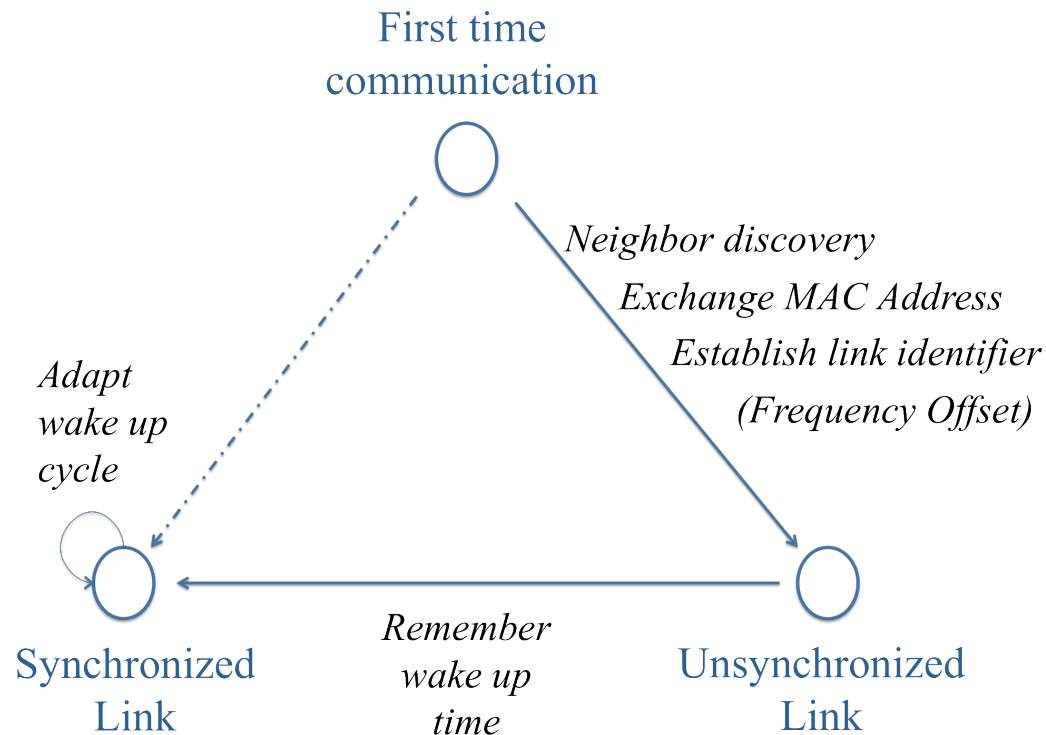


Preamble Sampling Protocols: Classification

- Short preamble burst
 - e.g., X-MAC, SpeckMac, ContikiMAC
- Remembering receiver's next wake up time
 - e.g., WiseMAC, TrawMAC, SyncWUF
- Duty cycle adaptation

TR-MAC: States

- *Unsynchronized links*: Short data-listen bursts are sent until it is acknowledged by the receiver
- *Synchronized links*: Both transmitter and receiver can store each other's next periodic wake up to reduce data-listen burst length

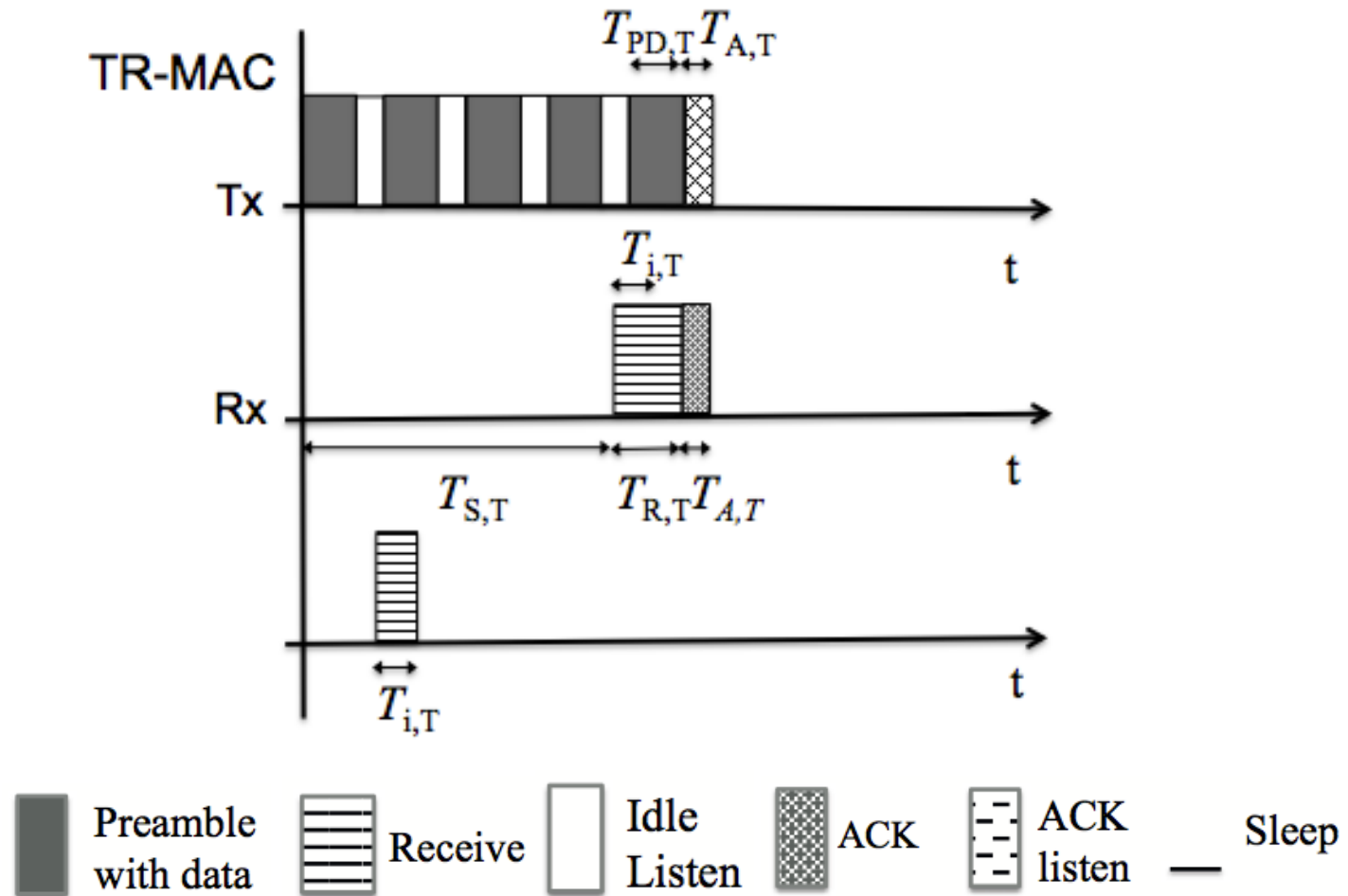




TR-MAC: Unsynchronized Links

- Link identifier can be derived from short preamble
- Small data packet is attached to the preamble
- Introduces listen periods after every preamble/data packet cause transmission is costly
- Minimizes the total data-listen iteration duration based on ack from receiver
- Overhears only wake up if same offset is used, and can go back to sleep after receiving one preamble

TR-MAC: Unsynchronized Links

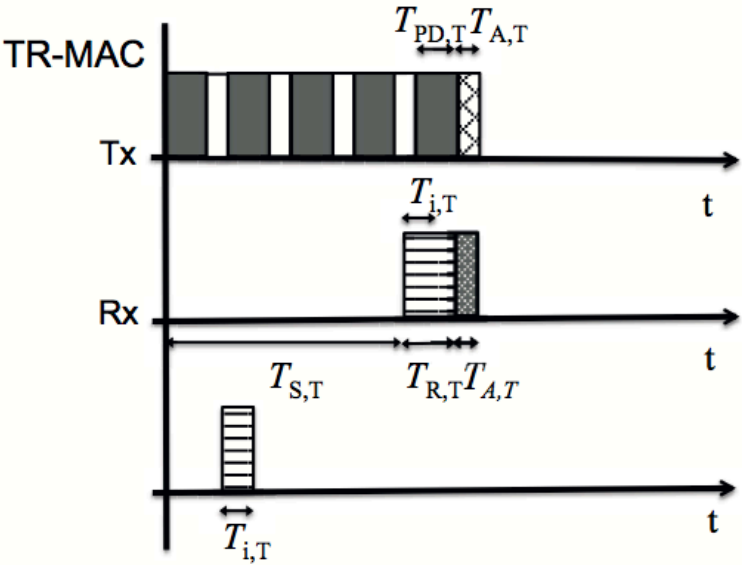




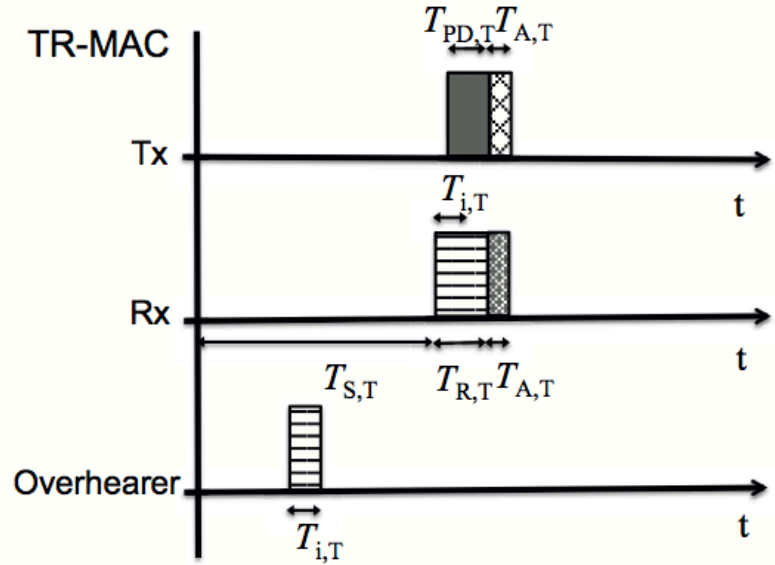
TR-MAC: Synchronized Links

- Nodes remember and possibly adapt each other's next wake up time
- Transmission can be either Tx-driven or Rx-driven => Ripple effect or Green wave
- Multiple access can be realized using different frequency offsets
- Duty cycle adaptation based on available energy on one node or application requirement

TR-MAC



Unsynchronized Link

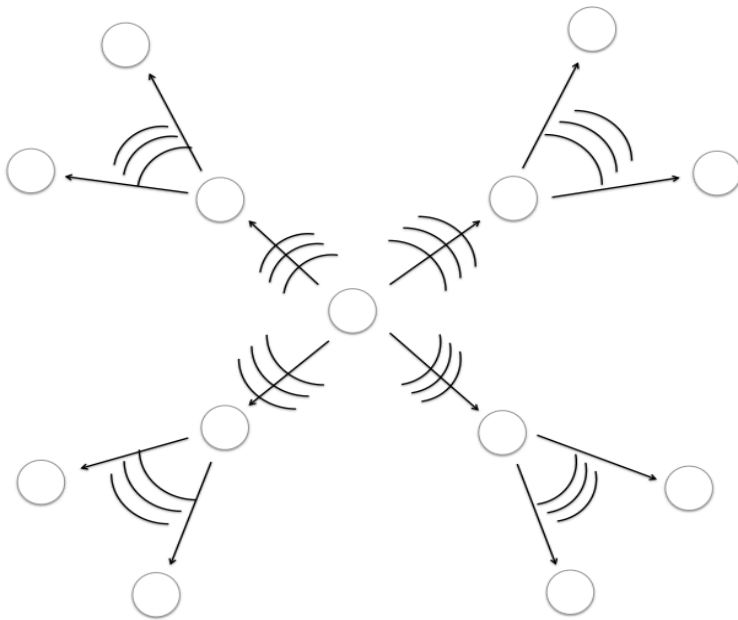


Synchronized Link

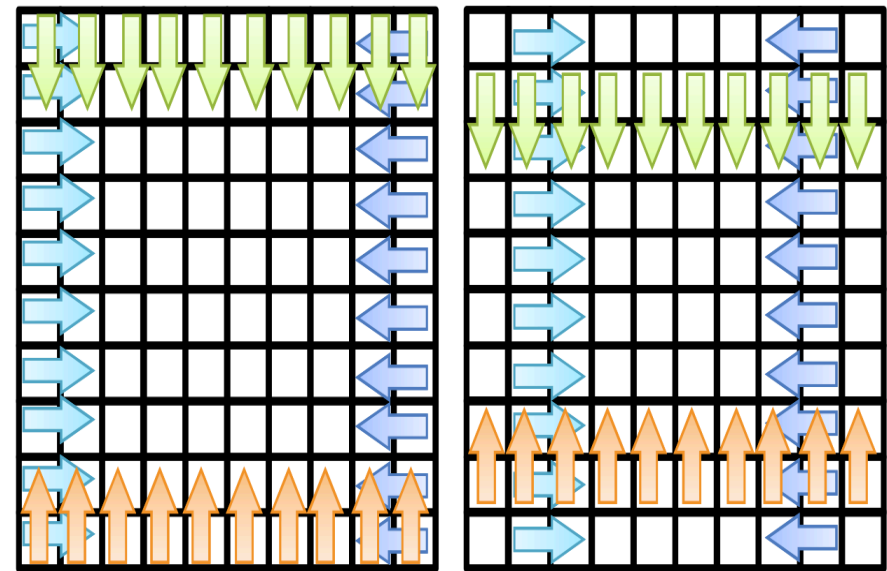
- Preamble with data
- Receive
- Idle Listen
- ACK
- ACK listen
- Sleep

TR-MAC: Multi-hop or Broadcasting

Ripple effect



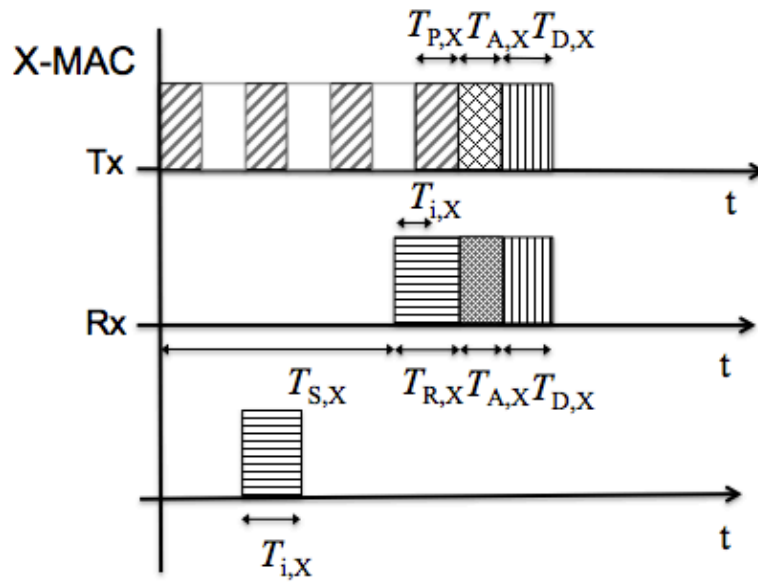
Green wave



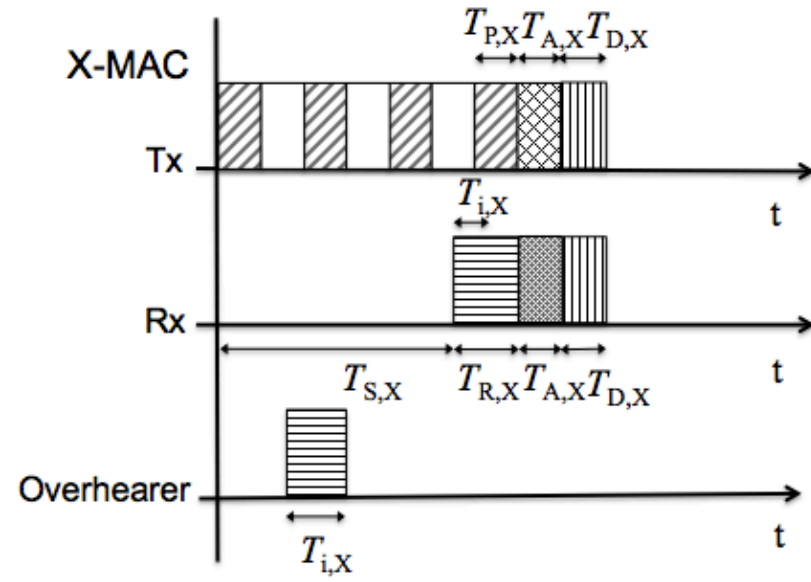
At slot t

At slot $t+1$

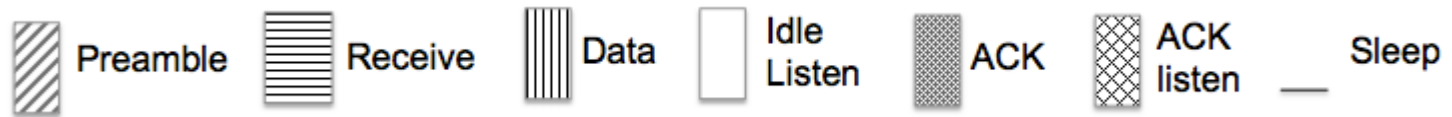
X-MAC, comparison with TR-MAC



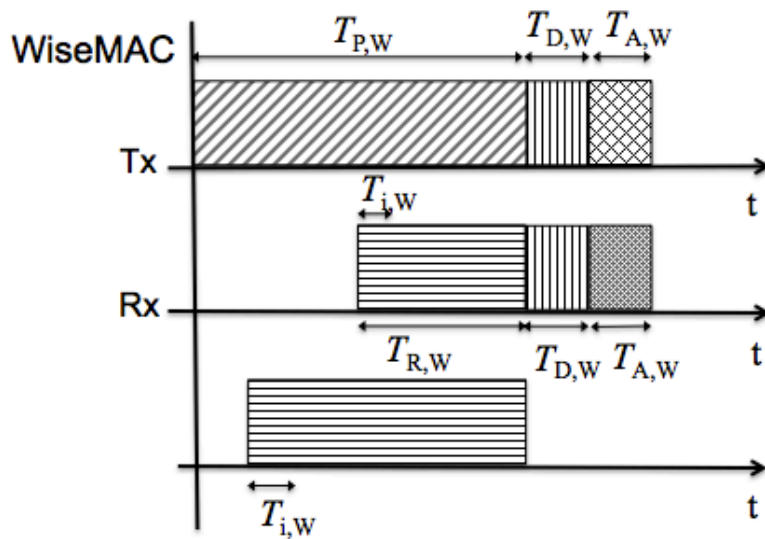
Unsynchronized Link



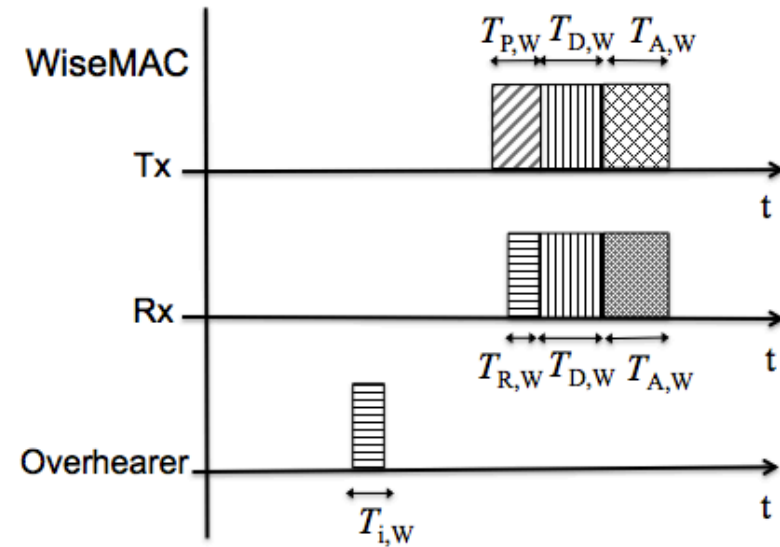
Synchronized Link



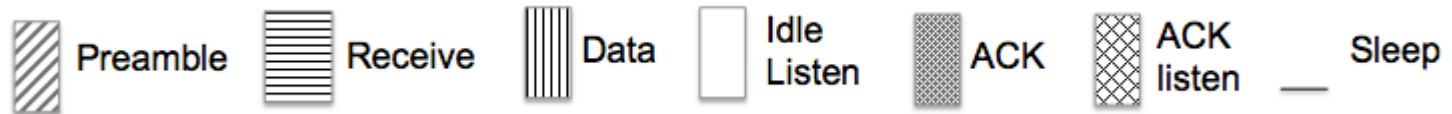
WiseMAC, comparison with TR-MAC



Unsynchronized Link



Synchronized Link

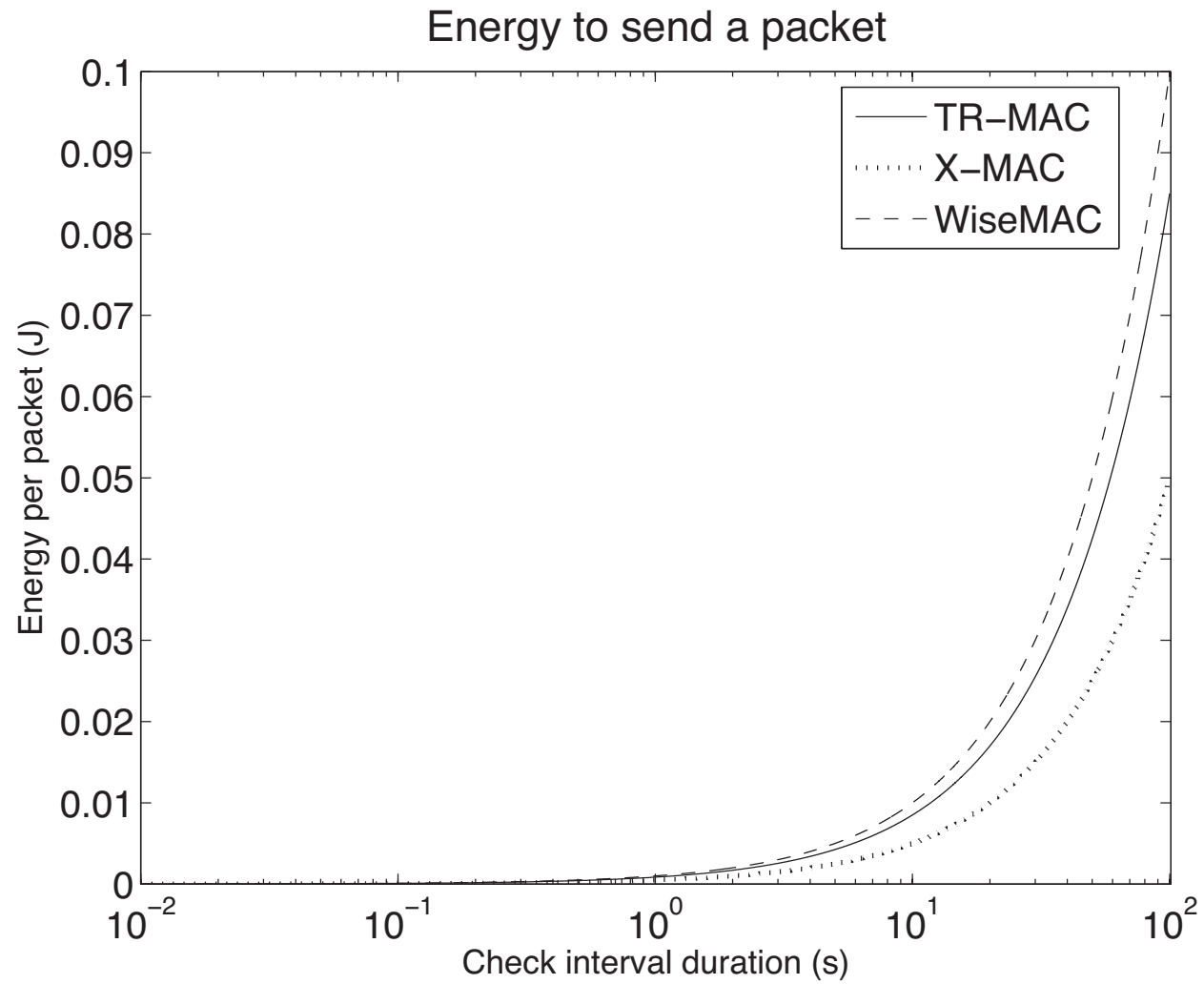


Analysis: Unsynchronized Links

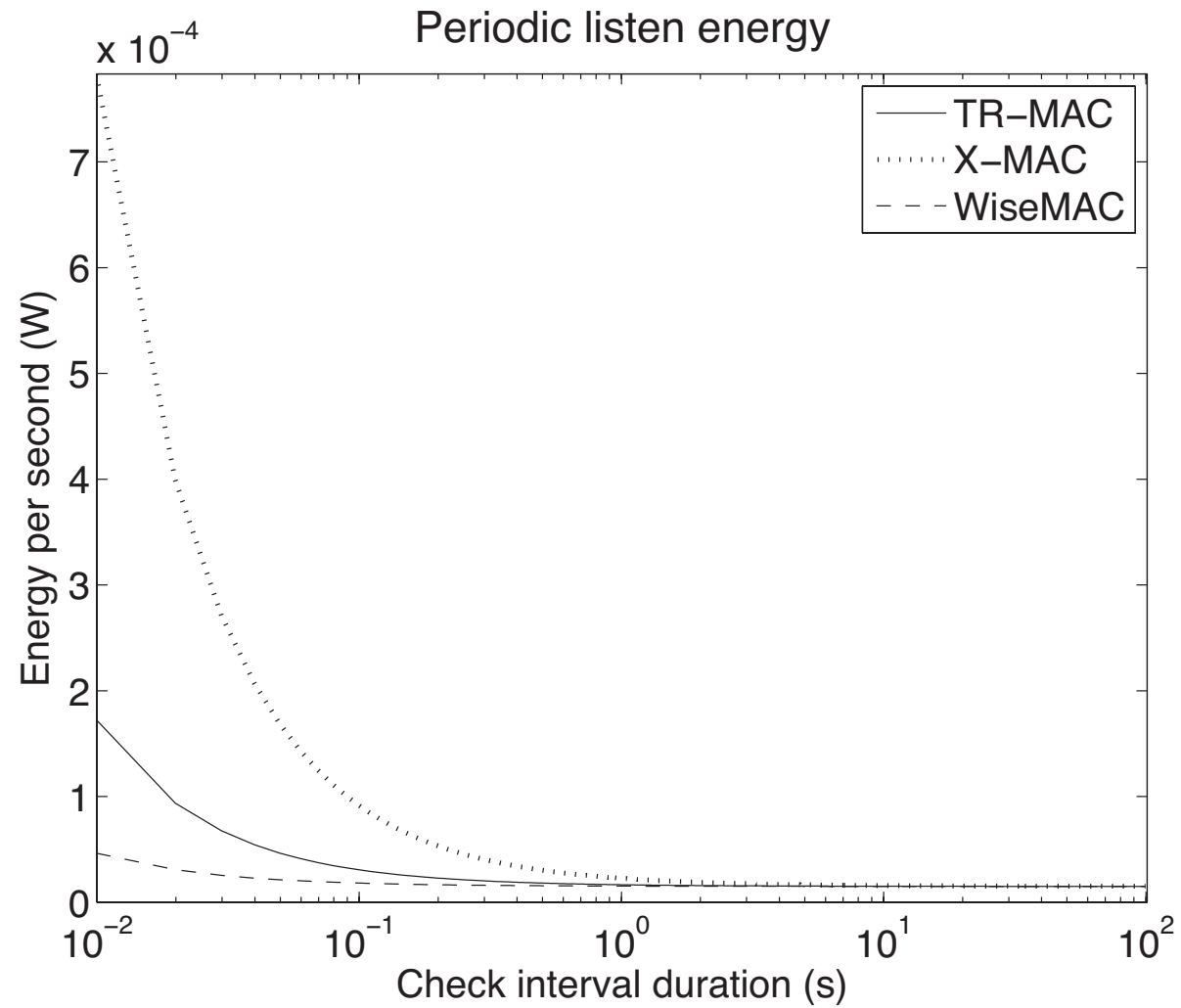
- Analytical Model (Equations are available in paper)
- Data rate = 25 kbps
- Data packet = 8 bits preamble + 16 bits header + 32 bits data
- ACK packet = 8 bits preamble + 16 bits header
- Check interval duration (T_w) = Periodic listen (T_i)
+ Sleep duration (T_s)

Parameters	TR-MAC	X-MAC [4]	WiseMAC [7]
Preamble duration, T_P	8 bits (.32 ms)	65 bits (2.6 ms)	T_w
ACK duration, T_A	24 bits (.96 ms)	65 bits (2.6 ms)	80 bits (3.2 ms)
Header duration, T_H	16 bits (.64 ms)	16 bits (.64 ms)	16 bits (.64 ms)
Data duration, T_{Data}	32 bits (1.28 ms)	32 bits (1.28 ms)	32 bits (1.28 ms)
Data+header duration, T_D	56 bits (2.24 ms)	48 bits (1.92 ms)	48 bits (1.92 ms)
Power to send, P_{Tx}	2 mW	1 mW	1 mW
Power to receive, P_{Rx}	1 mW	1 mW	1 mW

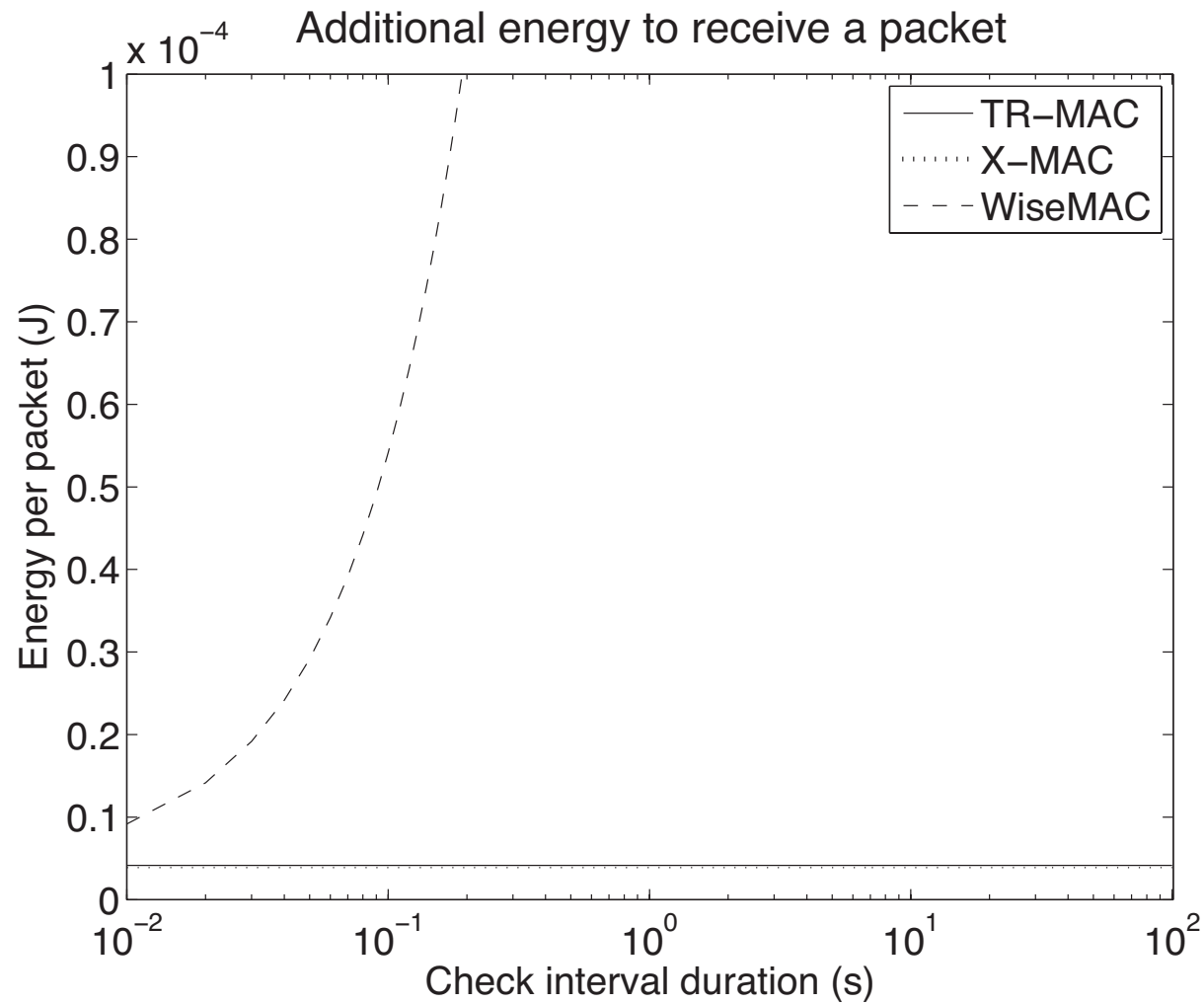
Energy to Send a Packet



Periodic Listen Energy



Additional Energy to Receive a Packet





Conclusion

- TR-MAC with noise-based TR modulation is
 - Energy-efficient by optimally exploiting characteristics of TR modulation
 - Suitable for short range low data rate applications
 - Flexible towards applications and network layer



Future Work

- Model the synchronized link stage for TR-MAC and compare with X-MAC and WiseMAC
- Compare TR-MAC with some other protocols that send data instead of preamble
- Finally, energy harvesting will be incorporated in the model in future

Comments & Questions

