Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [State of the Art in Asynchronous Low Power MAC]
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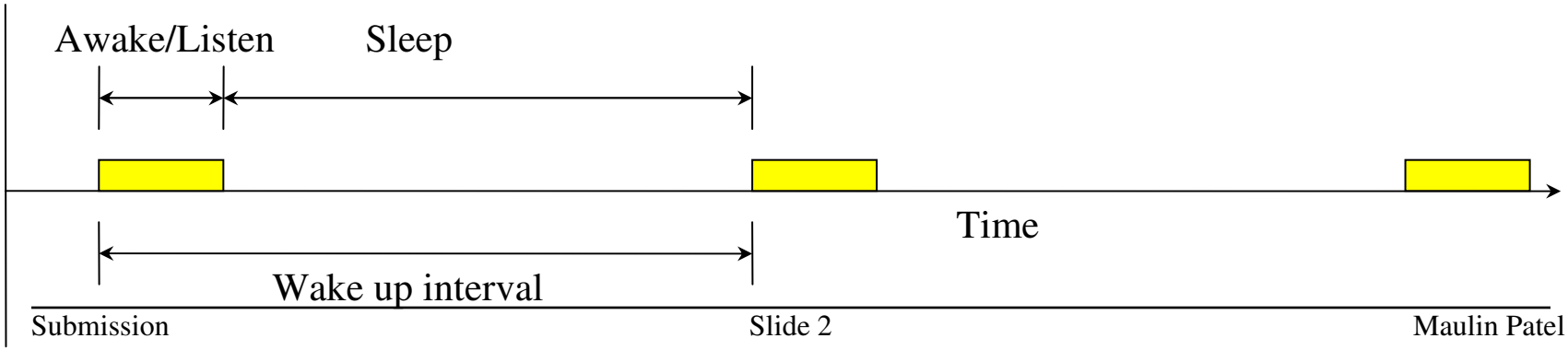
Abstract: [This document presents the state of the art low power MAC protocol proposed in the literature and analyses their pros and cons from the BAN perspective]

Purpose: [To analyze the pros and cons of asynchronous low power MAC protocol proposed in the literature]

Introduction

- Low power MAC protocols typically
  - Trade-off throughput, delay, QoS and scalability
  - For energy efficiency
- Energy is saved by
  - Duty cycling the receiver between the listen and the sleep state
  - Minimizing
    - Idle listening
    - Overhearing
    - Collisions
    - Control overhead



State of the Art in Low Power MAC

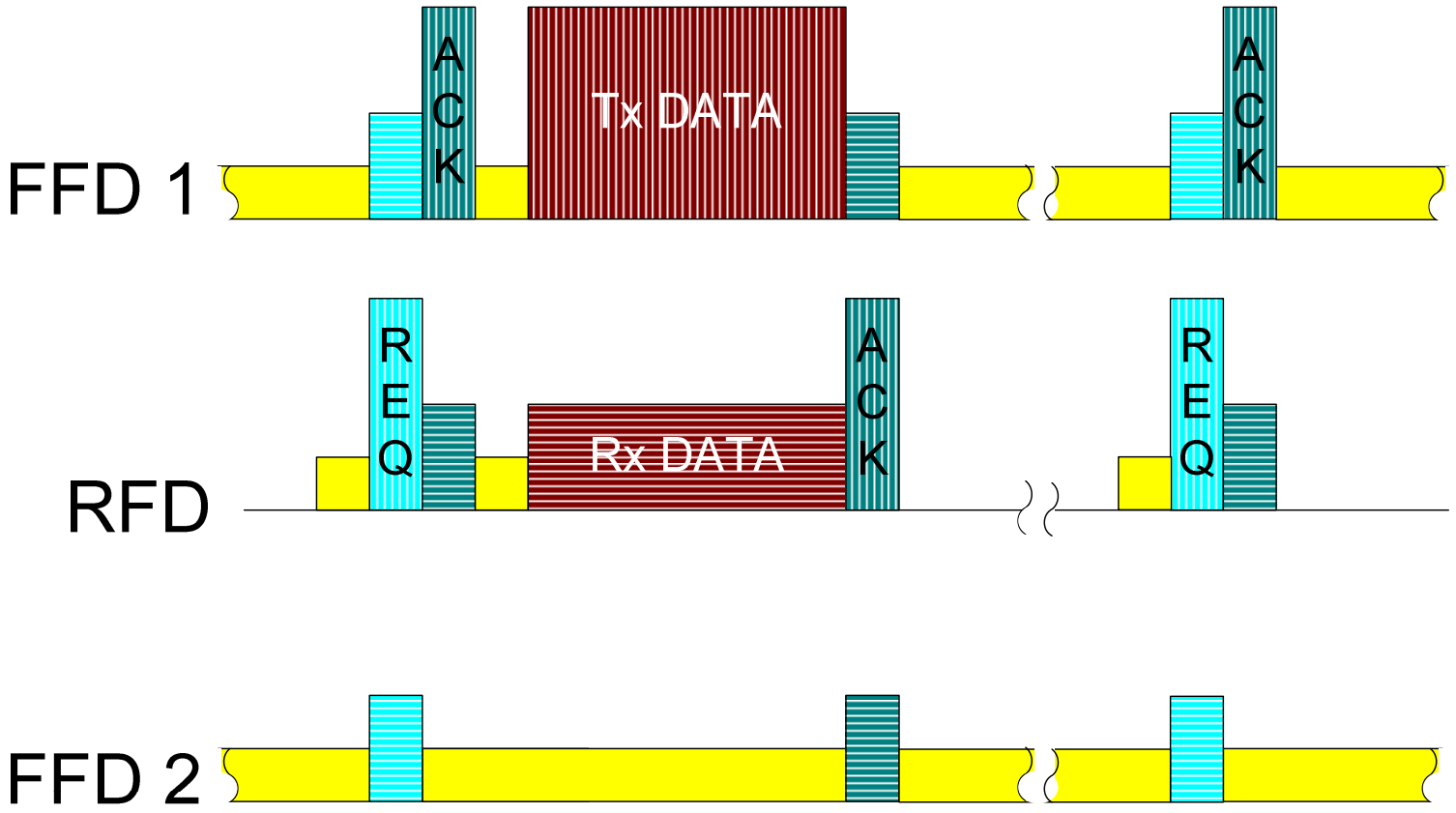
Synchronous	Asynchronous
• Periodically advertise sleep and wake up schedule and synchronize awake time • Explicit synchronization mechanism such as beaconing • E.g. S-MAC, T-MAC, SCP-MAC, IEEE 802.15.4 (Beacon enabled mode)	• Sender and listener can have independent sleep and awake times • No need for explicit synchronization • E.g. B-MAC, WiseMAC, X-MAC, IEEE 802.15.4 (Non-beaconing mode)

Common objective: Reduce idle listening, overhearing and collisions

Main Approach: Duty cycling between sleep and awake state

Asynchronous protocols

- IEEE 802.15.4 Non-beaconing Mode

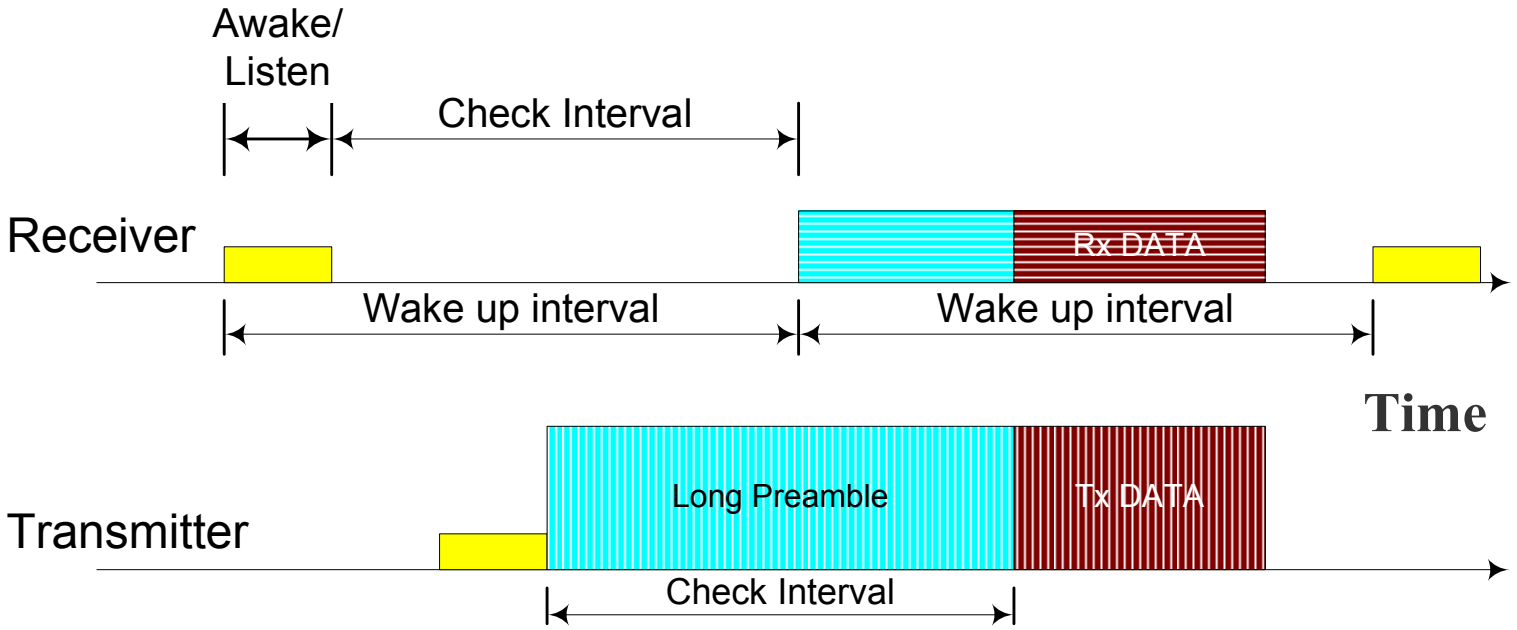


Why IEEE 802.15.4 is unsuitable for BAN?

- Primarily designed to support home control, lighting, industrial monitoring, meter reading and other applications
  - Infrastructure nodes are mains powered
  - Portable or mobile nodes are battery powered
    - E.g. remote control
- Full function devices are always listening
  - 100% duty cycle
  - FFDs do not conserve power
  - RFDs conserve maximum power
  - Asymmetric power consumption
- Reduced function devices can sleep for prolonged period of time
  - RFDs periodically wake up and poll data from FFD
- Very little QoS provision
  - Unslotted CSMA-CA
  - No provisions for prioritization

Preamble Sampling MAC

- Periodically wake up and listen channel using preamble detection technique
  - If no activity, go back to sleep until scheduled wake up time
  - Else, start receiving packet
- Preamble Length > Check-Interval



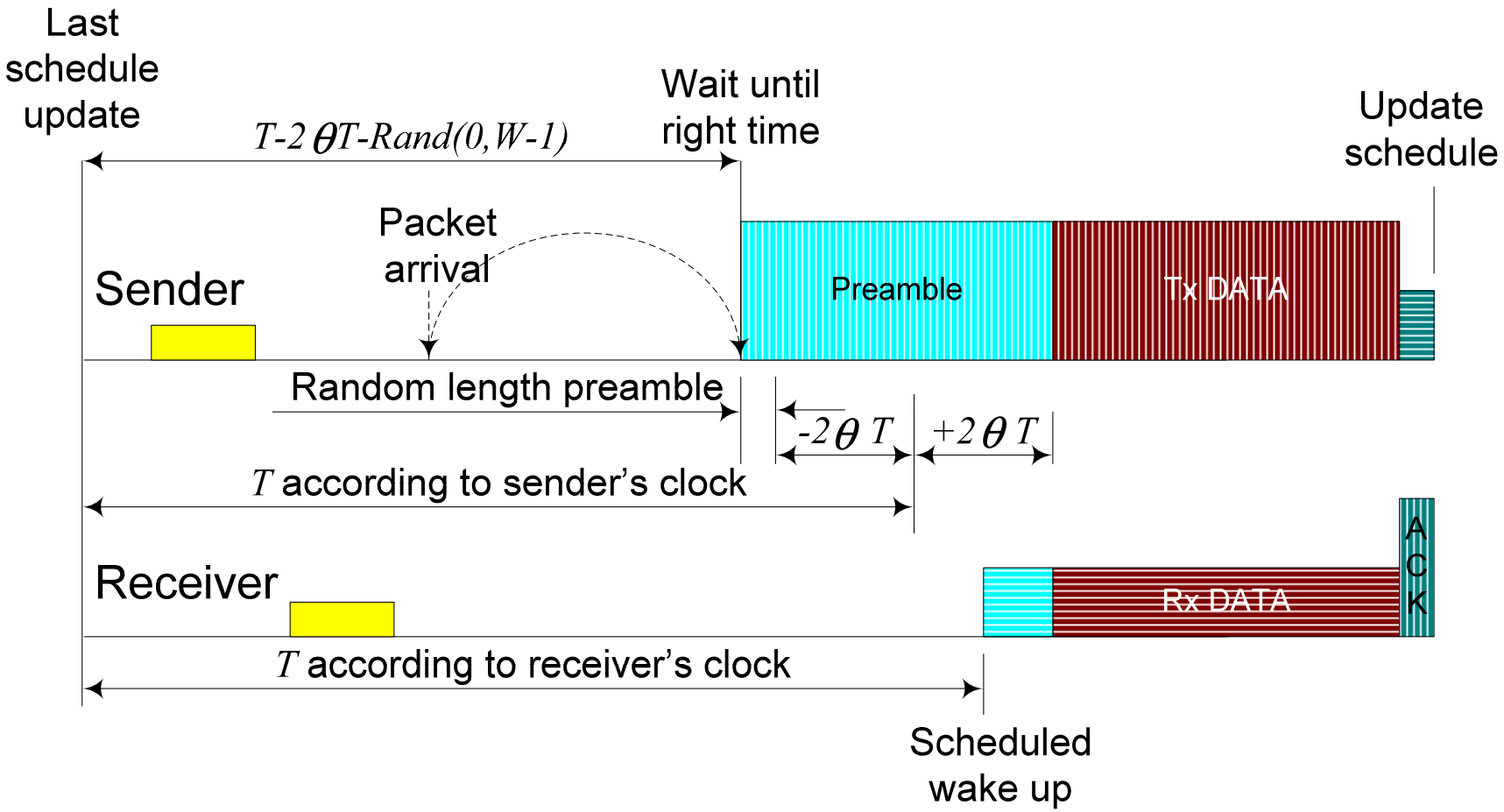
Preamble Sampling MAC (Cont'd)

- Long Preamble
  - Pros:
    - Long check interval
    - Nodes sleep longer
    - Less idle listening
    - Saves energy
  - Cons:
    - Channel occupied for too long which decreases throughput
    - Message delays increases
    - Higher probability of collision
    - More energy consumed in transmitting long preambles
    - Overhearing preamble all the nodes in neighborhood wake up (false alarm)
- Not suitable for adaptive duty cycling and broadcast/multicast

WiseMAC's approach to long preamble and overhearing problems

- WiseMAC piggybacks the next wake up time of the receiver in the acknowledgement
- Sender begins its preamble transmission just before scheduled wake up time of the receiver
- Start time of preamble and the duration of the preamble are calculated to compensate the clock drift between the sender and the receiver
- The clock drift is proportional to the time elapsed since the last acknowledgment received
- Gradually, due to clock drift the preamble length can grow as large as the check interval
- Limitation:
  - In WiseMAC, the check intervals are constant which precludes adaptive duty cycling

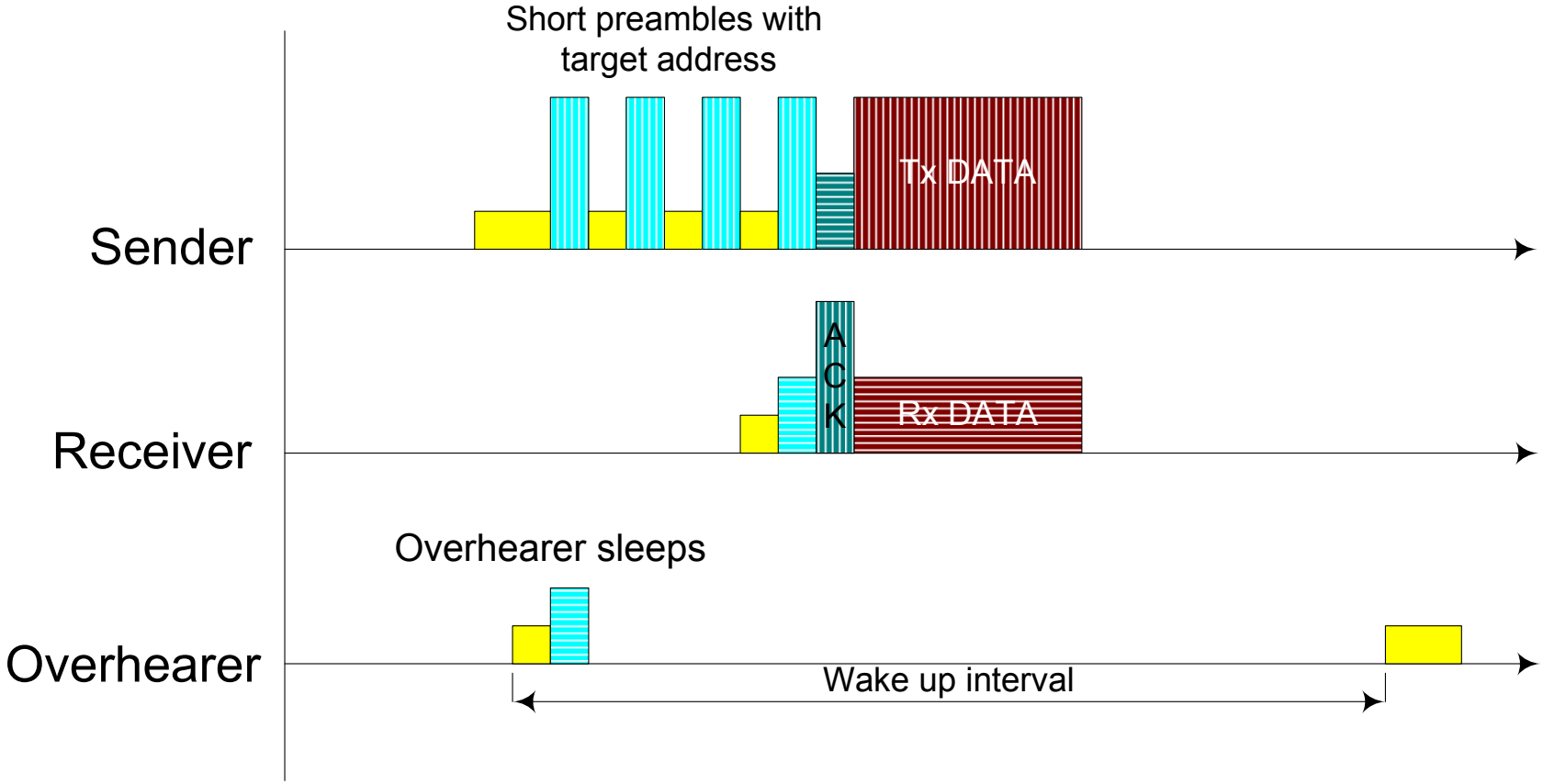
WiseMAC's approach to long preamble and overhearing problems (Cont'd)



WiseMAC's approach to long preamble and overhearing problems (Cont'd)

- When the length of the preamble exceeds the length of the data packet, the packet is composed of padding bits followed by repetitions of the data frames
- Non-target receivers can go back to sleep as soon as they receive the data packet and find out that the packet is not destined for them
  - Less overhearing
- Limitations:
  - Sender has to send the long preamble/data even though the receiver has woken up at the beginning
  - Receiver has to listen to the long preamble/data
  - Wastage of time and the energy

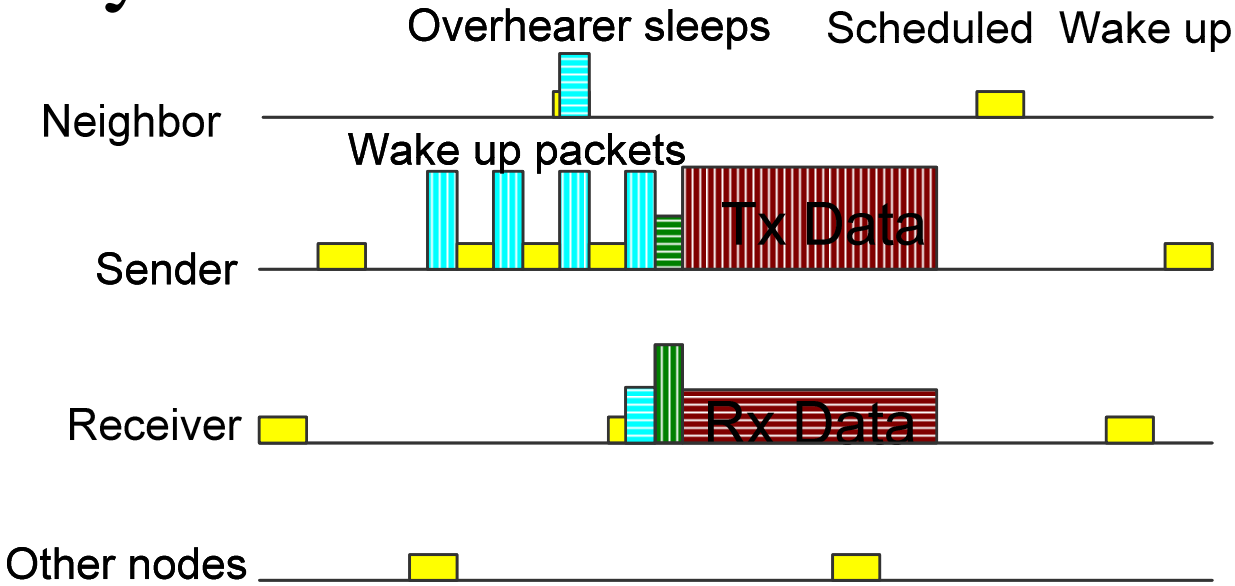
XMAC's approach to long preamble and overhearing problems



XMAC's approach to long preamble and overhearing problems (Cont'd)

- XMAC protocol embeds the ID of the target node into the preamble
- Non-target neighboring nodes can find out that they are not the intended receivers
  - Non-target nodes go back to sleep
  - Reduced overhearing
- Preamble is paused to allow target device to send back a short early ACK message
- Paused preamble saves time and energy
- Listen interval of the receiver is longer than the pause interval
  - Ensures that a receiver does not miss any preamble due to pauses

Asynchronous Access Mechanism



- Pros:
  - Low energy consumption
  - lower latency
  - No synchronization overhead
  - Independent wake up schedules
  - Lower probability of collision
- Cons:
  - Not suitable for
    - QoS
    - Broadcast/multicast
    - Device discovery

Listening to the medium for activity

References

- [IEEE 802.15.4] IEEE 802.15 WPAN Working Group, “Standard for Part 15.4 (2006): Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (LR-WPANs)”, ANSI/IEEE 802.15.4, 2006.
- [WiseMAC] A. El-Hoiydi and J.-D. Decotignie “WiseMAC: An Ultra Low Power MAC Protocol for the Downlink of Infrastructure Wireless Sensor Networks” in the Proceedings of the 9th IEEE Symposium on Computers and Communication, ISCC’04, June 2004.
- [B-MAC] Joseph Polastre, Jason Hill and David Culler, “Versatile Low Power Media Access for Wireless Sensor Networks”, in Proceedings of the ACM SenSys, Nov. 2004
- [X-MAC] Michael Buettner, Gary V. Yee, Eric Anderson and Richard Han, “X-MAC: A Short Preamble MAC Protocol for Duty-Cycled Wireless Sensor Networks” in Proceedings of the ACM SenSys, Nov. 2006