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

Submission Title: [State of the Art in Synchronous Low Power MAC]
Date Submitted: [17th March 2008]
Source: [Maulin Patel] Company [Philips]
Address [345 Scarborough Rd., Briarcliff Manor, NY 10510]
Voice:[+1 914-945-6156], FAX: [+1 914-945-6330], E-Mail:[maulin.patel@philips.com]

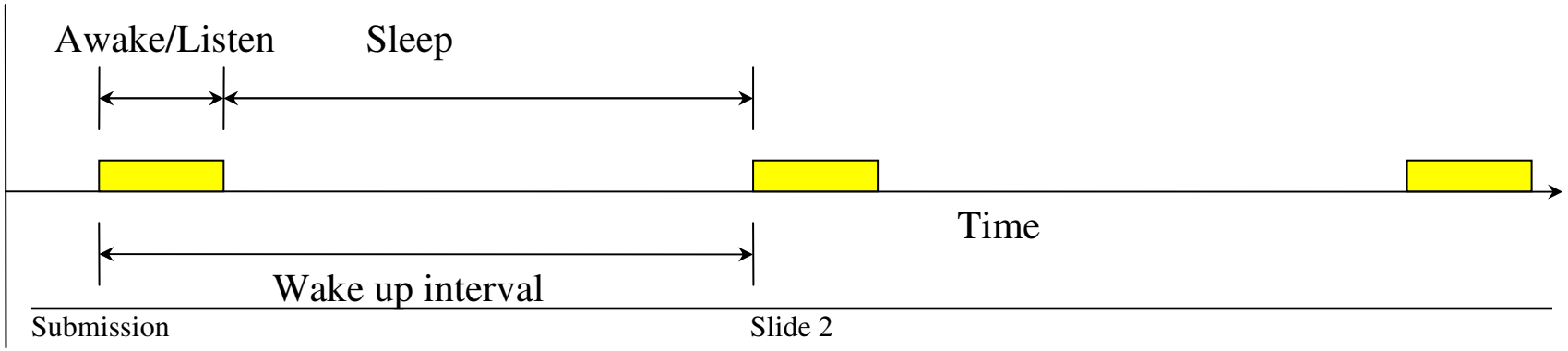
Re: []

Abstract: [This document presents the state of the art low power MAC protocol proposed in the literature and analyses its pros and cons from the BAN perspective]

Purpose: [To analyze the pros and cons of synchronous 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

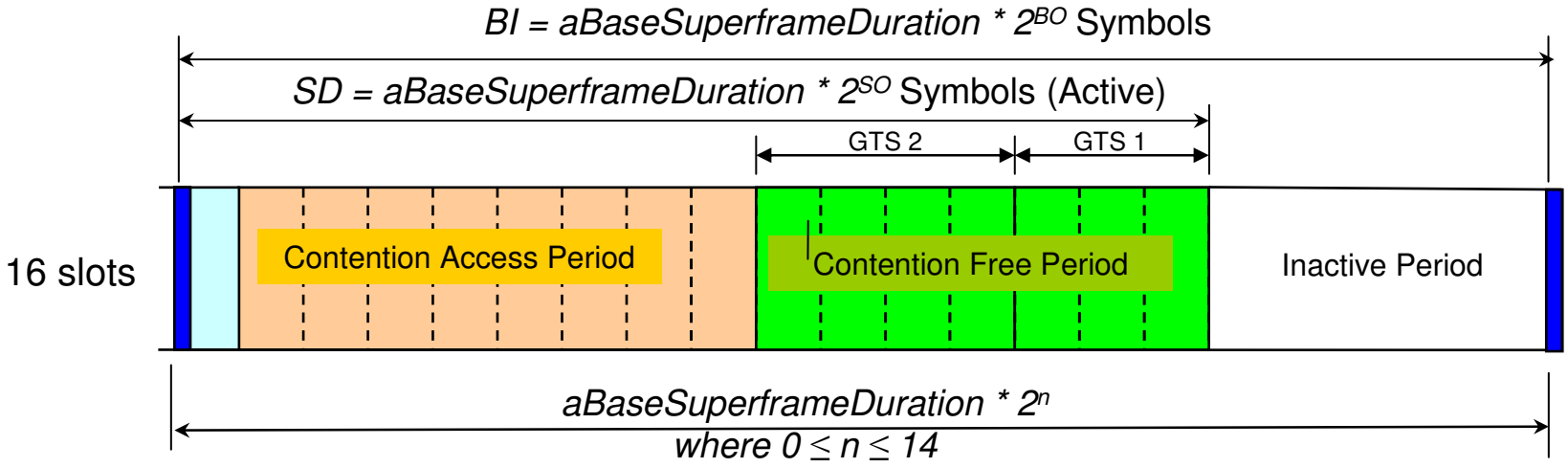
Synchronous	Asynchronous
• Periodically advertise sleep and wake up schedule and synchronize awake time • Explicit synchronization mechanism such as beaconing • E.g. S-MAC, T-MAC, SCP-MAC, IEEE 802.15.4 (Beacon enabled mode)	• Sender and listener can have independent sleep and awake times • No need for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

Synchronous protocols

- IEEE 802.15.4 (Beacon enabled mode) Superframe Structure

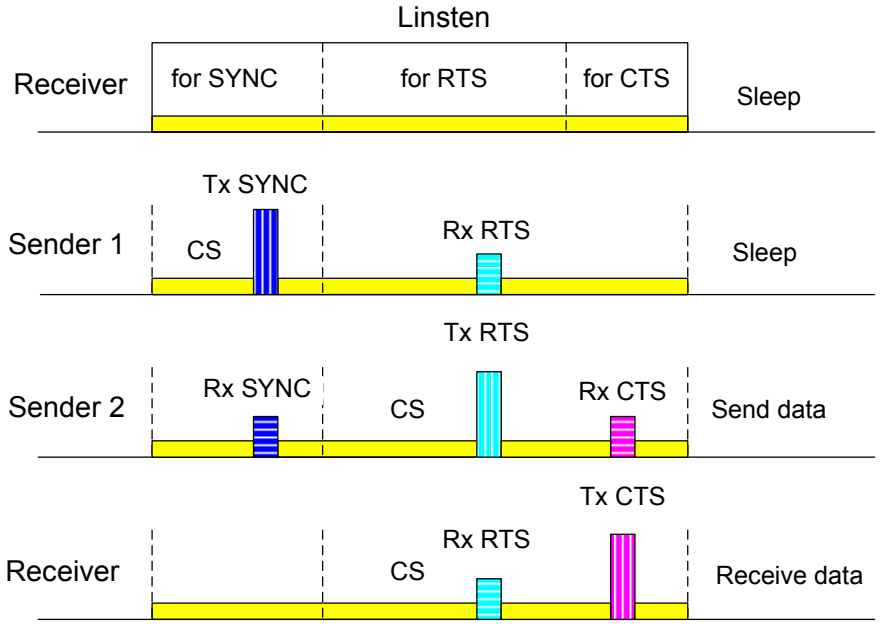


Network beacon		Transmitted by network coordinator. Contains network information, frame structure and notification of pending node messages.
Beacon extension period		Space reserved for beacon growth due to pending node messages
Contention period		Access by any node using CSMA-CA
Guaranteed Time Slot		Reserved for nodes requiring guaranteed bandwidth.

Why IEEE 802.15.4 is unsuitable for BAN?

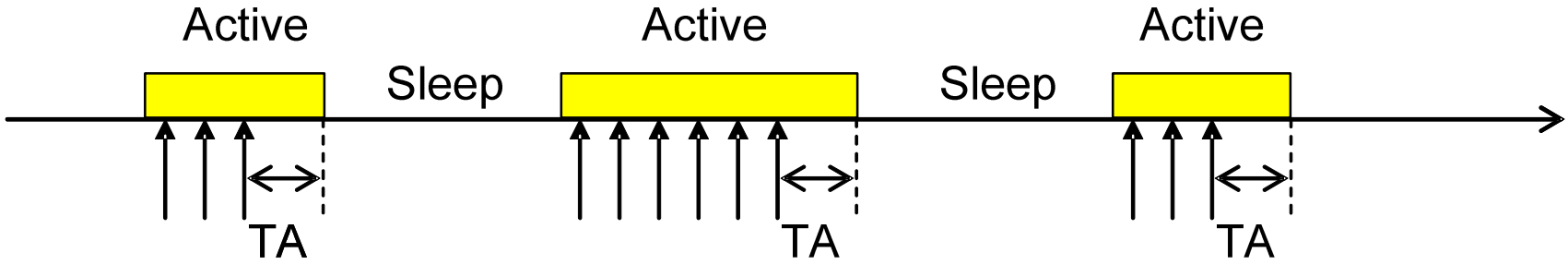
- Primarily designed to support star/tree topology in beaconing mode
- Centralize architecture
  - Failure of PAN-coordinator in star/tree network could disrupt the network
  - Takeover mechanism to mitigate PAN-coordinator failure are not defined
- Provisions for dynamic and flexible adaptation of superframe size and duty cycle are missing
  - Not adaptive to load and latency requirement
  - Fixed superframe size and beacon intervals invariably leads to either over provisioning or under provisioning
    - Over provisioning leads to higher energy consumption
    - Under provisioning leads to poorer QoS
- Very little QoS provision
  - Only 7 GTS and that too only for PAN coordinator
  - Not reliable enough for medical applications
- No provisions for detecting and resolving overlapping superframes
  - Beacon collisions could be disruptive
- Does not support mobility and co-existence

S-MAC (Synchronous-MAC)



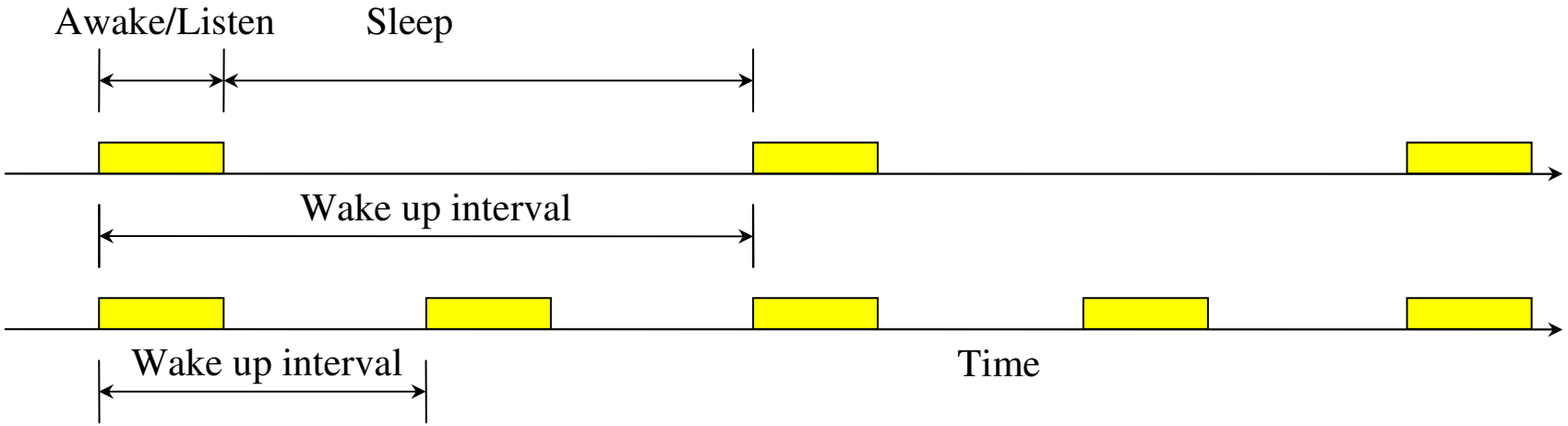
- Periodic listen and sleep, RTS-CTS handshake based MAC protocol
- Synchronized sleep and wake up schedules using periodic SYNC packets
- Network gets partitioned in virtual clusters
- Adaptive listening to reduce end-to-end latency
  - Overhearing nodes wake up at the end of data transmission for short duration
- Overall high latency
- Fixed duty cycle limits the performance

T-MAC (Timeout-MAC)



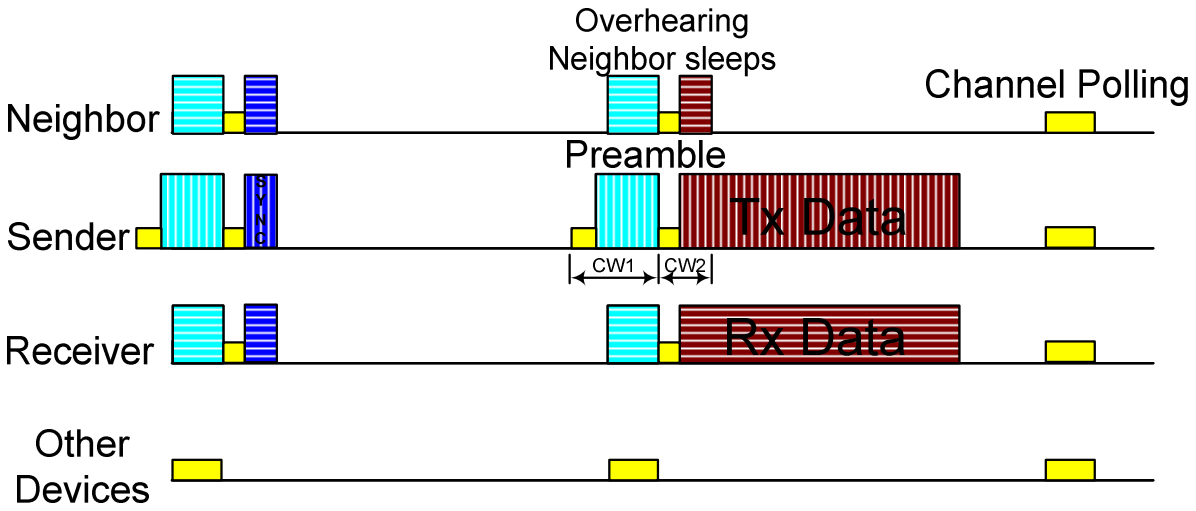
- Very similar to S-MAC
- Dynamically adjusts the duty cycle by changing the active time
- The active period ends if no activation event occurs during threshold amount of time
- The activation event could be
  - Transmission or reception of data
  - Sensing of medium activity
  - End of neighbor's data transmission
- Overall high Latency
- Variable duty cycle

DSMAC (Dynamic S-MAC)



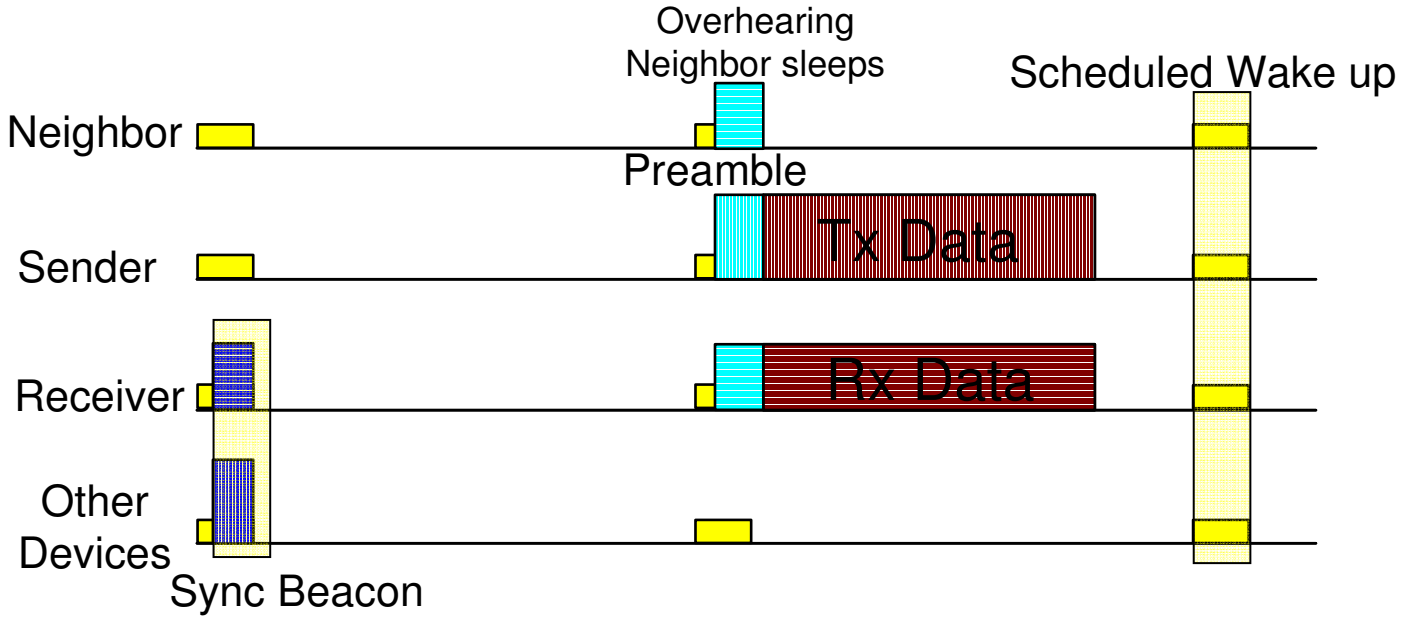
- Extends SMAC by enabling adaptive duty cycling
- Nodes track the average delay in transmitting the message
- If the average delay exceeds the predetermined maximum then the receiver doubles its duty cycle
- The duty cycle is dynamically increased (or decreased) in multiplicative powers of 2 and announced in SYNC packets
  - To match varying traffic and latency requirements
- Decreases the latency at the cost of increased energy consumption due to increased duty cycle

SCP-MAC (Schedule Channel Polling MAC)



- Nodes periodically send SYNC packets to synchronize their active times
- Potential senders contend to transmit a preamble during first CW which overlaps with receiver's active time
- Nodes sensing the medium idle during first CW go back to sleep
- Winners of first phase contention contend again to transmit data during second contention window
- Losers continue to listening to the medium
- Adaptive listening and multi hop streaming minimizes latency

Synchronous Access Mechanism



- Pros:
  - Suitable for QoS
  - Medium reservation
  - Broadcast/multicast
  - Co-existence
- Cons:
  - High synchronization overhead
  - Increased latency
  - Increased energy consumption
  - Higher probability of collision

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.
- [S-MAC] Wei Ye, John Heidemann and Deborah Estrin, “Medium Access Control With Coordinated Adaptive Sleeping for Wireless Sensor Networks” IEEE/ACM Transactions on Networking, Vol. 12, No. 3, June 2004.
- [T-MAC] Tijs van Dam and Koen Langendoen "An Adaptive EnergyEfficient MAC Protocol for Wireless Sensor Networks” in Proceedings of ACM SenSys, Nov. 2003
- [DSMAC] Peng Lin, Chunming Qiao and Xin Wang, “Medium Access Control With A Dynamic Duty Cycle For Sensor Networks” in Proceedings of the IEEE WCNC 2004
- [SCP-MAC] Wei Ye, Fabio Silva and John Heidemann “Ultra-Low Duty Cycle MAC with Scheduled Channel Polling” in Proceedings of ACM SenSys Nov. 2006