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

Submission Title: [Case Study: Preamble-based TDMA Protocol for Non-invasive WBAN]
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Abstract: [We study energy consumption of a non-invasive WBAN and propose a Preamble-based TDMA (PB-TDMA) protocol. We compare the proposed one with IEEE802.11 DCF and S-MAC in terms of energy consumption and packet delivery ratio and show that the proposed one outperforms among others. The PB-TDMA is one good candidate for in/on Body Area Network.]
Purpose: [To be considered in IEEE 802.15.6 standard]

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Introduction

- A wireless body area network (WBAN) allows the integration of low power, invasive or noninvasive miniaturized sensors around a human body.
- The data transmission rate of various biosensors is heterogeneous.
- The limited energy resources and computational power of these sensors have urged the development of low power energy efficient MAC protocol.
- We study the performance of preamble based time division multiple access (PB-TDMA) protocol for a heterogeneous non invasive WBAN.
- PB-TDMA protocol outperforms S-MAC and IEEE 802.11 DCF in terms of throughput and power consumption.

Related Work

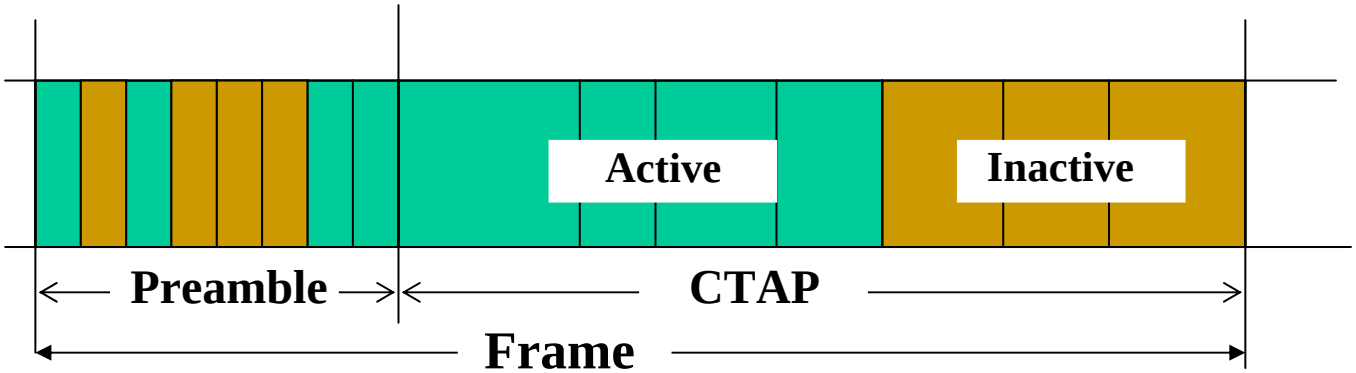
- H-MAC [1] exploits the biosignal features to improve energy efficiency.
- IEEE 802.15.4 [2]
  - **Non beacon enabled mode**
    - **Coordinator cannot communication with biosensors**
  - **Beacon enabled mode**
    - **Beacon overhearing**
  - **Not always enough**
- Traffic of biosensors: Heterogeneous characteristics
  - **MAC protocol for this property: Not yet studied & applied to WBAN**

Preamble Based TDMA Protocol

- In the preamble based TDMA Protocol [3], nodes are assigned specified slots for collision free data transmission and slots are repeated in fixed cycle.
- Each TDMA frame contains a preamble and a data transmission slot.
- A node always listens the channel during preamble and transmits in a data transmission slot.
- The preamble contains a dedicated subslot for every node.
- Subslots are used to activate the destination node by broadcasting the destination node ID of outgoing packet.
- Each node turns off its radio when it has no data to transmit.
- The radio is turned on, when the node finds its ID in the preamble or when the node has data to transmit.

Preamble Based TDMA Protocol

- Frame: a preamble for fixed TDMA-slots reservation and CTAP for SM allocation data slots



- Preamble activates destination node: nodes 1, 3, 7, 8
- Coordinator allocates Statistical Multiplexed (SM) CTAs based on TDMA reservation Preamble: 1, 3, 7, 8
- Sleep, when no data to transmit: nodes 2, 4, 5, 6
- Wake-up, when destination node ID is in preamble

Simulation Setup

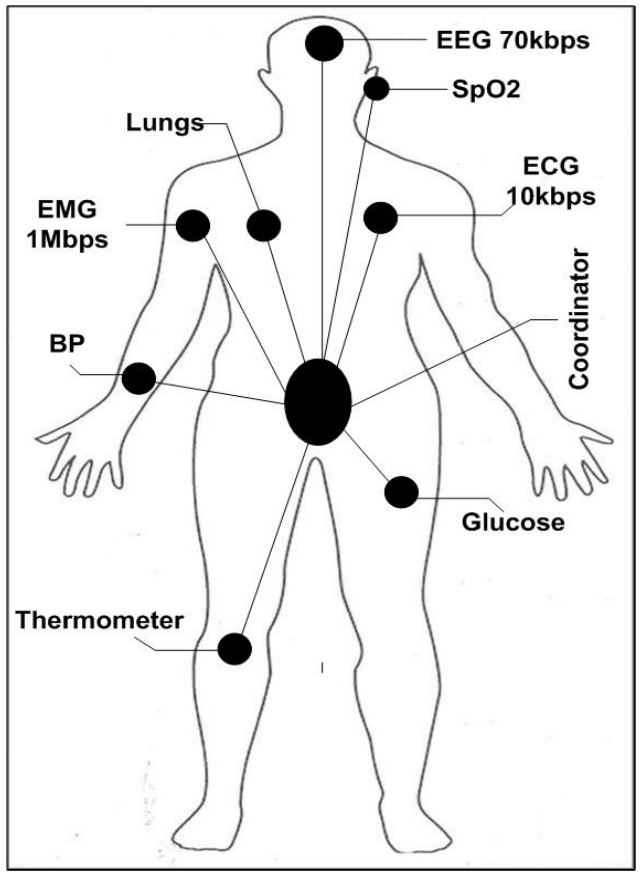
- PHY Setup
  - Low power Nordic nRF2401 transceiver [4]
  - Operation in 2.4-2.5 GHz band
  - Optimum transmission power
    - -5 dBm (verified up to -45 dBm)
  - Shadowing model used

Table1. Simulation Parameters

Parameter	Measured Value
Shadowing propagation model	
Path loss exponent	7.4
Reference distance	0.1m
Wavelength	0.125m
Shadow deviation	9dBm
Transmitting antenna gain	1.0
Receiving antenna gain	1.0
Nordic nRF2401	
Output power	-5 dBm
Maximum data rate	1000kbps
Supply current in transmit	10.5mA
Supply current in receive	18mA
Sensitivity	-90dBm
Threshold to avoid collision	-95dBm
Voltage	1.9V

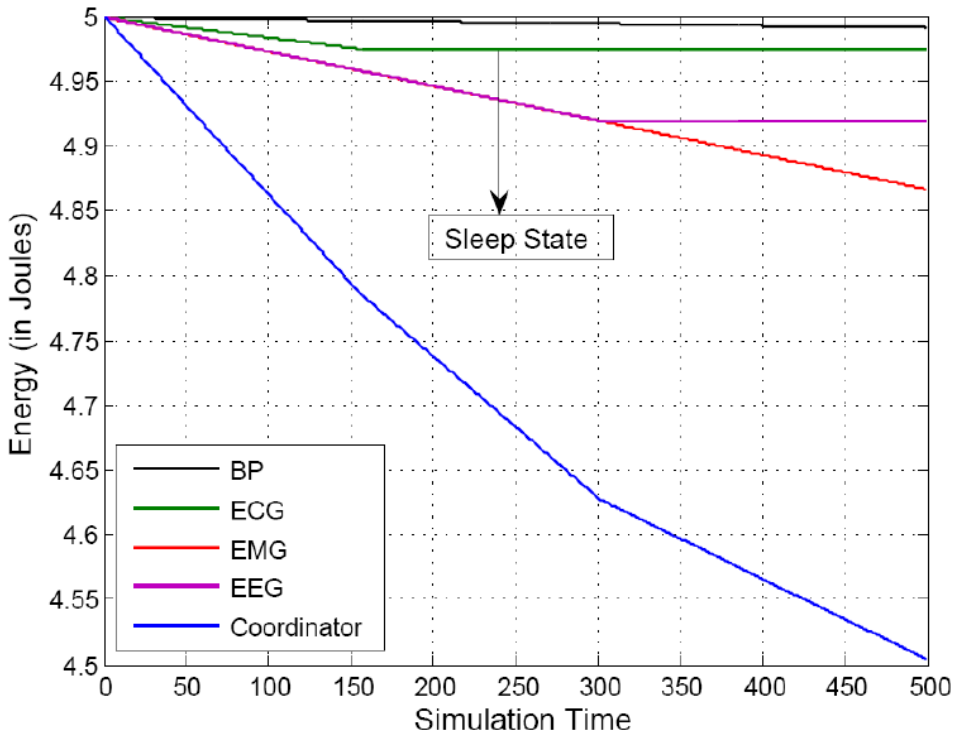
Simulation Setup

- Topology: Star in dimension of 1x1 m^2
- Traffic model: cumulative CBR (8 nodes)
  - BP/others-1kbps
  - ECG - 10kbps,
  - EEG - 70kbps
  - EMG - 1Mbps
- Packet size: 128 bytes
- M (Sensors) to 1 (Coordinator) transmission
- Context aware information



Simulation Results

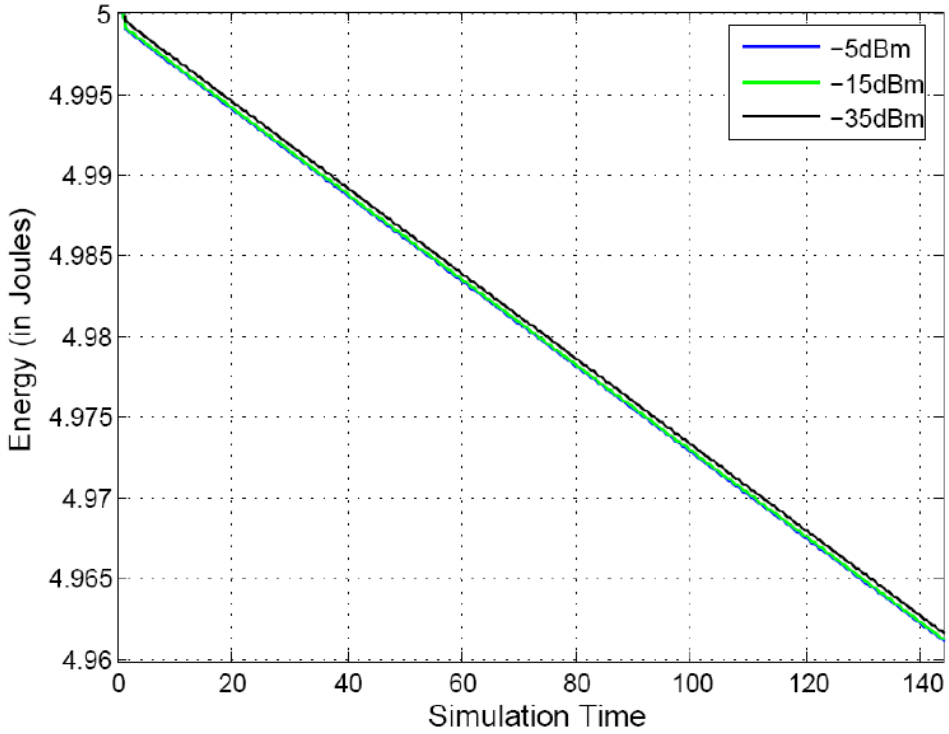
- Coordinator powers on all the operation period as a manager, which may be connected power line.
- BP consumes least energy
- ECG starts sleep state at time of 150
- EEG starts sleep state at 300



Energy loss at sensor nodes

Simulation Results

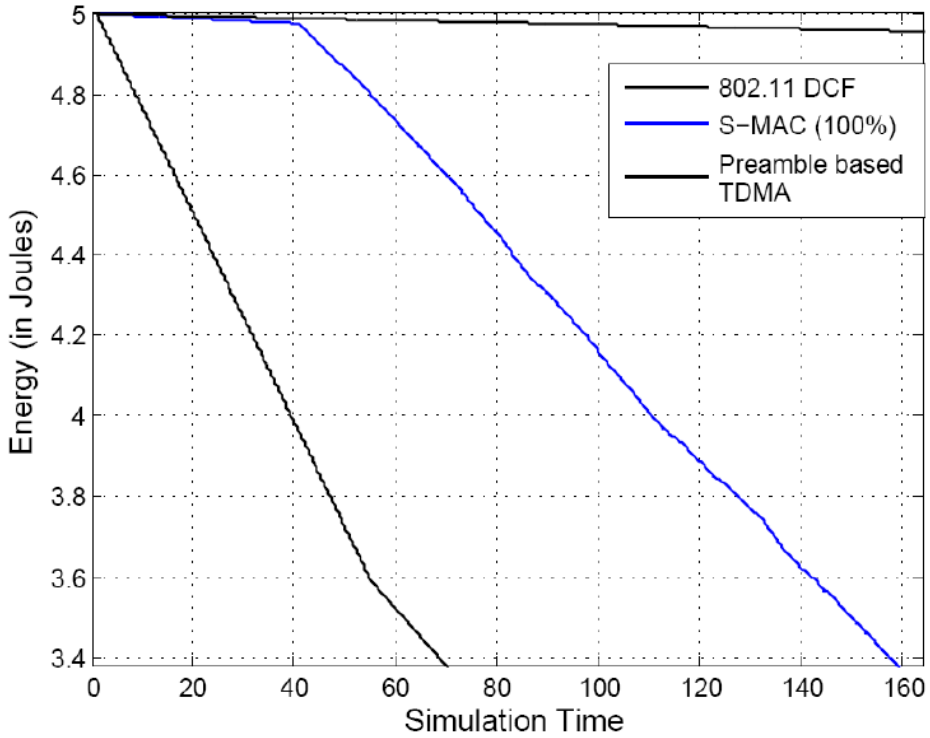
- Show nearly independency in terms of total energy consumption for deferent output power of each sensor node.



Energy loss at EMG sensor for different transmission power

Simulation Results

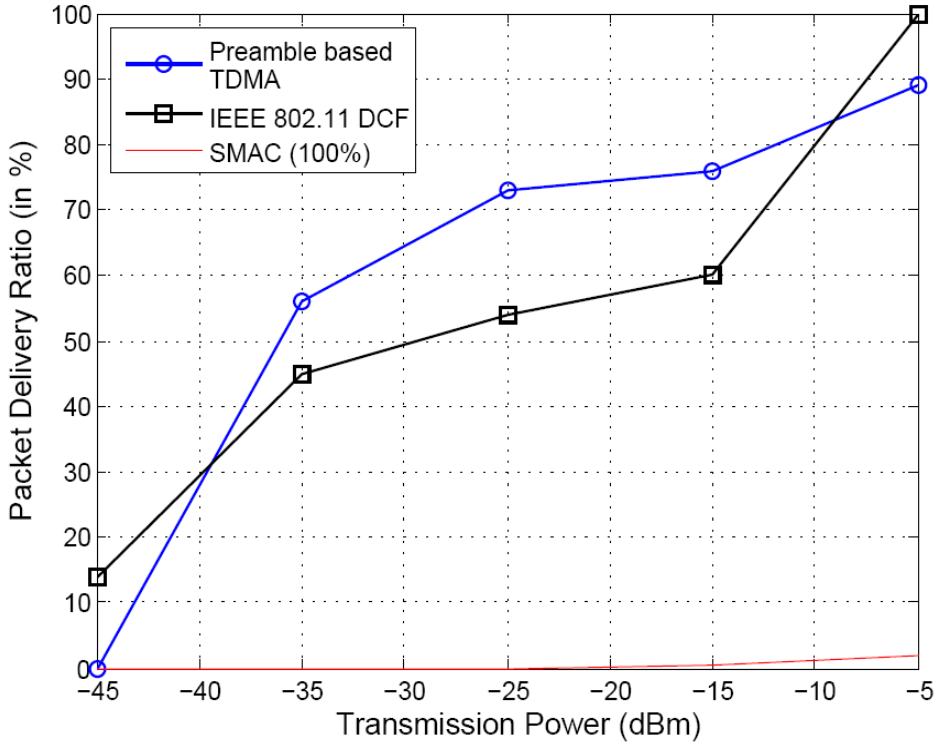
- Assume S-MAC uses 100% duty cycle.
- Performance of 802.11 DCF works worst in terms of energy consumption
- PB-TDMA works better in battery life and level of energy among the 3 candidates



Energy loss at EMG sensor for various MAC protocols

Simulation Results

- Assume S-MAC uses 100% duty cycle.
- S-MAC works worst in terms of packet delivery ratio
- PB-TDMA shows equivalent performance which is much better than S-MAC.



Packet delivery ratio of PB-TDMA and IEEE 802.11 DCF

Remarks on PB-TDMA

- PB-TDMA has network architecture of star topology with a coordinator and several nodes.
- PB-TDMA has a frame with preamble and payload fields
- Preamble has fixed TDMA reservation slots for given biosensors
  - **Overhead of this preamble is very small.**
- CTAP is allocated via the coordinators using statistical TDMA scheme
  - **CTAP has active part and inactive part which improves performance**
- PB-TDMA can efficiently manage a number of biosensors for on-body or in-body environment.
- PB-TDMA outperforms IEEE 802.11 DCF and S-MAC protocols.
- Heterogeneous characteristics of biosensors: PB-TDMA protocol is one good candidate

Conclusions

- PB-TDMA outperforms IEEE 802.11 DCF and S-MAC protocols.
- Heterogeneous characteristics of biosensors in on/in-WBAN
  - Requires innovative solution
- Additional efficient power management scheme is required.
- Further consideration:
  - Consider sporadic and periodic traffic, both controlled by one MAC
  - Non medical applications

References

[1] Huaming Li, Jindong Tan, “Medium Access Control for Body Sensor Networks”, *Proceedings of 16th International Conference on Computer Communications and Networks*, pg 210-215, ICCCN 2007

[2] Nicholas F. Timmons, William G. Scanlon, “Analysis of the performance of IEEE 802.15.4 for medical sensor body area networking”, IEEE SECON 2004

[3] http://www.isi.edu/nsnam/ns/doc/node178.html

[4] http://www.sparkfun.com/datasheets/RF/nRF2401rev1_1.pdf