Abstract

Comprehensive study of Medium Access Control (MAC) protocols for Wireless Body Area Networks (WBANs)

On-body or implanted biomedical sensor nodes to monitor physiological signs

Temperature, Blood Pressure, ElectroCardioGram (ECG), ElectroEncephaloGraphy (EEG) etc.

Design requirements for WBANs with major sources of energy dissipation

Existing designed protocols for WBANs

Open research issues for future work

Introduction

Portable, small and lightweight sensor nodes for long time health monitoring

Data streaming from human body to monitoring station

Low power signal processing and energy efficient communication mechanisms

Low-Rate Wireless Personal Area Networks (LR-WPANs)

IEEE 802.15.4 defines specification for Physical Layer and Data Link Layer

Energy efficiency at MAC layer

Time Division Multiple Access (TDMA) or Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)

Shared Medium Access

Table : Comparison of CSMA/CA and TDMA

Feature	CSMA/CA	TDMA
Power Consumption	High	Low
Bandwidth utilization	Low	Maximum
Traffic level support	Low	High
Mobility(Dynamic)	Good	Poor
Synchronization	N/A	Necessary

Design Requirements for WBANs

- Energy Efficiency
  - MAC layer provides higher level of energy savings
  - Optimal packet structure, smart signaling techniques and enhanced channel access techniques
- Reliability
  - Depends upon transmission delay of packets and packet loss probability
  - Packet transmission procedures at MAC layer and Bit Error Rate (BER)
- Scalability
  - Easily configuration of WBANs
  - MAC layer has potential to achieve scalability
- Quality of Service (QoS)

Sources of Energy Dissipation in WBANs

Sensor nodes with limited power capabilities

Minimization of energy consumption at MAC Layer

Low power MAC protocols

Sources of Energy Dissipation:

Collision of packets

MAC Protocols for WBANs

IEEE 802.15.4 MAC Protocol

Battery-aware TDMA Protocol

Priority Guaranteed MAC Protocol

Energy-Efficient Low Duty Cycle MAC Protocol

A power-efficient MAC Protocol for WBANs

Energy Efficient Medium Access Protocol

BodyMAC

MedMAC

Heartbeat-Driven MAC Protocol

IEEE 802.15.4 MAC Protocol 1/2

Designed for low data rate wireless applications

Use 68 MHz, 915 MHz and 2.4 GHz frequency bands

Two operational modes are defined for IEEE 802.15.4:

Beacon enabled (slotted CSMA/CA)

IEEE 802.15.4 MAC Protocol 2/2

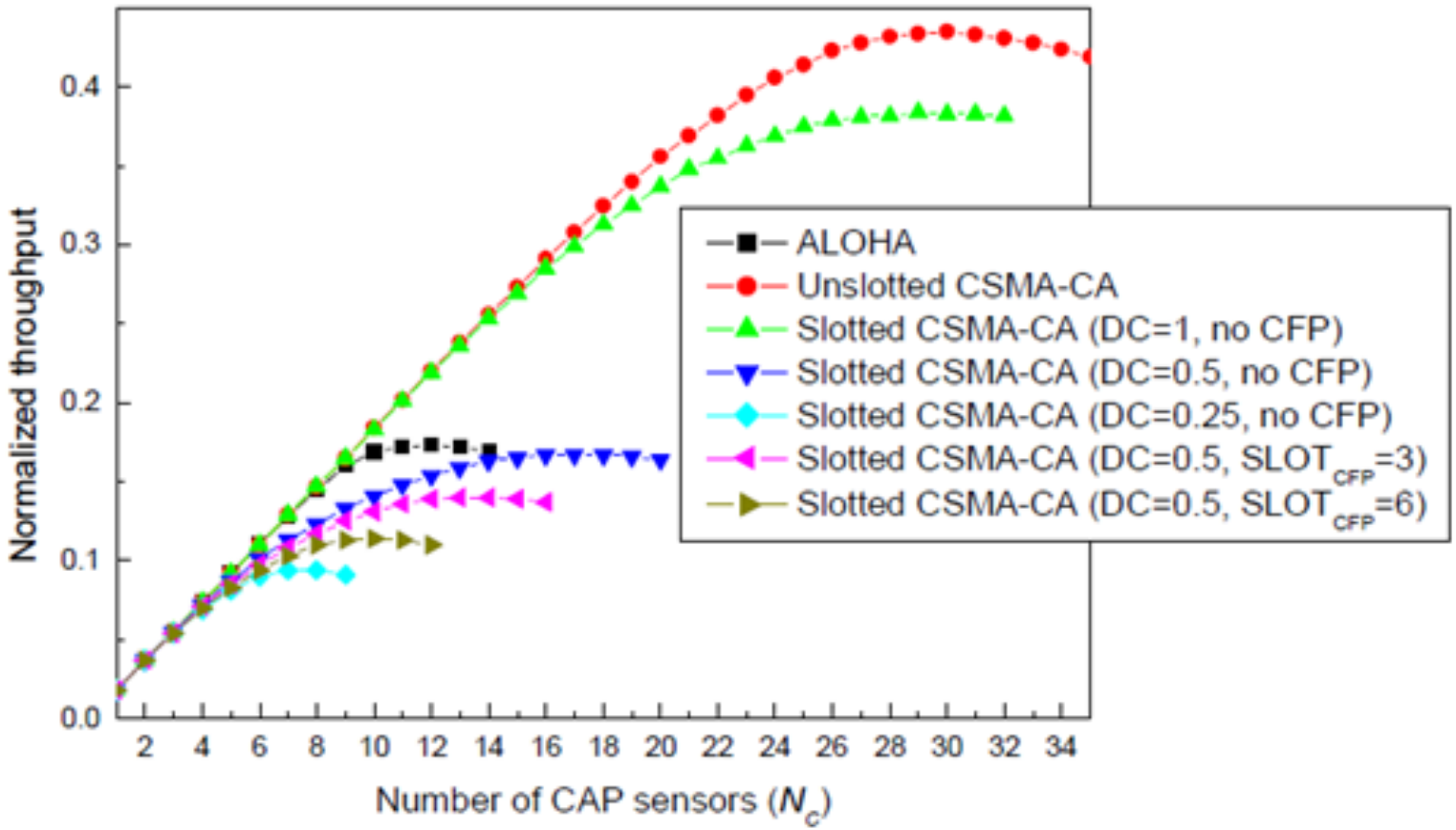

Figure : Normalized Throughput Versus NC

Battery-aware TDMA Protocol

Properties

- Electrochemical properties of battery, Time-varying wireless fading channel, and packet queuing characteristics
- Similar to IEEE 802.15.4 beacon enabled mode
- Beacon slot, active time slots and inactive period

Drawbacks

- No mechanism defined for emergency data
- High average delay and packet drop rate

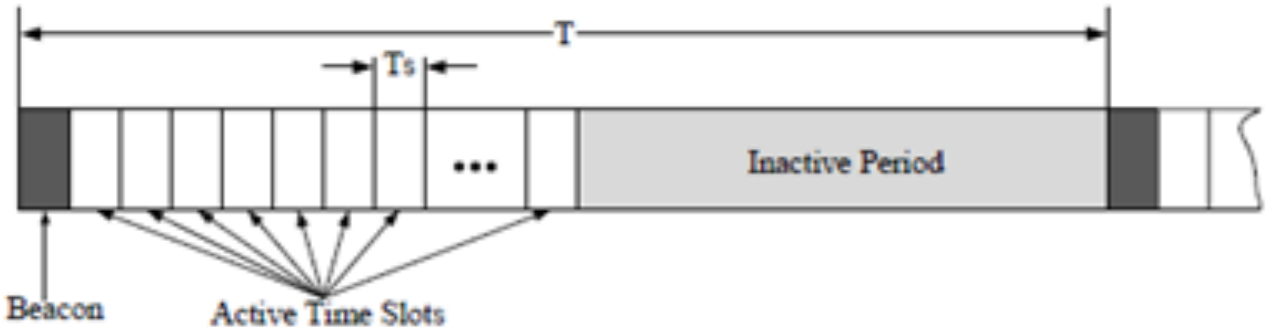

Figure : TDMA Frame Structure

Priority Guaranteed MAC Protocol

Properties

- Beacon, Control Channel AC1, Control Channel AC2, Time Slot Reserved for Periodic (TSRP) traffic, and Time Slot Reserved for Bursty (TSRB) traffic
- AC1 is used for uplink control of life-critical medical application
- AC2 is used for uplink control of Consumer Electronics (CE) applications
- Based upon TDMA approach to assign Guaranteed Time Slots (GTS)

Drawbacks

- Complex superframe structure
- Inadaptability to emergency traffic

Energy-Efficient Low Duty Cycle MAC Protocol

Properties

- For streaming large amount of data
- Static nature and TDMA approach are being utilized
- Time Frame is divided into multiple time slots
- Guard band time is inserted between two consecutive time slots

Drawbacks

- Periodic synchronization after N number of time frames
- No mechanism for on-demand traffic

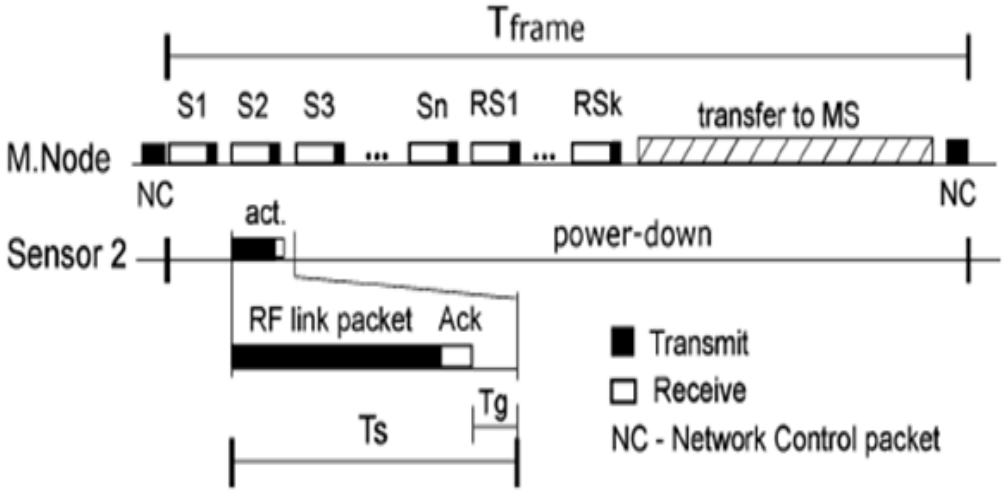

Figure : TDMA Frame Structure

A power-efficient MAC Protocol for WBANs

Properties

- Traffic-based wakeup mechanism for transmission of normal traffic
- Wakeup radio mechanism for emergency/on-demand data
- Time axis is divided into three parts:

Beacon message

Energy Efficient Medium Access Protocol

- Properties
  - Centrally controlled wakeup and sleep mechanisms to maximize energy efficiency
  - Wakeup Fallback Time (WFT) is introduced
  - Centrally controlled process reduces efficiently the extra energy consumption
- Drawbacks
  - Highly complex and has no proper mechanism to handle on-demand traffic
  - Limitation of nodes in one cluster

BodyMAC

Properties

- TDMA-based MAC protocol
- Uplink and downlink subframes
- *Burst Bandwidth procedure, Periodic Bandwidth procedure and Adjust Bandwidth procedure*

Drawback

- For uplink frame in CAP, CSMA/CA ends up with high energy consumption

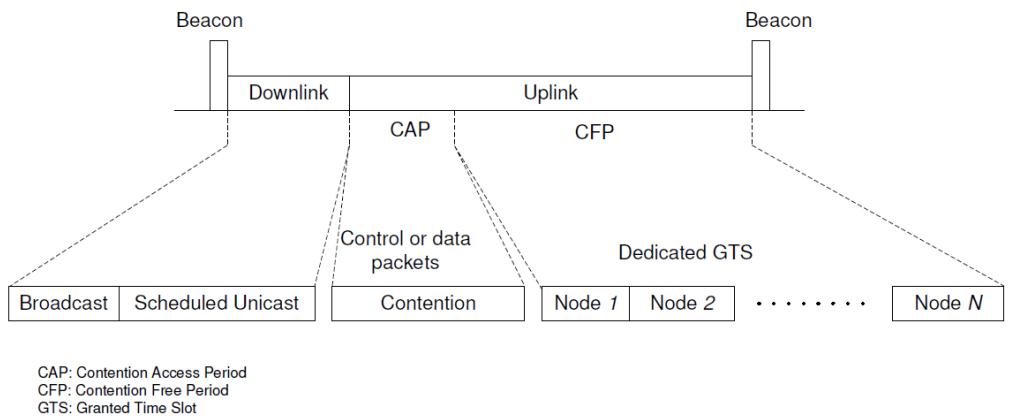

Figure : BodyMAC Frame Structure

MedMAC

Properties

- Improved channel access mechanism and reduce energy dissipation
- Using TDMA approach for time slots assignment
- Time slots are of variable length
- Timestamp scavenging with Adaptive Guard Band Algorithm (AGBA)

Drawback

- Not suitable for High Data rate medical application

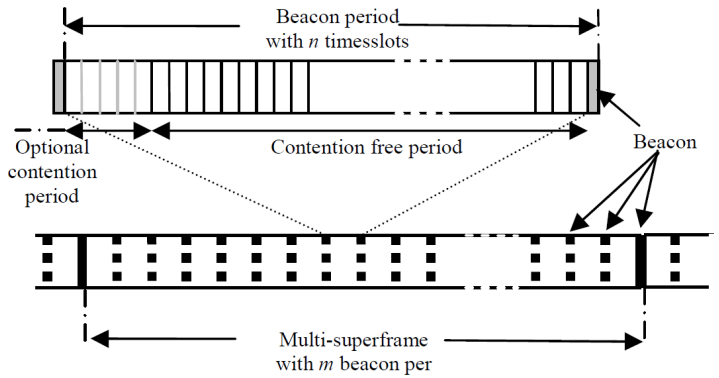

Figure : Multi-Superframe Structure for MedMAC Protocol

Heartbeat-Driven MAC Protocol

Properties

- TDMA based protocol for WBANs
- Heartbeat-Rhythm for synchronization
- Each biosensor extracts Heartbeat Rhythm information from its sensory data
- High efficiency is achieved by TDMA approach

Drawbacks

- Complexity
- Minimize bandwidth utilization.

Discussion and Open Research Issues

Energy efficiency is one of the main goals to achieve in WBANs

Cross layer design need to be consider for energy minimization

Mobility of sensor nodes, transparency at MAC layer,

Interoperability, security and QoS

Collision free communication is achieved by CDMA

CSMA based MAC protocols provide promising results

TDMA-based MAC protocols are contention free

Fairness at MAC layer, high bandwidth utilization, reliable communication, minimum delay, and reduced synchronization cost

MAC protocols are application and hardware dependent

Conclusion

Aim of this research work is to analyze existing MAC protocols for WBANs

Reliable communication

Flexibility, fair management, and QoS

MAC protocols based on random access and LPL are unable to accommodate emergency and on-demand traffic

TDMA is a vital approach for medium access to be used in WBANs

References 1/2


IEEE Std.802.15.4, Wireless medium accesses control (MAC) and physical layer (PHY) specif ications for low data rate wireless personal area networks (WPAN). IEEE: Piscataway, USA, 2006


Changle, L., Huan-Bang, L., and Kohno, R., *"Performance evaluation of IEEE 802.15.4 for Wireless Body Area Network (WBAN),"* in the Proc. of IEEE International Conference on Communications Workshops (ICC Workshops 2009) pp. 1-5, 2009.


Su, H., and Zhang, X., *"Battery-dynamics driven TDMA MAC protocols for wireless body-area monitoring networks in healthcare applications,"* IEEE J. Sel. Areas Commun. 27(4):424-434, 2009.


Zhang, Y., and Dolmans, G., *"A new priority-guaranteed MAC protocol for emerging body area networks,"* in the Proc. of Fifth International Conference on Wireless and Mobile Communications (ICWMC 2009), pp.140-145, 2009.


Marinkovi, S. J., Popovici, E. M., Spagnol, C., Faul, S., and Marnane, W. P., *"Energy-efficient low duty cycle MAC protocol for wireless body area networks,"* IEEE Trans. Inf. Technol. Biomed. 13(6):915925, 2009.


Kwak, K. S., Ullah, S., Kwak, D. H., Lee, C. H., and Lee., H. S., *"A power-efficient MAC protocol for WBAN,"* Journal of Korean Institute of Intelligent Transport Systems 8(6):131140, 2009.


A. El-Hoiydi et al., *"WiseMAC: An Ultra Low Power MAC Protocol for the WiseNET Wireless Sensor Network,"* Proc. 1st ACM SenSys Conf., ACM Press, 2003, pp. 302-303.


O. Omeni, A. C. W. Wong, A. J. Burdett, and C. Toumazou, *"Energy efficient medium access protocol for wireless medical body area sensor networks,"* IEEE Transactions on Biomedical Circuits and Systems. vol. 2, no. 4, pp. 251-259, Dec. 2008.

References 2/2


G. Fang and E. Dutkiewicz, *"BodyMAC: Energy efficient TDMA-based MAC protocol for wireless body area networks,"* 9th International Symposium on Communications and Information Technology, ISCIT, pp. 1455-1459, 2009.


N.F. Timmons and W.G. Scanlon, *"An adaptive energy efficient MAC protocol for the medical body area networks,"* 1st International Conference on Wireless communication VITAE, pp. 587-593, 2009.


Huaming L., and Jindong T., *"Heartbeat-Driven Medium-Access Control for Body Sensor Networks,"* IEEE TRANSACTIONS ON INFORMATION TECHNOLOGY IN BIOMEDICINE, VOL. 14, NO. 1, JANUARY 2010


H. Li and J. Tan, *"Body sensor network based context aware QRS detection,"* in Proc. 28th IEEE EMBS Annu. Int. Conf., Aug. 2006, pp. 32663269.


M. Aboy, J. McNames, T. Thong, D. Tsunami, M. S. Ellenby, and B. Goldstein, *" An automatic beat detection algorithm for pressure signals,"* IEEE Trans. Biomed. Eng., vol. 52, no. 10, pp. 16621670, Oct. 2005.


L. van Hoesel and P. Havinga, A lightweight medium access protocol (lmac) for wireless sensor networks, presented at the 1st Int. Workshop Netw. Sens. Syst. (INSS 2004), Tokyo, Japan, 2004.


W. Ye, J. Heidemann, and D. Estrin, An energy-efficientmac protocol for wireless sensor networks, in Proc. IEEE Infocom, 2002, pp. 15671576.


W. L. Lee, A. Datta, andR.Cardell-Oliver, FlexiMAC:Aflexible TDMAbasedMAC Protocol for fault-tolerant and energy-efficientwireless sensor networks, in Proc. 14th IEEE Int. Conf.Netw. (ICON 2006), Sep., pp. 16.

THANK YOU