An Approach for efficient energy consumption and delay guarantee MAC Protocol for Wireless Sensor Networks

Marwan Ihsan Shukur[a], Vooi Voon Yap[b]

[a]*Department of Electrical and Electronic Engineering*
Universiti Teknologi PETRONAS, 31750 Tronoh, Perak
[a]*e-mail:* mar_shaheen@yahoo.com

ABSTRACT

Wireless sensor networks is an emergent technology that open a world of environment controlling, helping the administrator to predict and anticipate for any possible action that the environment could produce. Unfortunately these energy constrained miniatures must operate in a way that keeps fair consuming between sensor nodes to reach efficient network productivity. In this paper we present a MAC protocol that offers an improved energy efficient consumption and efficient delay guarantee operation. Simulation results shows that the proposed scheme provided better operation than S-MAC protocol.

Keywords

MAC (Medium Access Control), SEA (Simple Energy Aware), WSNs (Wireless Sensor Nodes or Networks), RTS (Request To Send), CTS (Clear To Send), SYNC (Synchronize).

1.0 INTRODUCTION

Wireless sensor network is an infrastructure comprised of sensing (measuring), computing, and communication elements that gives an administrator the ability to instrument, observe, and react to events and phenomena in specified environment. The subject of wireless sensor networks has seen an explosive growth in interest in both academia and industry. Figure (1) is an example of a sensor node.

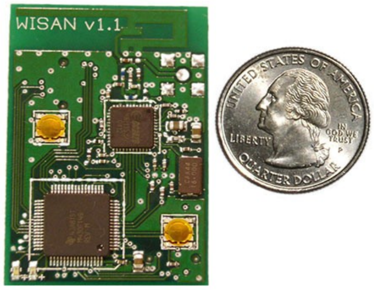

Figure 1: WISAN wireless sensor node

There are four basic components in a sensor network: (1) an assembly of distributed or localized sensors; (2) an interconnecting network (usually, but not always, wireless-based); (3) a central point of information clustering; (4) a set of computing resources at the central point (or beyond) to handle data correlation, event trending, status querying, and data mining. In this context, the sensing and computation nodes are considered part of the sensor network; in fact, some of the computing may be done in the network itself. Because of potentially large quantity of data collected, algorithmic methods for data management play an important role in sensor networks.

Those energy constrained miniatures must operate in a way that keeps fair consuming between sensor nodes to reach efficient network productivity. In practice, it will be necessary in many applications to provide guarantees that a network of unattended wireless sensors can remain operational without any replacements for several years. Hardware improvements in battery design and energy harvesting techniques will offer only partial solutions. This is the reason that most protocol designs in wireless sensor networks are designed explicitly with energy efficiency as the primary goal. Naturally, this goal must be balanced against a number of other concerns.

2.0 CHALLENGES IN PROTOCOL DESIGN

There are a lot of protocols for MAC layer. For wireless sensor networks the literature provided a lot of protocols and divided it into two major categories:

1. **CSMA (carrier sense multiple access) Based MAC Protocols**: the wireless nodes here contend to enter the medium of connectivity (which is the wireless medium in case of WSNs) and the winner node reserves the medium to itself until it finishes its operation. Examples for this kind of protocols are: the popular 802.11, S-MAC, T-MAC, R-MAC... etc.

2. **TDMA (time division multiple access) Based MAC Protocols**: the medium here is divided into time slots each node knows its time slot when to enter the medium and do its operation.

MAC protocols have challenges to overcome when it is meant to be designed for WSNs:

1. Reliable end-to-end data delivery.

2. Low latency data delivery.
3. Scalability and Adaptability.
4. Energy efficient consumption in wireless nodes.

Ioannis Mathioudakis et al presented the most energy wastage sources in MAC protocols for WSNs:

Collisions, it occurs when two or more nodes attempt to transmit simultaneously. Re-transmitting the packet that has been corrupted by collision increases the energy consumption.

The second source of energy wastage is idle-listening, where a node listens for traffic that it is not sent.

The third source of waste is overhearing, which occurs when a sensor node receives packets that are destined for other nodes.

Control packets overhead, which are required to regulate access to the transmission channel. Sending and receiving control packets consumes energy too, and less useful data packets can be transmitted.

The fifth source is over-emitting where the destination node is not ready to receive during the transmission procedure, and hence the packet is not correctly received.

Finally, the transition between different operation modes, such as sleep, idle, receive and transmit, can result in significant energy consumption. Limiting the number of transitions between sleep and active modes leads to a considerable energy saving.

Because our approach focuses on ***Contention Based*** protocols we will demonstrate related work in the same area in the next section.

2.1 Related Work

The most known MAC protocol for wireless networks is IEEE 802.11 which is the standard now for WLAN applications. IEEE 802.11 performs well on terms of latency and throughput but it is very unwanted in terms of energy consumption because of the (idle listening) problem issued with it. When the node is in idle listening state it is been proved that the node consumes energy equivalent to the receiving energy that is why this protocol is not preferred for WSNs applications.

*Wei et al***,** presented sensor-MAC (S-MAC), a contention based MAC protocol designed explicitly for wireless sensor networks. While reducing energy consumption is the primary goal in the design, the protocol also has good scalability and collision avoidance capability. It achieves good scalability and collision avoidance by utilizing a combined scheduling and contention scheme. It achieves efficient energy consumption by using a scheme of periodic listen and sleep reduces energy consumption by avoiding idle listening. It uses synchronization to form virtual clusters of nodes on the same sleep schedule. These schedules coordinate nodes to minimize additional latency. The protocol uses the same mechanism to avoid the overhearing problem and hidden channel problem that is used in IEEE 802.11 MAC protocol. S-MAC has a problem of latency because of periodic listen and sleep scheme which is fixed depending on the duty cycle.

Changsu suh et al, focused on the contention-based MAC protocol and present a novel scheme, named as TEEM (Traffic aware, Energy Efficient MAC) protocol. The proposed TEEM is originally inspired by S-MAC, probably the most often cited contention-based MAC protocol for sensor networks with the concept of periodic listen and sleep modes. The protocol achieves energy efficient consumption by utilizing 'traffic information' of each node, achieving a significant decrease in power consumption. Thus, the listen time of nodes can be reduced by putting them into sleep state earlier when they expect no data traffic to occur. Two important modifications TEEM protocol makes over the existing S-MAC protocol: firstly by having all nodes turn off their radios much earlier when no data packet transfer is expected to occur in the networks, and secondly by eliminating communication of a separate RTS control packet even when data traffic is likely to occur. Still it lacks on latency efficiency it subjected to energy efficient operation.

Shu Du et al, proposed another approach for efficient MAC protocol called RMAC (the Routing enhanced MAC protocol), that exploits cross-layer routing information in order to avoid the common problems without sacrificing energy efficiency. Most importantly, RMAC can deliver a data packet *multiple* hops in a single operational cycle. During the SLEEP period in RMAC, a relaying node for a data packet goes to sleep first and then intelligently wake up when its upstream node has the data packet ready to transmit to it. After the data packet is received by this relaying node, it can also immediately forward the packet to its next downstream node, as that node has also just woken up and is ready to receive the data packet. The mechanism is implemented using a packet called (Pioneer) this packet travels to all sensors in down-stream to synchronize the duty-cycles of the nodes to guarantee a multi-hop packet delivery. This protocol achieved latency efficient operation.

Miguel A. Erazo et al, developed S-MAC to SEA-MAC a protocol aims for energy efficient operation for WSNs for environment monitoring. The protocol assumes only the base station node has the time synchronization schedule. Sensor nodes suppose to be active only when there is a sample to be taken from the environment which decreases the duty-cycle of the node and preserves energy.

Next section will describe our proposed scheme.

3.0 PROPOSED SCHEME

This section explains the proposed scheme with some assumptions:

1. The Base Station sends a broadcast massage so that all the nodes in the area establish the routs to the base station.
2. The next hop information can be retrieved from the upper layer protocol agent (Network Layer) to be fed to the lower layer (MAC Layer) so the later can take the shortest or the best route to the Base Station.

Our scheme comprises of two important aspects:

1. The proposed scheme has combined between SYNC and RTS packets in one packet which will result in elimination of multiple transferring between states (this Idea was inspired from TEEM MAC protocol).
2. Secondly it managed to make the latest SYNC packet to travel from one node to the other node opening the way to the data packets to reach the destination node in a multi-hop fashion.

Figure (2) shows the proposed scheme operation scenario:

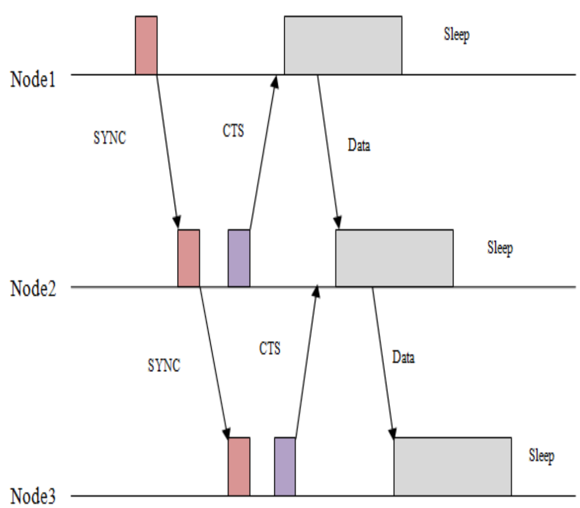

Figure 2: Proposed Scheme Operation

Consider the scenario above:

First (Node1) will enter (Carrier Sense) time and then reserves the medium. Node1 will send SYNC packet to Node2, Node2 will take this SYNC packet and schedule sleeping time and activation time with Node1. Before Node2 returns a CTS packet to Node1, Node2 will first send another SYNC Packet to Node3 in the downstream after finishing SYNC packet time Node2 will return CTS packet to Node1 so that the later can proceed in sending the DATA of interest until it reaches Node3.

This scheme will affect in latency for the first step and will provide an even energy consumption only as we will see in the results in the next section.

4.0 SIMULATION AND RESULTS

The simulation tool used is the Network Simulator 2 (NS2) (version 2.33) which is an open source free for public discreet event based simulator. NS2 is one of the well known and maybe the most popular networking scenarios simulator.

The simulation scenario was a streamline five nodes as shown in figure (3):

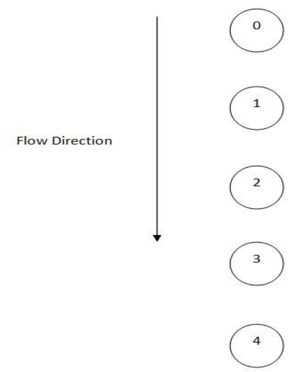

Figure 3: Simulation Scenario

Table (1) below shows the simulation parameters for each node:

Table 1: *simulation parameters*

Simulation Parameters	Amount
Node initial energy	1000J
Transmission energy	200mW
Receiving energy	100mW
Sleeping energy	0.1mW

The simulations were carried out in two deferent duty cycles first (5%) duty cycle and second (10%) duty cycle. We bench marked our work against S-MAC protocol as it is the most popular protocol available for wireless sensor networks and that in many aspects it was the base of our work.

Below are the results obtained from the simulations in terms of data packets delivery and energy consumption:

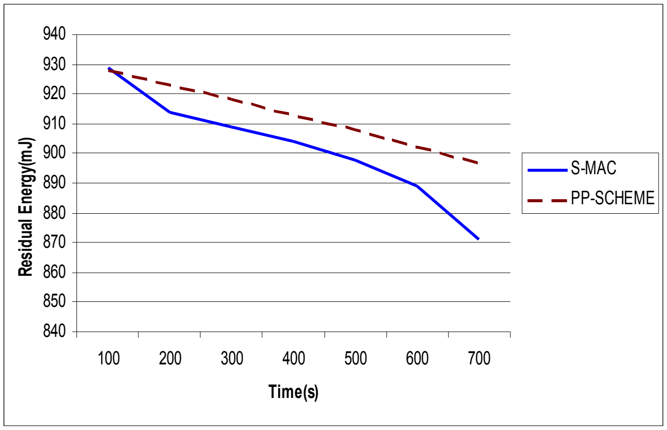

Figure 4: PP-Scheme vs. S-MAC energy consumption 5% duty Cycle

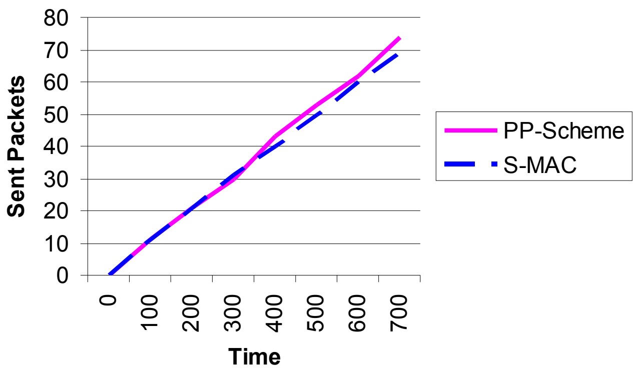

Figure 5: PP-Scheme vs. S-MAC throughput 5% duty Cycle

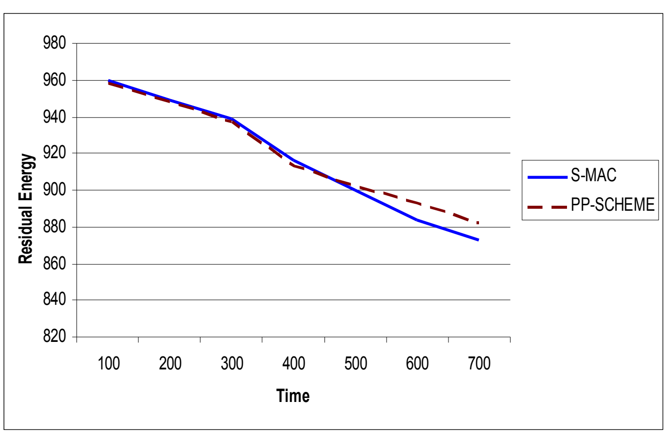

Figure 6: PP-Scheme vs. S-MAC energy consumption 10% duty Cycle

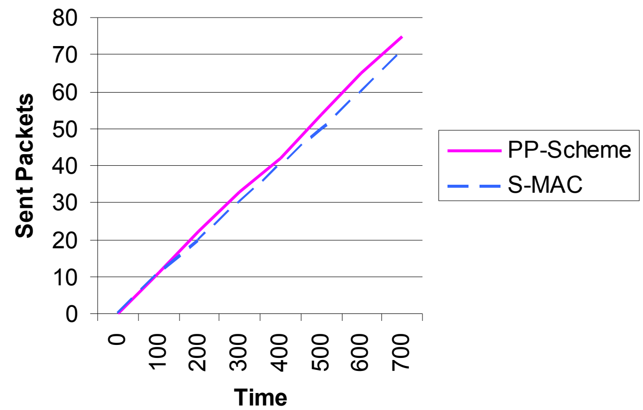

Figure 7: PP-Scheme vs. S-MAC throughput 10% duty Cycle

From the results above it can be seen that the proposed scheme can achieve lower power consumption better than S-MAC because of integrating original SYNC packet with RTS in one packet. In addition the proposed scheme can achieve improved throughput than S-MAC because of the rapid transmitting of the developed SYNC packet to multi nodes open the way in front of DATA to reach the destination.

Because the simulation scenario was a stream line of nodes and did not utilize any routing protocol in simulations.

5.0 CONCLUSIONS

The work described in this paper has show that the proposed scheme can achieve both efficient energy consumption and high throughput operation. The protocol is still in optimization level. It is evinced that the proposed scheme can be applied on another MAC protocols that are based on S-MAC protocol. In the end there is no MAC protocol considered as a standard MAC protocol for wireless sensor networks because of the deferent application that involves environment monitoring and sensing operations.

REFERENCES

Anirudha Sahoo, Prashant Baronia "An Energy Efficient MAC in Wireless Sensor Networks to Provide Delay Guarantee", Local & Metropolitan Area Networks, 2007. LANMAN 2007. 15th IEEE Workshop on.

Changsu Suh, Young-Bae Ko, "A Traffic Aware, Energy Efficient MAC protocol for Wireless Sensor Networks", IEEE 2005.

Farid Nait-Abdesselam, Brahim Bensaou, Thomas Soete and Ka-Lok Hung, "O-MAC: An Organized Energy-Aware MAC Protocol for Wireless Sensor Networks", IEEE 2007.

Ioannis Mathioudakis, Neil M.White, Nick R. Harris, Geoff V. Merrett, "Wireless Sensor Networks: A Case Study for Energy Efficient Environmental Monitoring", Eurosensors 2008, 7-11 September 2008, Dresden, Germany.

Jin Kyung PARK, Woo Cheol Shin, Jun HA "Energy-Aware Pure ALOHA for Wireless Sensor Networks", IEIC Trans. Fundamentals, VOL.E89-A, No.6 June 2006.

Miguel A. Erazo, Yi Qian, "SEA-MAC: A Simple Energy Aware MAC Protocol for Wireless Sensor Networks for Environmental Monitoring Applications", IEEE 2007.

QuinChun Yu, Chong Tan, Huaibei Zhou "A Low-Latency MAC Protocol for Wireless Sensor Networks", IEEE 2007.

Rajgopal Kannan, Ram Kalidini, S. S. Iyengar "Energy and rate based MAC protocol for Wireless Sensor Networks" SIGMOD Record, Vol.32, No.4, December 2003.

Rajesh Yadav, Shirshu Varma and N.Malaviya, "Optimized Medium Access Control for Wireless Sensor Networks", IJCSNS, Vol.8 No.2, February 2008.

Rebecca Braynard, Adam Silberstein, Carla Ellis "Extending Network Lifetime Using an Automatically Tuned Energy-Aware MAC Protocol", Proceedings of the 2006 European Workshop on Wireless Sensor Networks, Zurich, Switzerland (2006).

Sangheon Pack, Jaeyoung Choi, Taekyoung Kwon and Yanghee Choi, "TA-MAC: Task Aware MAC Protocol for Wireless Sensor Networks", Vehicular Technology Conference, 2006. VTC 2006-Spring. IEEE 63rd.

Shu Du, Amit Kumar Saha, David B. Johnson, "RMAC: A Routing-Enhanced Duty-Cycle MAC Protocol for Wireless Sensor Networks", INFOCOM 2007. 26th IEEE International Conference on Computer Communications. IEEE.

Sung-Chan Choi, Jang-Won Lee, Yeonsoo Kim, Hakjin Chong, "An Energy-Efficient MAC Protocol with Random Listen-Sleep Schedule for Wireless Sensor Networks", IEEE 2007.

Syed Waqar Hussain, Tashfeen Khan, Dr. S.M.H. Zaidi, "Latency and Energy Efficient MAC (LEEMAC) Protocol for Event Critical Applications in WSNs", IEEE 2006.

Tao Zheng, Sridhar Radhakrishnan, Venkatesh Sarangan, "PMAC: An adaptive energy-efficient Mac protocol for Wireless Sensor Networks", IPDPS 2005, IEEE.

Tijs Van Dam, Keon Langendoen "An Adaptive Energy-Efficeint MAC Protocol for Wireless Sensor Networks", SenSys'03, November 5-7, 2003.

Wei Ye, John Heidemann, Deborah Estrin "An Energy-Efficient MAC protocol for Wireless Sensor Networks", USC/ISI TECHNICAL REPORT ISI-TR-543, SEPTEMBER 2001.

Xiao-Hui Lin, Yu-Kwong Kwok, "On Channel Adaptive Energy Management in wireless Sensor Networks", ICPPW 2005, IEEE.

Yanjun Sun, Shu Du, Omer Gurewitz and David B. Johnson, "DW-MAC: A Low Latency, Energy Efficient Demand-Wakeup MAC Protocol for Wireless Sensor Networks", Mobihoc'08, May 26-30, 2008, ACM.

The Network Simulator (http://www.isi.edu/nsnam/ns/). 2008.