Journal of Engineering and Applied Sciences 14 (Special Issue 1): 3877-3881, 2019
ISSN: 1816-949X
© Medwell Journals, 2019

Developed Energy Protocol PW-MAC to MPW-MAC to Save Energy in Wireless Sensor Networks

Ibtisam A. Aljazaery
Department of Electrical Engineering, College of Engineering, University of Babylon, Hilla, Iraq

Abstract: A Wireless Sensor Network (WSN) is formed by a large number of sensor nodes where each node is equipped with a sensor to detect physical phenomena such as light, heat, pressure, etc. Sensor nodes have limited battery power source and in most cases it is difficult to replace. The researchers put different routing algorithms in order to keep power in the sensor and thus, general network. This study presents a Modified Predictive-Wakeup MAC protocol (MPW-MAC) for WSNs. This modification was done due to the PW-MAC drawbacks. Energy consumption is an important drawback which was covered by this research. A proposed method was designed by NetLogo simulator to estimate the energy consumption. PW-MAC and MPW-MAC routing protocols algorithms were used to study the WSN behaviors after implemented them simultaneously. Randomly setting choices were applied on sensors nodes: like, nodes distribution, selecting the nodes states, wakeup times of nodes and the interval wakeup. It was noted in simulated results that the outcomes of MPW-MAC protocol much better than the old protocol PW-MAC.

Key words: Energy consumption, MPW-MAC, PW-MAC, WSN, NetLogo, sensor nodes

INTRODUCTION

WSNs composed of a different number of sensor nodes, spread according to the nature of the desired application. WSNs used in many applications such as: medical, military, environmental sensing and security (Kabara and Calle, 2012). Sensor node is a device that has the ability to sense the physical changes in a particular environment and connects to it. Sensing unit, processing unit, transceiver and power unit are the main parts of the sensor node's architecture but some of them have different architecture according to the application domain such as the GPS or a power generator (so, they can use solar energy) (Weber, 2009). Batteries are the source's power of the sensors nodes. So, they have limited lifetime. Even with additional source of energy from the external environment, it was still limited resource that must be consumed wisely (Alippi *et al*., 2009). The main issues in wireless sensor networks are the energy consumption. The energy management efficiently is the common goal of the sensor networks to prolong the network lifetime. An efficient approach for achieving low energy consumption in WSN is to make sensor nodes periodically go to sleep and wakeup. In order to help the sensor nodes save energy, duty cycling has been introduced into wireless sensor networks. With duty cycling, a node periodically turns its radio on and off (Demirkol *et al*., 2006). This study focuses on modifying one of the receiver-initiated asynchronous duty-cycling MAC protocol (PW-MAC) to increase the energy saving. Simulation is an imitation to run the process in the real world or the system over time. It is even more important when the actual system is more difficult and costly to build and reconfigure often. Therefore, the simulation can be found as a tool to evaluate the performance of the system under many different restrictions and configurations that may be occurred in real time. Simulation was used to reduce the cost, risk and failure states in the building operation of the actual system (Mohsin, 2011). It can be also considered as a process of designing logical or mathematical model corresponding to the real system and then use the computer to perform many experiments to predict and explain the behavior of the actual system (Saranen, 2010).

MATERIALS AND METHODS

MAC protocols: The subject of energy conservation in the nodes sensing and achieve the longest possible battery life is one of the most important topics in WSNs. So, it must work to find algorithms to keep as much as possible on battery power during the duty cycle of sensors in the WSN. Usually, duty cycle is classified to synchronous and asynchronous (Wei-Cheng, 2013). This study focuses on increasing the energy saving in WSN by modified one of the receiver-initiated protocol which is PW-MAC protocol. Figure 1 shows the classification of MAC protocol (Bharghavan *et al*., 2012).

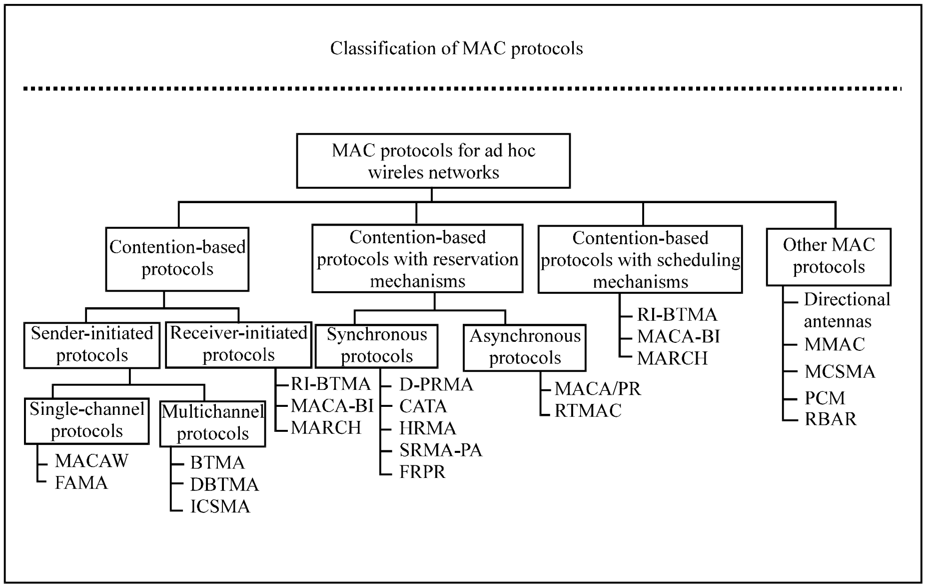

Fig. 1: MAC protocols for wireless sensor networks

PW-MAC protocols: The PW-MAC protocol use pseudo random schedules technique as not all nodes need to be wakeup at the same time to transmit data in order to avoiding collision occurs. When the receiver node wakeup it sends a beacon in order that other senders knows that it wake up and ready to receive a data packet. Then sender sends a data packet to the receiver and asks for information about its current time and its current seed that used in the pseudo random schedule. Sender node in PW-MAC can then use this seed in LCG to predict wakeup time of receiver node and thus, sender node sleeps and wakeup slightly before the receiver node is a wakeup (Tang *et al.*, 2011).

The drawbacks of the PW-MAC protocol are in the random network and under high traffic load the PW-MAC protocol has high average duty cycles and this is due to the backoff time that PW-MAC protocol used when there is collision and need to retransmission the packet and this led to consumed more energy and overhead that cased due to the number of the parameter that receiver node need to send to the sender node for compute the predictive state of receiver node (Liu *et al.*, 2012). Due to the indicated shortages and challenges in the real and simulation applications of the PW-MAC. This study suggests a modified version (MPW-MAC) to this routing protocol in order to improve the protocol and network behavior.

Developed protocol: The MPW-MAC protocol is improved the existing PW-MAC protocol. The MPW-MAC protocol apply the same concept of PW-MAC of the prediction state but in different way such as instead of used random number for its wakeup time and the interval wakeup time that generated by Linear Congruential Generator (LCG), so, instead of sending four parameter used in the LCG to compute the predictive state of the receiver node in the MPW-MAC protocol used random variable, so, needed to send one parameter instead of four. Also there is different between the random number and the random variable, since, the random variable can reflect the behavior of wireless sensor network and when represent the random variable graphic, we can see the reflect of its behavior. To generate the random variable used one of the random distribution (Eq. 2 and 3). Every random distribution has different graphic represent that reflect different behavior. So, by using random distribution, we can decide which random distribution equation, we want to reflect behavior that needed it. Also, due the design of the MPW-MAC improves the performance of the WSN when there is random network and under high traffic load.

Energy consumption: Developed approach was suggested to compute the energy consumption in both protocols. Each protocol makes switching between sleep and wakeup states of sensors nodes. Depending on behavior of both protocols, power consumption divided to three parts:

First; Node consumption: The energy consumed according to the state of nodes if its sender or receiver or sleep in each states the nodes consumed different amount of energy.

Second; Communication consumption: The energy consumed from nodes to generate beacons, acks and messages.

Third; Switching consumption: The energy consumed from nodes due switching between the nodes states. So, for each node define counters to count how many times node being in each state mean how many times nodes being in the sender state how many times nodes being in the receiver state and how many times nodes being in the sleep state. Also, define counters for each node to count how many times switching between node states. So, energy consumed will calculate as:

$$\text{Energy} = \sum_{i=0}^{n} \begin{bmatrix} \text{Energy of node(i) in sender state+} \\ \text{Energy of node(i) in receiver state+} \\ \text{Energy of node(i) in sleep state} \end{bmatrix} \quad (1)$$

In order to know how much energy consumed due to the switching between the node's states, a nine counter has define for each node to count the switching state and used these counters to calculate the energy consumed:

$$\text{Energy in sender state} = \begin{bmatrix} (1.875*\text{send})+ \\ (1.4*\text{type of traffic source})+ \\ (1.875*0.01*\text{msts})+ \\ (1.875*0.01*\text{mstr})+ \\ (1.875*0.01*\text{mstsl})+ \end{bmatrix} \quad (2)$$

Send is the counter that count how many node be in the sender state which multiplied by the energy consumed (1.875) when node is in sender state. Then we multiply the energy need to generate message (1.4) with number of the messages which depending on the type of the traffic source because the number of messages varied according to the type of the traffic source. The energy of switching can be calculated by multiplying the energy consumed in the switching (its value is 0.01) by the number of switches happens in each state [msts: node be sender again, mstr: node switches from sender to receiver, mstsl: node switches from sender to sleep state]:

$$\text{Energy in receiver state} = \begin{bmatrix} (1.3*\text{res})+ \\ (1.4*\text{res+}) \\ (1.4*\text{type of traffic source})+ \\ (1.3*0.01*\text{msts})+ \\ (1.3*0.01*\text{mstr})+ \\ (1.3*0.01*\text{mstsl})+ \end{bmatrix} \quad (3)$$

Rec is the counter that count how many node be in the receiver state which multiplied by the energy consumed (1.3) when node is in the receiver state. When the node is in the receiver state the node will generate beacons and after its received message it will generate ACK. So, we multiply the energy need to generate beacons (1.4) with the number of receiver nodes because the beacons equal to the number of the receiver node, then multiplied the energy need to generate ACK (1.4) with number of the ACK which depending on the type of the traffic source because the number of ACK is equal to the number of received messages and this varied according to the type of the traffic source. The energy of switching can be calculated by multiplying the energy consumed in the switching (its value is 0.01) by the number of switches happens in each state [mrtr: node be receiver again, mrts: node switches from receiver to sender, mrtsl: node switches from receiver to sleep state]:

$$\text{Energy in sleep state} = \begin{bmatrix} (0.045*\text{sle})+ \\ (0.045*0.01*\text{mslts})+ \\ (0.045*0.01*\text{msltr})+ \\ (0.045*0.01*\text{msltsl})+ \end{bmatrix} \quad (4)$$

Sle is the counter that count how many node be in the sleep state which multiplied by the energy consumed (0.045) when node is in the sleep state. When node is in the sleep state it's not need to generate anything. The energy of switching can be calculated by multiplying the energy consumed in the switching (its value is 0.01) by the number of switches happens in each state [msltsl: node is in sleep state again, mslts: node switches from sleep state to sender state, msltr: node switches from sleep state to receiver state]. So, now the total energy consumed will be calculated as in Eq. 1. Table 1 shows the parameters of WSN environment.

Table 1: WSN environment

Parameters	Values
Simulator	NetLogo 5.0.4 Version 2013
Node's number	15, 100, 200
Energy of each node	10000 J
Area size	600*600
Traffic source	Optimistic, normal, random and pessimistic
Hop's number	5

RESULTS AND DISCUSSION

This study presents the results of simulation program and discusses these results. Simulation program deals with MPW-MAC and PW-MAC. Table 1 shows the parameters of WSN environment.

Table 2 summarizes the simulation results of running simulation program 30 times with both protocol (PW-MAC and MPW-MAC) and suggested method to compute the energy consumption.

Table 2: Simulation results of PW-MAC, MPW-MAC protocol of the energy consumption

Nodes	Average energy (joule) in optimistic (PW-MAC/MPW-MAC)	Average energy (joule) in normal (PW-MAC/MPW-MAC)	Average energy (joule) in pessimistic (PW-MAC/MPW-MAC)	Average energy (joule) in random (PW-MAC/MPW-MAC)
15	1543279/1332203	1356861/1332561	1951119/1329270	1376861/1139391
100	5087965/3460046	7384239/3931377	7654066/4989531	8163579/4311299
200	6377861/5405940	7940651/6223231	8940336/6910759	8003898/5964723

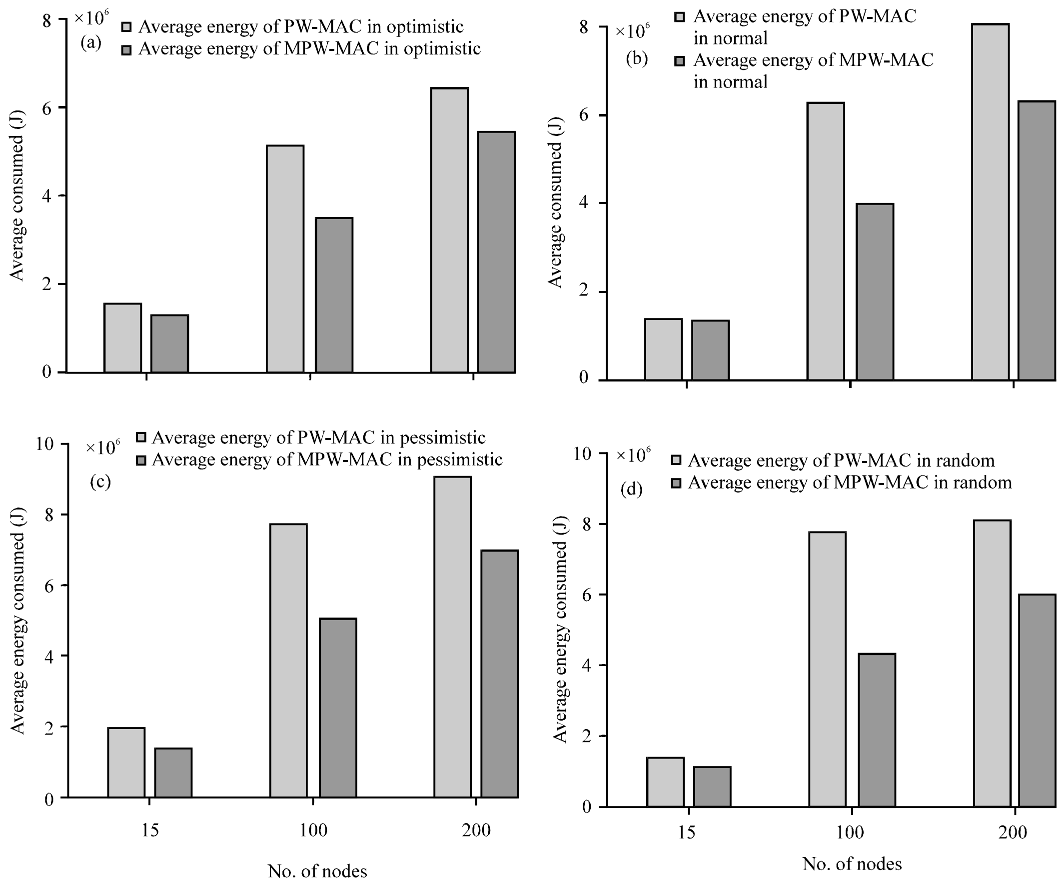

Fig. 2: a-d) Average of energy consumed of both (MPW-MAC and PW-MAC) protocols with varying of traffic source and number of nodes

According to the results mentioned in Table 2, it was noted the effects of the varying of the traffic source on the average total energy consumed. It was also noted the MPW-MAC protocol consumed fewer amounts of the energy comperes with the PW-MAC protocol in all type of the traffic source. The results in Table 2 are graphed in Fig. 2.

Some observations may be considered as results of this research: firstly, the average total energy consumed of both protocols and their effects with varying the traffic source. So, when the traffic source was being in its optimistic case (the best case of network behavior since it's presented the low traffic load), the average total energy consumed is better and lower than its values in other traffic source cases.

The average total energy consumed when the traffic source is in its pessimistic case (the worst case of network behavior, since, it's presented the high traffic load) was found to be higher (worse) than its values in other traffic source cases.

When the traffic source was being in its random case (random case of network behavior, since, it's presented the random traffic load) and the number of nodes equal to 100, the MPW-MAC protocol reduce the energy consumption comparing with energy consumption by PW-MAC protocol.

The average total energy consumed increase with increasing of the number of nodes. And varying of nodes number effects on protocol's behavior.

Finally, it was noted the MPW-MAC protocol consumed less amount of the energy comparing with the PW-MAC protocol in all types of the traffic source and with different number of node.

The results of simulation program of MPW-MAC and PW-MAC, Table 1 shows the parameters of WSN environment as. Table 2 summarizes the simulation results of running the simulation program 30 times with both protocols (PW-MAC and MPW-MAC) with suggested method to compute the energy consumption.

CONCLUSION

The effort of this study is to modify PW-MAC for WSNs in order to save the energy consumption and prolog the network life time. The developed Modified Predictive-Wakeup MAC protocol (MPW-MAC) was implemented and tested using NetLogo Simulators. The recorded results showed an improvement in saving energy compared with the old PW-MAC protocol. In this study, the simulation results show that energy consumed increased with the increasing of the traffic source. When the traffic source was being in its optimistic case, the energy consumed seems to be better and lower than its values in other traffic source cases. While the energy consumed when the traffic source is in its pessimistic case was found to be higher (worse) than its values in other traffic source cases. The energy consumed increase with the increasing of the number of nodes due to the increasing of the traffic sources. According to the developed approach that used to estimate the energy consumption, it was observed that the energy consumed in each node due to the switching between the nodes states is too much less than the energy consumed when one keep that node wakeup and not switched to sleep state. Finally, the result shows that the energy consumption with different number of nodes and with different type of traffic source was reduced by using the MPW-MAC protocol comparing to the PW-MAC protocol. It means that MPW-MAC has improved the performance of the WSN and prolog life time of network as an important and challenge issues in WSNs.

REFERENCES

Alippi, C., G. Anastasi, M. Di Francesco and M. Roveri, 2009. Energy management in wireless sensor networks with energy-hungry sensors. Instrumen. Measur. Mag., 12: 16-23.

Bharghavan, V., A. Demers, S. Shenker and L. Zhang, 2012. MAC protocols for ADHOC and sensor networks. MSc Thesis, S-MAC, Manhattan's East Village, New York, USA.

Demirkol, I., C. Ersoy and F. Alagoz, 2006. MAC protocols for wireless sensor networks: A survey. IEEE Commun. Mag., 44: 115-121.

Kabara, J. and M. Calle, 2012. MAC protocols used by wireless sensor networks and a general method of performance evaluation. Int. J. Distrib. Sensor Networks, Vol. 2012 10.1155/2012/834784

Liu, Y., F. Jiang, H. Liu and J. Wu, 2012. SC-MAC: A sender-centric asynchronous MAC protocol for burst traffic in wireless sensor networks. Proceedings of the 18th Asia-Pacific Conference on Communications (APCC'12), October 15-17, 2012, IEEE, Jeju Island, South Korea, ISBN:978-1-4673-4726-6, pp: 848-853.

Mohsin, H.H., 2011. Building a computer simulation model to enhance the utilization of railway network in Iraq. M.Sc Thesis, University of Babylon, Hillah, Iraq.

Saranen, J., 2010. Intermodal Transportation in Emergency Situations in the Gulf of Finland. European Union, Brussels, Belgium, ISBN:978-952-214-936-7, Pages:138.

Tang, L., Y. Sun, O. Gurewitz and D.B. Johnson, 2011. PW-MAC: An energy-efficient predictive-wakeup MAC protocol for wireless sensor networks. Proceedings of the Conference on IEEE InfOCOM, April 10-15, 2011, IEEE, Houston, Texas, ISBN:978-1-4244-9921-2, pp: 1305-1313.

Weber, V., 2009. Smart sensor networks: Technologies and applications for green growth. Proceedings of the 2009 OECD Conference on ICTs Environment and Climate Change, May 27-28, 2009, OECD Publishing, Helsingor, Denmark, pp:1-48.

Wei-Cheng, X., 2013. Physical implementation of synchronous duty-cycling MAC protocols: Experiences and evaluation. MSc Thesis, Rice University, Houston, Texas.