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Life Time Based Analysis of MAC Protocols of Wireless Ad Hoc Networks in WSN Applications

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Abstract**—**Wireless Sensor Networks (WSN) are emerging because of the developments in wireless communication technology and miniaturization of the hardware. WSN consists of a large number of low-cost, low-power, multifunctional sensor nodes to monitor physical conditions, such as temperature, sound, vibration, pressure, motion, etc. The MAC protocol to be used in the sensor networks must be energy efficient and this should aim at conserving the energy during its operation. *In this paper, with the focus of analyzing the MAC protocols used in wireless Adhoc networks to WSN, simulation experiments were conducted in Global Mobile Simulator (GloMoSim) software. Number of packets sent by regular nodes, and received by sink node in different deployment strategies, total energy spent, and the network life time have been chosen as the metric for comparison. From the results of simulation, it is evident that the IEEE 802.11 protocol performs better compared to CSMA and MACA protocols.*

Keywords**—**CSMA, DCF, MACA, TelosB

I. Introduction

WIRELESS Sensor Networks (WSN) are emerging because of the developments in wireless communication technology and miniaturization of the hardware. WSN consists of a large number of low-cost, low-power, multifunctional sensor nodes to monitor physical conditions, such as temperature, sound, vibration, pressure, motion, etc. Also it has the ability of computing and communicating either among each other or directly communicating with sink node. Sink node is the master node which collects the data from nodes and to processes it. The nodes are limited in power, computational capacity, and memory.

The applications of WSN include agriculture, target tracking, health care monitoring system, etc. Wireless sensor network is a type of Adhoc network with unique features [1]. The number of nodes in the sensor network application is higher than the number of nodes in an Adhoc networks. Nodes are densely deployed and prone to failure. There is no fixed topology in wireless sensor network. The nodes are not having global ID as the number of nodes is very high.

Application-specific deployment, random deployment, and grid deployment are node deployment approaches used in WSN [2], [3].

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In wireless sensor network applications, the MAC protocols play a very vital role in energy conservation to increase the life time of the network. Packet collisions occur at a receiver node if more than one packet arrives at the same destination. Collisions are discarded and the re-transmissions of these packets results in increase of the energy consumption. The overhearing, over-emitting, and idle listening [4] are the other reasons for energy wastes in WSN. The Carrier Sense Multiple Access (CSMA), Multiple Access with Collision Avoidance (MACA) protocol with RTS-CTS exchange, IEEE 802.11 protocol are some of the MAC protocols used in Adhoc networks. The detailed principle of working of these protocols along with illustration can be found in [5] - [8].

The rest of the paper is organized as follows: Section 2 depicts the requirements of medium access control in wireless sensor networks. Section 3 describes the simulation environment for the performance study. Results obtained are discussed in Section 4. Section 5 concludes the paper.

II. Requirements Of Medium Access Control Protocols For Wireless Sensor Networks

The sensor node used in WSN applications consists of a processor, memory, a transceiver, and a battery. The low power capacity of the battery used in the sensor nodes enables limited coverage and communication range compared to devices used in other mobile networks. In contrast to other wireless networks, the nodes in WSN are unattended and it is difficult to change or replace the exhausted batteries in critical applications such as forest fire, border surveillance applications, etc. Hence, the primary focus of WSN applications is to maximize the network life time by using the energy efficiently. Also, as the communication of data consumes more energy than computation, it is important to reduce the communication while achieving the desired operation with respect to the particular application. The following are the reasons for energy wastage in WSNs:

Collision: Reception of more than one packet at the same time leads to collision which in turn increases the number of retransmissions and hence the amount of energy spent [9].

Overhearing: A node receives packets destined for other nodes. Energy is wasted in receiving also.

Control packet overhead: Minimum number of control packets must be used for data transmission. More number of control packets means more energy is wasted.

Idle Listening: Nodes listening to the medium for possible traffic.

Over emitting: Node is sending packet when the receiver is not ready. Therefore, the requirement for the MAC protocol used in WSN is that it should reduce the energy waste.

III. SIMULATION ENVIRONMENT

The simulation software used in this paper is GlomoSim version 2.03. Number of nodes used in this simulation is four and ten. The simulation has been carried for single hop WSN. Network protocol used is IP and routing algorithm used in the simulation is Bellman-Ford. Node placement strategy and other necessary parameters such as terrain dimension, propagation path loss, propagation limit, bandwidth, radio frequency, radio transmitter power, antenna gain, receiver sensitivity, and receiver threshold used in the simulation are specified through config.in file as follows:

Terrain-Dimension <2000, 2000>	Propagation Limit -111.0
Radio-TX-Power 15dbm	Radio-RX-Threshold -81.0
Radio-Frequency 2.4e9	Radio-Antenna-Gain 10.0
Radio-Bandwidth 2000000 bits	Radio-RX-Sensitivity -81.0
Propagation Path Loss Free-Space	

In this simulation, node 1 is considered as sink node and other nodes as regular nodes which may send packets to the sink node. Also, ten nodes simulation is done in such a way that nodes 0, 2, 3, 5, 6, and 7 will be sending the data packets of the sensed information from the field to sink node and other regular nodes are silent nodes. The size of each packet is 512 bytes. Nodes 2 and 7 start sending packets at 70 s and nodes 0, 3, 5, and 6 start sending the packets from the start of the simulation, 0 second to the end 100 seconds. The inter departure time between the packets is 5 milliseconds. The sample code for generating packets from regular nodes and sending to sink node in GlomoSim is as follows:

```
CBR 0 1 0 512 5MS    0   0        CBR 5 1 0 512 5MS  0     0
CBR 2 1 0 512 5MS 70s  0          CBR 6 1 0 512 5MS  0     0
CBR 3 1 0 512 5MS  0    0         CBR 7 1 0 512 5MS 70s 0
```

Nodes.input file contains the details of node positions in application specific approach. In WSN simulation, nodes are placed in 2000 x 2000 terrain dimension. The main objective of this simulation is to analyze the performance of CSMA, MACA, and IEEE 802.11 protocols in terms of total packets sent by the regular nodes, received by the sink node, total energy spent to send and receive data packets, and life time of the network.

The following wireless sensor network scenario is considered for calculating energy spent for transmitting and receiving packets:

Energy consumption while CPU running
(for doing calculations) : 08 mA
Additional consumption for sending (via radio) : 10 mA
Additional consumption for receiving (via radio) : 06 mA

It is assumed that energy for idle state is negligible. Every 200 milliseconds a measurement has been taken.

A single measurement takes 5 milliseconds. Data rates of 2 Mbps, 200 Kbps, and 20 Kbps are taken for analysis in the simulation. Energy calculation for the wireless radio connection with a capacity of 2 Mbps is as follows:

Energy for computation and processing:
5 samples/second x 0.005 seconds (for single measurement) x 8 mA = 0.2 mAs

Sending energy for one packet:
(512 bytes x 8 bit)/ (2000000 bits/s) x [(8 mA (basic consumption) + 10 mA (for sending)] = 0.0368 mAs

Receiving energy for one packet:
(512 bytes x 8 bit)/(2000000 bits/s) x [(8 mA (basic consumption) + 6 mA (for receiving)] = 0.0286 mAs

Sending energy for data rates of 200 Kbps and 20 Kbps works out to be 0.368 mAs and 3.6864 mAs respectively. Receiving energy for data rates of 200 Kbps and 20 Kbps works out to be 0.2867 mAs and 2.8672 mAs respectively.

IV. PERFORMANCE COMPARISON

A. Comparison of MAC Protocols in Terms of Number of Packets Received

The number of packets received by the sink node in three different deployment strategies using CSMA, MACA, and IEEE802.11 protocols at different data rates are determined and tabulated in Table I. Total number of packets sent in four nodes simulation is 46000 and ten nodes simulation is 92000.

In the application specific placement, node placement is specified and the nodes are placed 600 meters apart. In random placement approach, nodes are placed randomly within the physical terrain and in grid placement nodes placement start at (0, 0) and are placed in grid format with each node 100 m away from its neighbours. From Table I, it is understood that the number of packets received is less in case of CSMA because of hidden and exposed terminal problem.

The RTS-CTS message exchange reduces the collision in MACA and the number of packets received by sink node is comparatively good and it is better in IEEE 802.11 because of RTS-CTS-ACK mechanism. When the number of nodes increases, total number of packets received by the sink node increases. But, when the number of nodes increases or when the data rate is low the throughput of MACA decreases when compared to CSMA. Moreover, the performance of all the MAC protocols is almost same when the data rate is low.

B. Comparison of CSMA and IEEE 802.11 in Terms of Energy Spent

In order to compare MAC protocols, the energy for sending the sensed information by the regular nodes, the energy for receiving the data by the sink node, the total energy for 100 second simulation time are calculated, and tabulated as shown in Table II. On comparing the number of packets sent (46000 or 92000) and number of packets received in Table I, it found that the total energy spent in Table II is mostly dominat ed by the energy spent in sending

TABLE I
NUMBER OF PACKETS RECEIVED BY SINK NODE VERSUS MAC PROTOCOLS

No. of Nodes	MAC protocol	Number of Packets received by Sink node								
		Application Specific Placement			Random Placement			Grid Placement		
		2Mbps	200Kbps	20Kbps	2Mbps	200Kbps	20Kbps	2Mbps	200Kbps	20Kbps
4	CSMA	1133	95	82	5430	117	44	5338	231	133
	MACA	17527	601	6	14916	496	10	17710	619	8
	802.11	28636	3880	393	28692	3882	397	28794	3885	393
10	CSMA	11705	100	80	12161	217	104	15973	736	229
	MACA	11563	177	1	11746	190	1	11320	162	1
	802.11	28868	3855	360	28930	3854	372	29064	3863	367

TABLE II
TOTAL ENERGY SPENT FOR SENDING AND RECEIVING PACKETS

No. of Nodes	MAC protocol	Total Energy Spent (mAs)								
		Application Specific Placement			Random Placement			Grid Placement		
		2Mbps	200Kbps	20Kbps	2Mbps	200Kbps	20Kbps	2Mbps	200Kbps	20Kbps
4	CSMA	11151.8	26201.8	179025.9	12134.1	26212.5	178909.4	12113.1	26268.0	179182.3
	MACA	14899.5	26448.1	178792.8	14302.6	26397.0	178805.1	14941.3	26456.9	178798.9
	802.11	17438.9	28043.9	179979.8	17451.8	28044.9	179992.1	17475.1	28046.4	179979.8
10	CSMA	24461.4	52359.9	357794.2	24565.6	52416.8	357867.8	25437.0	52669.4	358251.2
	MACA	24428.9	52397.3	357551.9	24470.7	52403.7	357551.9	24373.4	52390.0	357551.9
	802.11	28384.8	54187.4	358652.9	28398.9	54186.9	358689.8	28429.6	54191.3	358674.5

TABLE III
LIFE TIME OF THE NETWORK

No. of Nodes	MAC protocol	Life Time of the Network (Hours)								
		Application Specific Placement			Random Placement			Grid Placement		
		2Mbps	200Kbps	20Kbps	2Mbps	200Kbps	20Kbps	2Mbps	200Kbps	20Kbps
4	CSMA	42.40	18.04	2.64	38.96	18.04	2.64	39.03	18.00	2.64
	MACA	31.73	17.88	2.64	33.06	17.91	2.64	31.64	17.87	2.64
	802.11	27.11	16.86	2.63	27.09	16.86	2.63	27.06	16.86	2.63
10	CSMA	48.32	22.57	3.30	48.12	22.55	3.30	46.47	22.44	3.30
	MACA	48.39	22.56	3.31	48.30	22.56	3.31	48.50	22.56	3.31
	802.11	41.64	21.81	3.30	41.62	21.81	3.30	41.58	21.81	3.30

The total energy spent in CSMA and IEEE 802.11 for various data rates and for two different simulation scenarios in random deployment are plotted in Fig. 1. From the graph, it is understood that more energy is spent in IEEE 802.11 as the number of packets received by sink is more compared to CSMA. Hence, MAC protocol with RTS-CTS mechanism performs well.

C. Comparison of MACA and IEEE 802.11 in Terms of Energy Spent

The total energy spent in MACA and IEEE 802.11 for various data rates and for two different simulation scenarios in random deployment are plotted in Fig. 2. From Fig. 2, it is seen that the total energy spent in IEEE 802.11 is more as the mechanisms of collision avoidance before RTS transmission, and the acknowledgment (ACK) by the receiver after the successful reception of the data packet decrease the number of collisions and increase the number of packets received.

D. Comparison of Life Time of the Network

Wireless sensor network life time depends on battery life time. In order to compare the network life time, TelosB sensor mote is considered. TelosB contains two AA batteries 10].

One Carbon Zinc AA battery provides 591 mAh. So, energy provided by TelosB sensor mote is 1182 mAh. Life time of network calculations for a network with four nodes using application specific node deployment strategy with CSMA protocol at 2 Mbps data rate is as follows:

Node battery Initial Energy = 1182 mAh
Total Initial Energy = Number of nodes x Initial Energy = 4 x 1182 mAh = 4728 mAh

From Table II, total Energy Spent for 100 seconds is 11151.8 mAs.
Energy per Second = 11151.8 /100 =111.52 mAs

Therefore, the life time of the network
= 4728 x 60 x 60 / 111.52 = 152625.54 seconds
= 42.4 Hours

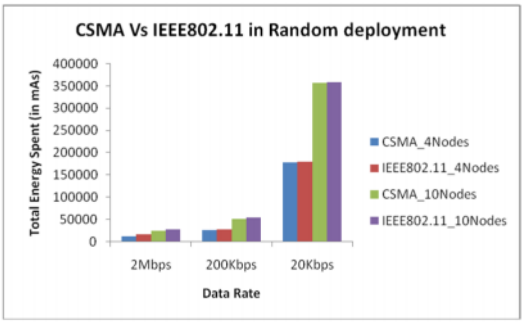

Fig. 1 Comparison of Energy Spent in random deployment node placement strategy withCSMAand IEEE 802.11

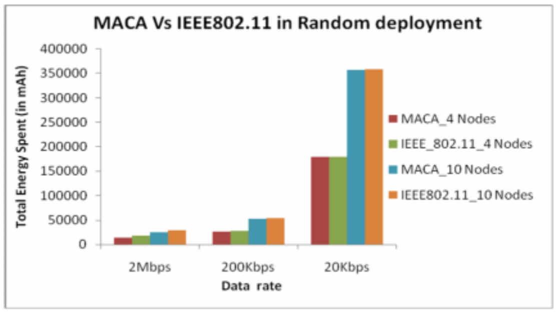

Fig. 2 Comparisonof Energy Spent in random deployment node placement strategy withMACA and IEEE 802.11

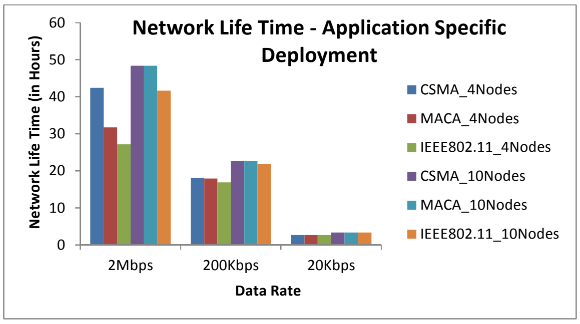

Fig. 3 LifeTime of the network for Application Specific Deployment

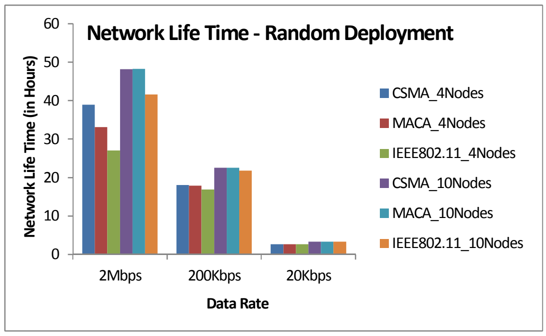

Fig. 4 LifeTime of the network for Random Deployment

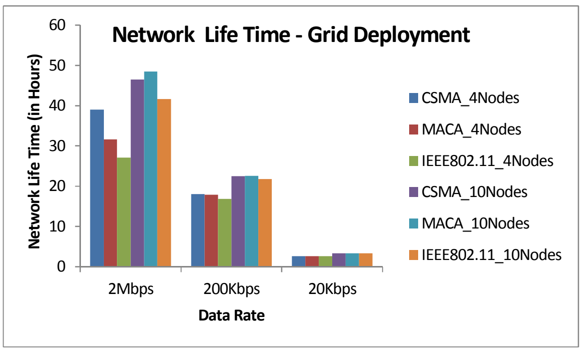

Fig. 5 Life Time of the network for Grid Deployment

Similarly life time of the network with four and ten nodes using different deployment strategies for CSMA, MACA, and IEEE 802.11 MAC protocols at different data rates are calculated, and tabulated in Table III. The life time versus protocols for various placement strategies are plotted as shown in Fig. 3, 4, and 5. From the graphs, it is understood that the life time of the network is same for all the MAC protocols in low data rates. The reason is that the number of packets received by sink node is almost the same and hence the total energy spent is same for all the MAC protocol. Further, it is seen that the life time increases as the data rate is increased because at higher date rates per packet transmission time is less and hence the energy spent is also less. Also, when number of nodes increases total number of packets transmitted increases and the energy required for transmission also increases leading to reduction in life time.

V. CONCLUSION

For WSN applications, it is required to use a protocol that is very scalable, energy-efficient, flexible and highly adaptable, robust with reliable packet delivery, and predictable with bounded delay. But energy efficiency stands among the top attributes given the constrained battery energy of sensor node in unattended environments. Hence in this paper, the focus has been on the total energy spent for transmission and reception of packets to evaluate the performance of wireless Adhoc mobile MAC protocols for WSN applications and to determine the life time of the network. The results revealed that the IEEE 802.11 protocol performs well in terms of number of packets received. Further the life time of the network is increased at higher data rates.

REFERENCES

[1] Ian F. Akyildiz, Weilian Su, Yogesh sankarasubramaniam, and Erdal Cayirc, "Survey on Sensor Networks", IEEE Communications Magazine, pp. 102-114, August 2002.
[2] Edoardo S. Biagioni, and Galen Sasaki, "Wireless Sensor Placement for Reliable and Efficient Data Collection", 36th Annual Hawaii International Conference on System Sciences (HICSS'03) vol. 5,pp.10, 2003.
[3] Kenan Xu, Glen Takahara, and Hossam Hassanein, "On the robustness of grid-based deployment in wireless sensor networks", Proceedings of the International conference on wireless Communications and mobile computing, IWCMC '06, 2006.
[4] Ilker Demirkol, Cem Ersoy and Faith Alagoz, "MAC Protocol for Wireless Sensor Networks:A Survey", IEEE Communications Magazine, pp.115-121, April 2006.
[5] Kleinrock, L., and Tobagi, F.A, " Packet Switching in Radio Channels: Part I- Carrier Sense Multiple-Access Modes and Their Throughput-Delay Characteristics", IEEE Transactions on communications, 23(12): pp.1400-1416, 1975.
[6] Karn P, " MACA - A New Channel Access Protocol for Packet Radio", Proceedings of the ARRL/CRRL Amateur Radio Ninth Computer Networking Conference, pp. 134-140, 1990.
[7] Guido R. Hiertz, Sebastian Max, Rui Zhao, Dee Denteneer, and Lars Berlemann, " Principles of IEEE 802.11s", 6th International Conference on Computer Communications and Networks (ICCCN), pp. 1002-1007, 2007.
[8] Carrier Sense Multiple Access (CSMA), Available at http://en.wikipedia.org/wiki / Carrier_sense_multiple_access.
[9] 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, pp. 493-506, June 2004.
[10] TelosB Mote Specification, Available at www.willow.co.uk.

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