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Abstract- Wireless Sensor Network (WSN) is a self-organizing and distributed collection of small sensor nodes with limited energy are connected wirelessly to the sink, where the information is needed. The significant trait for any Wireless Sensor Network is power consumption since WSNs finds its most of the applications in unsafe, risky areas like Volcano eruption identification, Warfield monitoring, where human intervention is less or not possible at all. Hence designing a protocol with minimum energy consumption as a concern is an important challenge in increasing the lifetime of the sensor networks. Medium Access Control (MAC) Layer of WSN consumes much of the energy as it contains the radio component. Energy problems in MAC layer include collision, idle listening, and protocol overhead. Our Proposed MAC protocol provides solution for the problem of: collision by providing multiple channels; idle listening by providing sleeping mechanism for the nodes other than the active node; overhead by reducing the number of control messages. Avoiding collision results in the decrease in number of retransmissions which consumes more energy, avoiding idle listening problem will fairly increase the lifetime of the sensor node as well as the network's lifetime and reducing overhead in turn consumes less energy.

Keywords- *Wireless Sensor Networks, MAC, Energy efficiency.*

I. INTRODUCTION

A wireless sensor network (WSN) consists of abundant number of dispersed self-directed sensors to observe physical or ecological conditions, such as temperature, sound, compression, etc. and to compliantly permit their data through the network to a main location. The more recent networks are bi-directional, also empowering control of sensor action [1]. The growth of wireless sensor networks was driven by military applications such as battlefield surveillance; nowadays such networks are used in many industrial and consumer applications, such as manufacturing progression checking and control, device strength observing, and so on. The WSN is built of nodes from a few to numerous hundreds or even thousands, where each node is associated to one or sometimes several sensors. Each sensor network node has generally quite a few parts: a radio transceiver with an internal antenna or linking to an peripheral antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an power source, typically a battery-operated or an embedded form of energy harvesting [1]. A sensor node might differ in dimension to the size of a particle of dirt, though operational "motes" of genuine microscopic measurements have yet to be made. The price of sensor nodes is likewise adjustable, fluctuating from a few to hundreds depending on the complexity of the individual sensor nodes [2].

In most applications the sensors are battery-operated and have a restricted energy, which is used to make data procurement, processing and to withstand the communications. Efficient usage of energy is of essential point in sensor nets and numerous methods have been proposed in order to extend the battery lifetime. While existing technologies used for wireless networks can be used for small zone networks, it is rigid to relate them to sensor networks directly [3].
Our proposed MAC protocol aims to address the problem of collision by providing multiple channels for communication. The problem of idle listening is controlled by incorporating sleeping mechanism for the nodes other than the one which involves in data transmission.

The rest of the paper is organised as follows. In the next section, we present some of the related research works. Section III gives the detailed explanation about the proposed protocol architecture. Section IV discusses the implementation of our work with simulation results. Section V outlines the conclusion and future work.

II. RELATED WORK

Yi-Huai Hsu et.al. (2008) [4], in this paper authors proposed an efficient multichannel MAC protocol for cluster based Wireless Multimedia Sensor Networks in order to achieve higher throughput, lower delay and improved energy efficiency. The proposed methodology combines the advantages of both CDMA and TDMA techniques. Authors made an assumption that clustering process has been completed by some existing clustering techniques. Within a cluster, first Channel assignment phase has been executed following request phase, scheduling phase and transmission phase which would be executed sequentially. Simulation results have shown the proposed system with increased throughput and

reduced delay but the channel allocation involves protocol overhead which will not be suitable for low power sensor networks.

Muhammad Haneef Zhongliang Deng, (2010) [5], the aim of this research work was to study the MAC protocols along with their merits and demerits for Wireless Sensor networks in the application specific prospective. Wide range of applications may be related to Industrial control and monitoring, Security and military intelligence, Asset tracking and supply chain management, Intelligent agriculture and environmental sensing, Health monitoring, Home automation and consumer electronics. Throughput, latency, connectivity and reliability are equally important along with power saving in all of the above applications.

Jalel Ben-Othman et.al. (2011), proposed a the priority based MAC protocol (PRIMA) that provides Quality of Service (QoS) by employing a queuing model to classify the traffic depending on its importance into four different queues. Higher priority queues have absolute preferential treatment over low priority queues. The channel access method is composed of TDMA for data messages and CSMA for control messages. To handle the network scalability issues, the protocol consider a clustering algorithm. The performance of the protocol was compared with Q-MAC, simulation and analytical analysis shown that the PRIMA protocol outperforms Q-MAC protocol in terms of energy consumption, Packet Delivery Ratio and Average packet delay.

GholamHossein EkbataniFard and Reza Monsefi (2011), described an asynchronous and adaptive MAC protocol, namely MAMAC [7] was designed with energy efficiency by utilizing Quorum system. Quorum systems have been widely used in distributed systems to deal with the mutual exclusion problem, fault tolerance, voting, and also have been utilized to design protocols for wireless network. This protocol adaptively adjusts sleep/wake-up time of sensor nodes and asynchronously tunes to exchange data. And also it uses multiple channels to send and receive data without synchronization overhead. Adaptive matching of wakeup intervals makes the proposed protocol more flexible. To evaluate the MAMAC, the simulator OPNET Modeler 14.0 is used and is compared with TMCP and QMAC protocols. Simulation results in OPNET simulator verify that MAMAC protocol reduces energy consumption which increases the network lifetime and keeps the latency low while increasing the throughput.

Pei Huang et.al. (2012) in this survey [8], detailed the evolution of MAC protocols in four categories: asynchronous, synchronous, frame-slotted and multichannel. The work provide an overview of WSN MAC protocols from perspectives of both energy efficiency and data delivery performance with more recently proposed work. To save energy, duty cycling mechanism is adopted. Synchronous and Asynchronous are related to the mechanism of duty cycling. To provide high throughput, frame-slotted mechanisms allocate time slots in a way that no two nodes within the two-hop communication neighborhood are assigned to the same slot. This address collision and hidden terminal problem, providing a collision free data transmission environment. The concept of Multichannel is employed to further boost network capacity. Distributed channel assignment and efficient cross-channel communication are two major challenging issues in multichannel MAC protocols. With extensive analysis of the protocols many future directions are stated at the end of this survey. The performance of different classes of protocols could be substantially improved in future designs by taking into consideration the recent advances in technologies and application demands.

Fang Wei et.al. (2012), in this paper [9] authors proposed a novel threshold-based control system, called balanced control system (BCS) that involves in deciding to switch to another channel according to the real time traffic load and interference, whether, which channel should be switched to and how to perform the switch. The control model was designed based on a fuzzy logic control. The threshold which assists to make the channel switch decisions that could be deduced dynamically according to the real-time traffic of each node. They also designed a novel dynamic channel assignment scheme, which has been used for the selection of the new channel. The performance of the existing protocols has been changed in order to perform the proposed channel switching policy. The limitation of this proposed methodology is that it would consume much energy which will not be reliable for sensor networks.

III. PROTOCOL ARCHITECTURE

Energy saving Multi channel MAC protocol for WSNs focuses on an efficient control access to the wireless medium in order to utilize the network resources with minimum energy consumption. The protocol addresses the foremost energy problems, such as collision, overhead, idle listening, on the MAC layer by utilizing different mechanisms.
The algorithm for our protocol assumes the following parameters

- ChannelList -> list of channels available for the complete network
- TempChanList -> temporary list of channels from the available channel list
- Node j and Node k are the neighbors of Node i
- c-> indicates the current channel used by the Node i

- Add the channels used by node j and k to the TempChanList of the Node i
- Xi -> indicates that the channel is busy
- Si-> indicates that it is important to send the data (nooftimes >= 3)

Algorithm 1: Channel Access Mechanism

```
1:   Node i send Channel_State_Req; // First time requesting the channel
2:   If Node j receives a Channel_State_Req;
3:   if (Node j ∈ neighbornodelist && Node j ← Xi && Si) then
4:   Node i send Channel_State_Req; // Second time requesting the channel
5:   if (Node j ∈ neighbornodelist && Node j← Xi && Si) then
6:   Node i send Channel_State_Req; // Third time requesting the channel
7:   if (Node j ∈ neighbornodelist && Node j← Xi && Si) then
8:   Switch channel and update phyCurrentChannel Node i;
9:   Add neighbornode's channel to TempChanList of Node i;
10:  else Update channel table;
```

The key feature of our work is to make use of sleeping mechanism after sensing the channel as busy. If a node requests the channel to check whether free or busy using Channel_State_Req message. If the channel is free the node can transmit the data else it will go to sleep mode. But in case of existing CSMA CA protocol, the node will switch to idle mode which will again consume considerable amount of energy. Hence our mechanism reduces the problem of idle listening. Figure 1 and Figure 2 shows the working of our MAC protocol and working of traditional CSMA-CA protocol's working respectively. In figure 1, the node switches to sleep state if the channel is busy. Node sends the channel request message only when there is data to transmit else the nodes will be in sleep state. But in CSMA-CA as in Figure 2, the node switches to idle mode which creates the problem of idle listening and consumes energy.

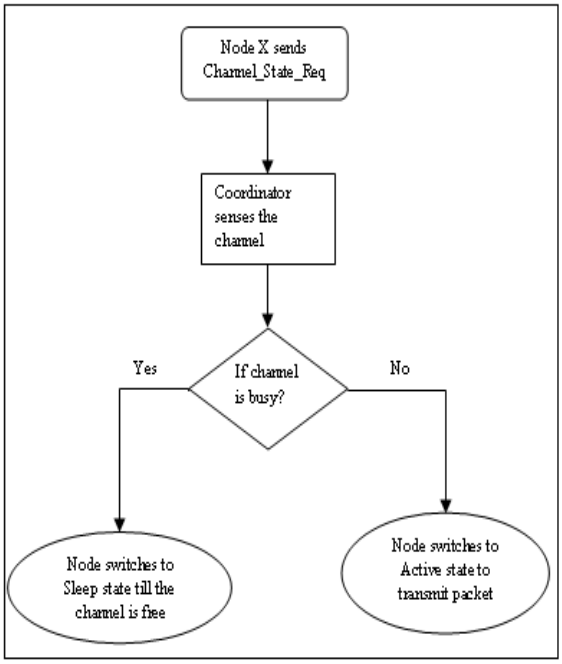

Figure 1. Energy Saving Multi-channel MAC Protocol's working

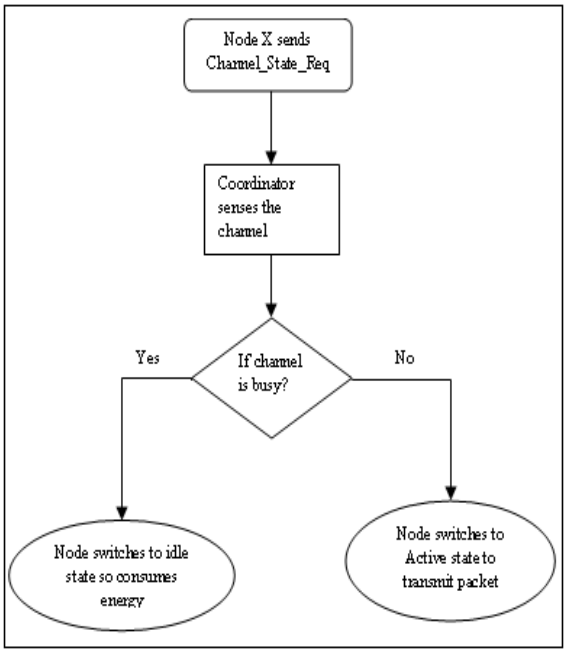

Figure 2. Traditional CSMA-CA Working

The coordinator will be any node with maximum energy to process and schedule the token to the corresponding nodes. Collision is avoided in our protocol by using different channels for communication. The nodes other than the one sending data will be in the sleep mode rather than idly listening to the channel which will consume considerable amount of energy.

IV. IMPLEMENTATION

In order to implement our Token on demand MAC protocol, we used the QualNet Simulator. It is a network simulation tool that simulates wireless and wired packet mode communication networks. QualNet Developer is a discrete event simulator used in the simulation of MANET, WiMAX networks, satellite networks, and sensor networks, among others. QualNet has models for common network protocols that are provided in source form and are organized around the OSI Stack. QualNet is a commercial tool derived from GloMoSim that was first released in 2000 by Scalable Network Technologies (SNT) [10]. The simulation parameters required to run our proposed scenario is given in the following table 1.

SIMULATION RESULTS

We analyzed the performance of MAC protocol in terms of PDR, Energy consumed in idle mode and Percentage of time in idle mode.

Packet Delivery Ratio (PDR)
The packet delivery ratio defined as the number of received data packets divided by the number of generated data packets. PDR will be represented in percentage (%) as shown in Figure 3.

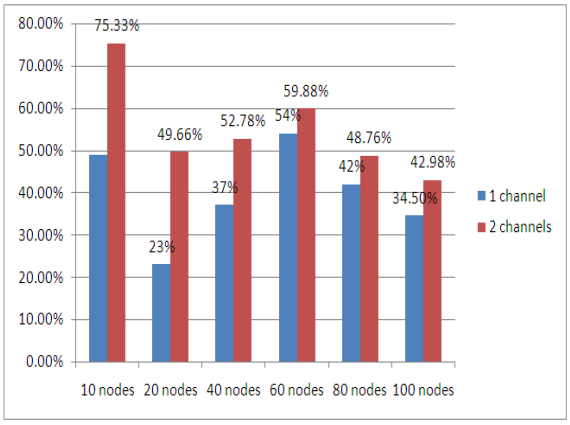

Figure 3. PDR output for CSMA-CA

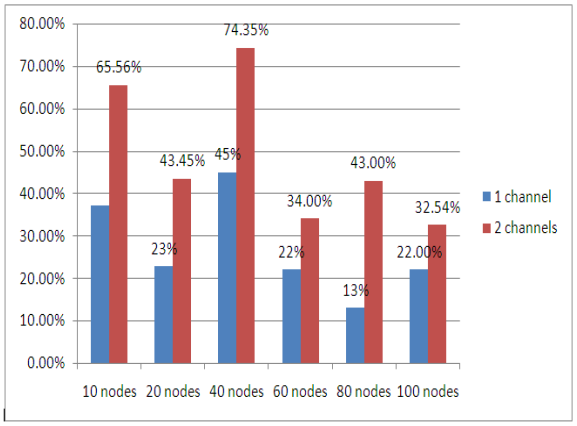

Figure 4. PDR output for Energy Saving Multi-channel MAC protocol

Time in idle mode

It is the amount of time spent by the node in idle mode. It is expressed in terms of percentage (%) as shown in figure 5 and 6.

Table 1. Simulation parameters

Terrain	500*500 m^2
No of common nodes	10
Simulation time	200s
Items to Send	100
Item Size	70
Routing protocol	AODV
Physical layer	802.15.4 Radio
MAC	802.15.4
Application Layer Traffic	CBR
Start Time	5s
End Time	0s
Pause Time	30s
Mobility Model	None
Number of CBR	3

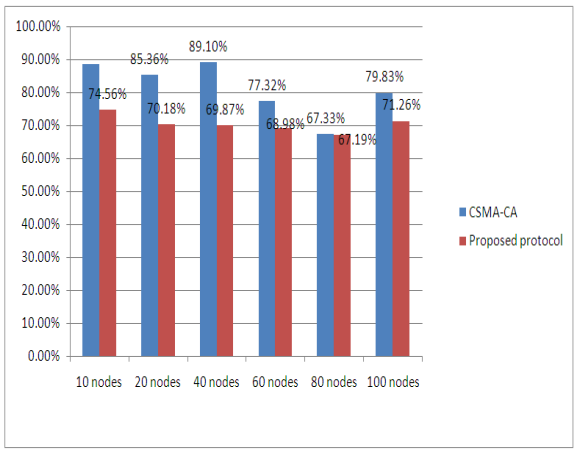

Figure 5. Time spent in idle mode for 1 channel

In Figure 5, time spent in idle mode for 1 channel is provided and in figure 6, time spent in idle mode for 2 channels is given.

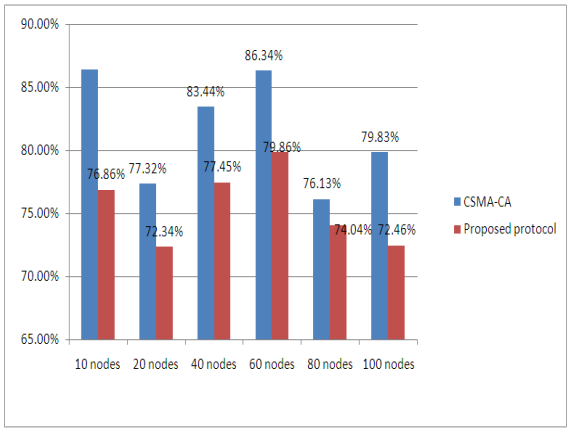

Figure 6. Time spent in idle mode for 2 channels

Energy consumed in idle mode

This refers to the amount of energy consumed in idle mode. Energy is generally expressed in terms of seconds (s) as shown in Figure 7.

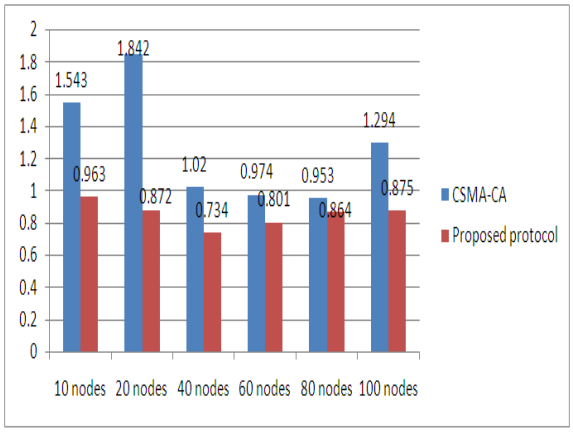

Figure 7. Energy consumed in idle mode

The above Figure 3, Figure 4, Figure 5, Figure 6 and Figure 7 shows the overall performance of the proposed MAC protocol with respect to different parameters like number of channels, energy and time

spent in idle mode.. In our scenarios, we considered 1 channel and 2 channels for performance assessment. The three metrics PDR, Time in idle mode, Energy consumed in idle mode are analyzed. The performance of the protocol according to energy is very much reduced when compared with the traditional CSMA-CA protocol. PDR is comparatively reduced for the proposed protocol but it is increased when the number of channels increased because of decrease in collision. Even the time spent on idle mode is decreased for our protocol which will consume considerable amount of energy since the receiver of the nodes will be active when the nodes are in idle mode. Hence it is desirable to use different channels in order to enhance the performance of the protocol by reducing the collision and energy is saved much with our proposed protocol.

V. CONCLUSION AND FUTURE WORK

We analyzed the performance of the protocol by changing the number of channels for data transmission and studied in terms of metrics like packet delivery ratio, time spent in idle mode and energy consumed in idle mode. The problem of collision has been reduced with help of multiple channels. Energy has been consumed much by switching the nodes to different states rather than be in active mode, when not in communication. As part of future work, we planned to implement the separate channels for control and data messages in order to enhance the performance of current MAC protocol by increasing the packet delivery ratio and by decreasing the overhead of the protocol.

REFERENCES

[1] http://en.wikipedia.org/wiki/Wireless_sensor_network

[2] ArchanaBharathidasan, Vijay AnandSaiPonduru,"Sensor Networks- An Overview", http://www.eps2009.dj-inod.com/docs/09-02-01/sensor_networks_an_overview

[3] Subhasis Dash, AmulyaRatna Swain, Anuja Ajay, "Reliable Energy Aware Multi-Token Based MAC Protocol for WSN", 26th IEEE International Conference on Advanced Information Networking and Applications, 2012

[4] Yi-Huai Hsu, Kuochen Wang Rong-Hong Jan, Yuh-Jyh Hu and Tien-Hsiung Ku, "An Efficient Cluster-based Multi-channel MAC Protocol for Wireless Multimedia Sensor Networks", http://pds.cis.nctu.edu.tw/Kwang/paper/C64_An Efficient Cluster-based Multi-channel MAC Protocol for Wireless Multimedia SensorNetworks.pdf, 2008

[5] Muhammad HaneefZhongliang Deng, "Application specific analysis of MAC layer protocols used in Wireless sensor networks", IEEE 2010

[6] Jalel Ben-Othman, Lynda Mokdad, Bashir Yahya, "An Energy Efficient Priority-based QoS MAC Protocol for Wireless Sensor Networks", IEEE International Conference on Communications(ICC), 2011

[7] GholamHosseinEkbataniFard, Reza Monsefi, "MAMAC: A Multi-channel Asynchronous MAC Protocol for Wireless Sensor Networks", International Conference on Broadband and Wireless Computing, Communication and Applications, IEEE 2011

[8] Pei Huang, Li Xiao, SoroorSoltani, Matt W. Mutka, and Ning Xi "The Evolution of MAC Protocols in Wireless Sensor Networks: A Survey", Communication Surveys and Tutorials, IEEE 2012

[9] Xiaoguang Li, Jie Wu, Shan Lin, Xiaojiang Du, "Channel Switching Control Policy for Wireless Mesh Networks "International Journal of Parallel and Distributed Computing, Volume 72, Issue 10, October 2012

[10] Scalable Network Technologies, QualNet-5.0.2-UsersGuide