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Exploitation of SMAC for Energy Optimization in WSNs in Dynamic Spectrum Access

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Abstract— In the present era, Wireless sensor networks has emerged as one of the most prominent area in the field of research. In wireless networks, most of the bandwidth goes unutilized in fixed spectrum allocation. In order to acknowledge the mentioned problem, we have implemented WSNETs, using dynamic spectrum allocation technique. We have simulated and implemented TDMA based protocol known as SMAC as it allows to access multiple channels at a time. The single channel medium access protocol suffers from multi-channel hidden terminal problem. The SMAC protocol overcomes this problem as it allows the other users (secondary users) to sense and utilize the bandwidth which is left unused by the primary users. A comparison is made between IEEE 802.11 and the proposed SMAC model. The results of the simulation show that the proposed model is energy efficient and have high network throughput. The complete model is deployed over NS2.
Keywords— Dynamic spectrum Access, WSNETs, IEEE 802.11, S-MAC, Network Simulator 2.9.

I. INTRODUCTION

Networking with the implementation of wireless sensors is increasing at a very faster rate. The application includes robotics, medical equipments/devices, monitoring and many more. The setup includes the arrangement of sensor nodes that are widely distributed and arrange themselves into the multihop environment. Each node in the Wireless Sensor Networks consists of sensors and the number of sensors may vary depending upon the requirement, along with the processors that are embedded in them and the low power radios.

Earlier fixed spectrum policy was followed and the allotment of the spectrum is regulated and controlled by the government organization. In wireless networks, using fixed spectrum policy the data is broadcast to every node in the network and it uses a very small portion of the spectrum and the major portion of the spectrum gets wasted up. The fluctuations of the spectrum utilizaton is depicted in the Fig. 1.

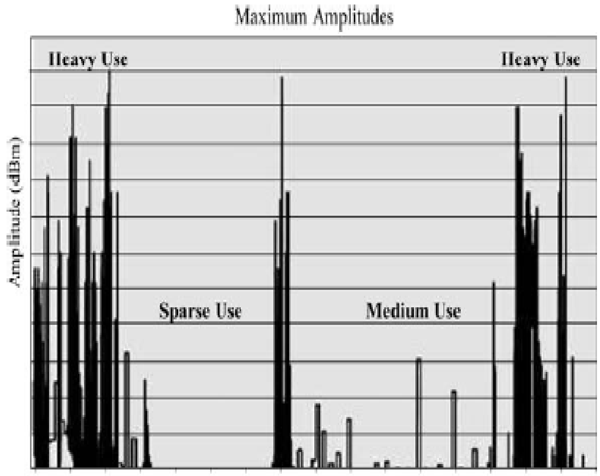

Fig. 1. Utilization of Spectrum

Fixed spectrum allocation could be so improper because of the availability of free channel and underutilization of the fixed allocated spectrum.

The solution to this problem is Dynamic Spectrum Access (D&A). It is new technique to overcome the limitation of fixed spectrum allocation, i.e. availability of free channel. It allows the cognitive radios to be operational in the channel that is best available among the available ones [2].

This technique was initially proposed by Joseph Mitola III [3]. Another asset of this technique is that it provides an easy demarcation of portion of the spectrum available for usage. Moreover by virtue of this technique licensed users are also authenticated when they operate in licensed band and this feature is called as spectrum sensing [4].

Apart from this, it also coordinate for the channel access with other active users and whenever there is a detection of licensed user in the channel, then it vacates the channel and made available for the licensed user. This technique is termed as spectrum mobility. Manifested characteristics of this technique also include topologies which are dynamic in nature. Constraints of the energy and bandwidth and instability of time, these features lead to the challenges while providing the communication to WSNs.

Other than all these technical factors, the major challenge is energy consumption element. As the nodes in WSNs, owns a limited battery so the consumption of energy must be highly analyzed and devour accordingly.

Sensor nodes in wireless networks also get activated when it needs to transmit the received data . Also it became difficult to synchronize with other nodes and to acquire the needed channel. Therefore, SMAC protocol is used for communication as the requirement arises for central authority.

SMAC uses these novel techniques, emphasizing on minimizing the consumption of energy while the node listens to the channel. When the channel is idle and during periodic sleep of the nodes. Like PAMAS, when the other nodes are doing data transmission, SMAC sets radio to sleep for the rest of the nodes that are not involved in data transmission during that time.

Further to descend contention latency, SMAC uses message passing for sensor network based applications.

In order to maximize the utilization of spectrum by the wireless networks, the designing of SMAC layer should be done in such a manner so that multi channels can be utilized parallel. The infliction of multi channel entile innumerable transmissions on varied channels. This leads to the overall increase of overall throughput. Therefore, multi channel MAC protocols are in very much practical use as compare to multiple access MAC. They offer less interference between the users and also reduces the count of nodes that will be affected if the licensed user is returned. At present IEEE 802.11 devices are furnished with half duplex transreceivers. This limit the devices to hear to single device at a time which leads to multi channel hidden terminal problem. This problem is overcome by multichannel SMAC protocol.

Dynamic Spectrum Access (DSA) has transpire as new mode of communication to overcome the issue of improper utilization of channel in fixed spectrum allocation model in wireless networks. The accredit technology for Dynamic Spectrum Access is Cognitive Radio (CR) in wireless network.

The Cognitive Radio is the radio that has the capability to change its transmits power on the basis of environment in which it operates. The CR technology allows the users to check which portion of spectrum is available for utilization. In wireless sensor networks, each node may have the availability of more than single channel for communication. This creates issues in synchronizing multiple nodes to operate in single channel. Hence a MAC protocol will overcome this limitation by managing the access of the channel among the active nodes. Further SMAC protocol authorizes the secondary users to utilize the frequency spectrum left unutilized by the primary users in WSNET. This is known as multi channel utilization. It in turn increases the network throughput.

In this paper, we have used NS-2 which is a discrete event computer network simulation model [5]. This implements SMAC on distinctive level that provides features like multi channel utilization, spectrum sensing which leads to optimization of energy consumption in WSNs. It constructively oversee the multi channel hidden terminal problem.

This paper is divided into six sections. The second section describes the various reasons of energy wastes in WSNs. The third section describes the overview of SMAC design and its components. Section IV describes the simulation environment used and results. Section V concludes the paper. And the last section i.e Section VI proposes the future work.

II. VARIOUS REASONS OF ENERGY WASTES IN WSNs.

In the operation of WSNs, there are various reasons that leads to the wastage of the battery of the sensor nodes Some of them are mentioned below:

A. Energy wastes due to packet collisions

When a receiving node, receives more than one data packets at a time. The received packets are called as collided packets. If these packets collide even partially. Then all such packets will be discarded and re transmission of such packets will need more energy.

B. Overhearing

The receiver gets the packets that are meant for other nodes. This leads to the wastage of energy as re transmission is required to send the data packets to the correct node [1].

C. Idle Listening

This refers to the energy waste when a node listens to the idle bandwidth [7].

D. Overemitting

Energy waste when a packet is sent by the transmitter but the receiver is not ready to receive. This will again require re transmission [6].

E. Wastage of energy due to overheads of the packets.

Overheads are required for maintaining the data transmission as they are the control packets and they ensure for the successful delivery of message during the data transmission.

III. OVERVIEW OF SMAC DESIGN

A. Design goals of SMAC

There are multiple design goals of SMAC. Firstly it reduces energy consumption at the nodes. Secondly it supports good scalability. Thirdly it allows nodes to be self-configurable. These features of SMAC makes this protocol very much efficient [9].

Apart from this SMAC tries to reduce wastage of energy from all four sources of energy inefficiency.

1) Collision: SMAC reduces the energy waste due to collision by using RTS (Ready to Send) and CTS(Clear to Send) packets.

2) Overhearing: SMAC allows the radio to toggle between the off and on mode. It switches the radio to off mode when transmission is not meant for that node.

3) Control Overhead: It reduces the wastage of energy by implementing message passing.

4) Idle listening: SMAC do not keep the node in active mode all the time. Using periodic listen and sleep it reduces the wastage of energy.

B. Components of S-MAC

1) Periodic Listen and Sleep: Each node goes into periodic sleep mode during which it switches the radio off and sets a timer to awake later. When the timer expires, it wakes up and becomes active. Selection of sleep and listen duration is based on the application scenarios. As different applications requires different duration of sleep and listen periods. Neighboring nodes are synchronized together. Nodes exchange schedules by broadcast. Multiple neighbors contend for the medium for the transmission. Once transmission starts, it does not stop until completed.

2) Choosing and Maintaining Schedules: Each node maintains a schedule table. Initial schedule is established. Synchronizer helps in synchronizing the schedules. Follower helps nodes in following the schedules maintained in the schedule table.

3) Maintaining Synchronization: While maintaining the synchronization, it is required to prevent the clock drift. SYNC packets are used for updating the nodes periodically. Receiver nodes adjust their counters as per the received SYNC packets. Listen interval is divided into two parts and each part is further divided into time slots which is depicted in Fig. 2.

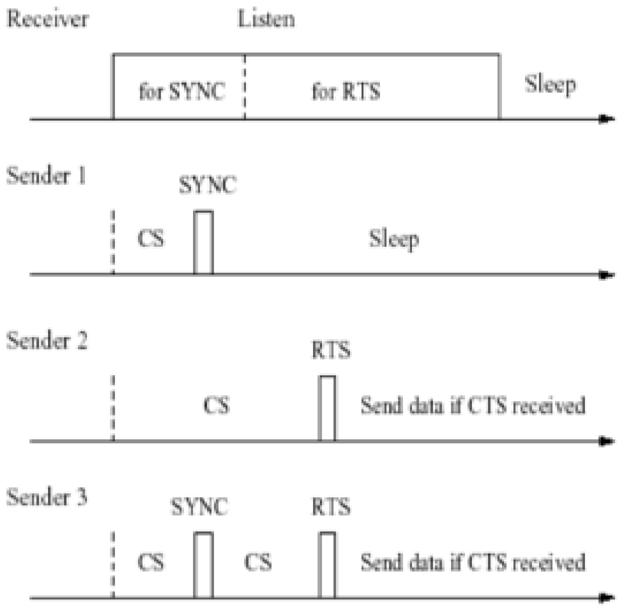

Fig .2. Time relationship

4) Collision Avoidance: SMAC uses RTS/CTS mechanism similar to IEEE 802.11 to avoid collision which inturn prevents re - transmission and results in minimizing the wastage of energy. SMAC performs virtual and physical carrier sense before transmission. RTS (Request to Send) / CTS(Clear to send) addresses the hidden terminal problem. Each packet contains a field NAV (Network Allocation Vector) which indicates how long the remaining transmission will be. It gives the idea to the nodes when to start off the transmission. Every time before starting the transmission, nodes check the NAV field value and if it is zero then it indicates that the channel is free for transmission and if the value is not zero then it indicates that the channel is busy. This is called as virtual carrier sensing.

5) Overhearing Avoidance: SMAC puts the interfering nodes to sleep after they hear the RTS or CTS packet. Also if the NAV value is not zero, indicating that the channel is busy then all the immediate neighbors of sender and receiver should go to sleep which helps in avoiding overhearing leading to the prevention of the wastage of energy consumption of the sensor nodes [8].

IV. SIMULATION RESULTS

This section describes the implementation and simulation results for the optimization of energy consumption in WSNs in dynamic spectrum access using SMAC protocol. This section will also explain the simulation environment used and performance of the proposed model. The results of the SMAC protocol are compared with IEEE 802.11.

A. Network Simulator 2

In order to evaluate the performance of SMAC protocol in dynamic spectrum access, we have used network simulator version 2.9. There are multiple advantages of NS2, implementation of SMAC in NS2 is one of the important out of them. The proposed model is highly scalable as it allows implementation of multiple protocols at higher level without modifying the basic architecture of it. Like, sleeping schedules of these nodes are synchronized by the neighbouring nodes. Further it turns the nodes to sleep mode when other nodes communicates.

B. Consumption of energy at intermediate node

In order to check for the consumption of energy at intermediate nodes we have used three node topology [09]. Out of which one is sender, one is router and last is sink. Then the intermediate nodes are tested for ideal energy state [10]. It is observed that the change of the consumption of energy at intermediate node is very less while for SMAC it is very large. This is represented in the Gnuplot in Fig. 3.

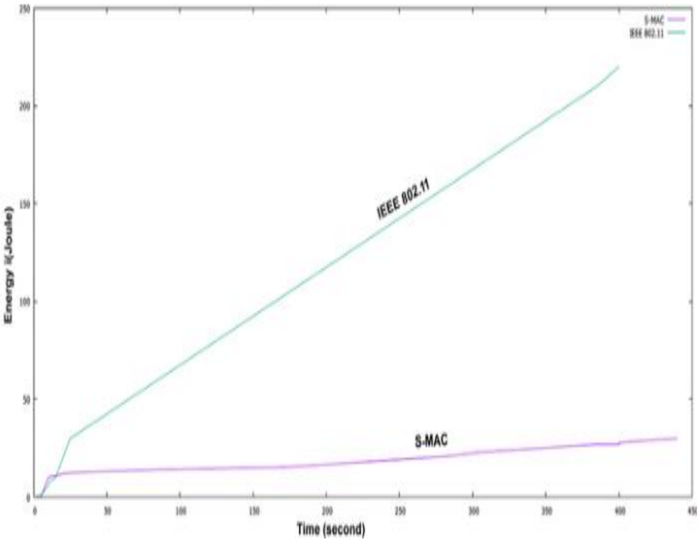

Fig.3. Consumption of energy at intermediate node.

Also if we change the duty cycle which results in changing the listen period. Then listen period is directly proportional to energy consumption and inversely proportional to delay. Further the Gnuplot of efficiency and Link bandwidth is represented in Fig.4.

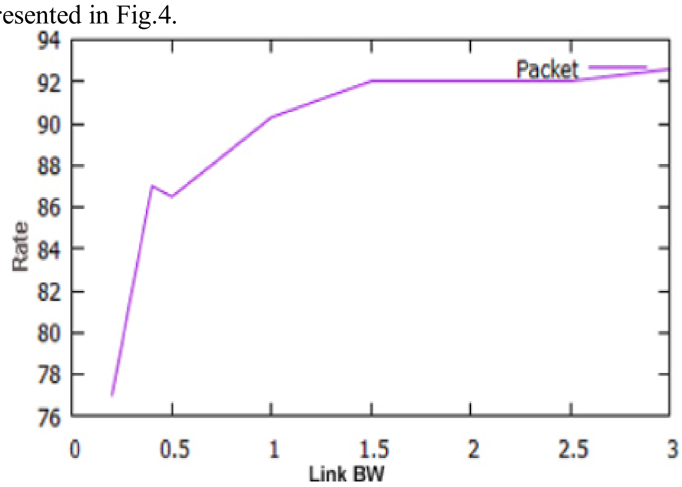

Fig.4. Rate and Link BW.

V. CONCLUSION

The aim of the paper is to simulate an energy efficient WSN under dynamic spectrum access. We have used NS2 to have a network that have features like spectrum sensing. Also S-MAC has good energy conserving properties comparing to IEEE 802.11. So we have implemented SMAC protocol in the proposed network. Then we have compared the results generated using the SMAC with protocol IEEE 802.11.
Results shows that the SMAC protocol have higher network throughput as compare to IEEE 802.11 as SMAC uses multiple channels at a time which leads to the improvement of network throughput.

After analysing the results of the simulation, conclusions are mentioned below:
Energy losses due to idle listening are effectively reduced by the implementation of SMAC protocol with periodic sleep as it uses sleep and wakeup strategies. However it reduces throughput and increases latency. Hence between delay and latency, SMAC protocol is a tradeoff.

VI. FUTURE WORK

Energy optimization using the combination of SMAC and TMAC as TMAC specifically reduces the inactive time of the sensors as compare to SMAC. This combination will further improve the energy consumption for Wireless Sensor Networks.

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