Efficient Energy Conservation Technique in Wireless Sensor Network

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Abstract- This paper has presented efficient energy conservation for wireless sensor network (WSN) security. As a form of distributed network, a WSN aids the gathering of information in wireless communication within an area of interest. A WSN deployed for application faces the challenge of limited power over use time. This is because the energy of nodes in sensor networks ensures that reliable communication among nodes is achieved with less cost when properly managed. An algorithm that performs routine task anchored on node clustering to improve and efficiently manage energy level of sensor nodes is modeled and implemented. A WSN topology model and algorithm was developed and implemented in MATLAB. Simulations were conducted in MATLAB environment to analyze the effectiveness of the developed algorithm in ensuring that energy consumed by a node is minimized. Results obtained indicated that the overall energy consumed by the WSN topology was less than the initial energy of each node set as 2.0 J. In terms of the variation of energy consumed with respect to traffic volume, it was observed that as the number of messages transmitted across the WSN increases, the average energy consumed per node and energy consumed by the network increases. In the case of the average energy consumed per node, the value increases from 0.0008075 J to 0.003358 J, and increases from 0.1116 J to 0.3820 J in terms of energy consumed by nodes for 5000 messages to 20000 messages respectively.

Indexed Terms- Energy conservation; WSN topology; Sensor; Wireless communication

I. INTRODUCTION

In the composition of wireless sensor network (WSN), a set of sensors are used to explore the physical environment. The sensors in the network search their physical environment for information by measuring physical parameters and consequently send the measurements to a nearby central controller through a feedback mechanism. The controller collects the information from all the sensor nodes and manipulates them and then interfaces WSN to distant locations where users can use the information to plan and execute given actions.

As ad-hoc networks, sensor nodes in WSNs, are broadly spread in an area of concern for real time extraction of data. These nodes serve as both sensing and routing devices. Several sensor nodes may be employed to send data from the primary source node to the destination node for example, multi-hop communication. The destination node is described as a sink node [1].

Once a WSN is set up, every sensor node has a fixed amount of energy. There is a power subsystem that powers the sensors. Hence, each sensor in the network place an energy cost or burden for every action carried out, which gradually reduces power of the sensor. There are actions such as communication that need a huge amount of power, while some need very small amount of power. When power is lost by a sensor, it cannot sense information, interact with other sensors (nodes) or route information. The sensor in this case is said to be dead. If single node dies, a major impact may not be felt on the WSN. However, as more and more nodes die out, the impact on WSN becomes obvious and the performance of the network degrades as it may become divided and no longer reliable.

In order to enhance energy efficiency wireless sensor network (WSN), a technique for energy efficiency is studied in this paper.

II. LITERATURE REVIEW

A. *Conservation of Energy in Wireless Sensor Network*

Conservation of energy in a WSN is an important issue since all the sensor nodes are in a network powered by limited battery sources. Designing energy efficient system for a WSN has attracted significant interest from many researchers. This has brought about in the development of different techniques for saving the limited energy of the sensor nodes, and by extension prolonging the life of the network [2-4].

Sensors make use of their energy for sensing and processing data and also to carry out transmitting and receiving data. More energy consumed by the communication subsystem of a sensor node consumes than the processing subsystem. It has been revealed that transmitting one bit of data may take as much energy as executing a few thousand computational instructions [2]. Therefore, it is essential that energy efficiency be focused on the communications subsystem as only minimal gains are achieved by optimizing the energy of the sensing and processing subsystems. In developing energy efficient communication methods in a WSN, the focus will be on the network layer of the protocol stack. Efficient models or algorithms can be developed at the network layer such that consistent route setup and relaying of data from the sensor nodes to the sink is accomplished and the lifetime of the network is maximized [6].

There are three broad categories of energy efficient routing protocols for WSN namely, data centric protocols, hierarchical or clustering based protocols, and location based or geographical protocols. Three famous techniques have emerged from these three categories. Data centric routing techniques uses a model that is query driven to reduce the amount of transmitted data and are also capable of collecting data while conveying it to the sink. Directed Diffusion and Adaptive Protocols for Information Dissemination in WSNs (Sensor Protocol for Information via Negotiation known as SPIN) are the dominant data centric protocols [7]. Low Energy Adaptive Clustering Hierarchy (LEACH) is best among the hierarchical or clustering based protocols. These three techniques have become common performance baselines, with most of energy efficient routing study focused on improving their performance. Some of the parameters that are employed in evaluating these routing protocols are compared in Table 1.

TABLE 1 SPIN, LEACH, and Directed Diffusion are compared with one another [8]

	SPIN	LEACH	Directed Diffusion
Optimal Route	No	No	Yes
Network Lifetime	Good	Very Good	Good
Resource Awareness	Yes	Yes	Yes
Use of meta-data	Yes	No	Yes

B. *Empirical Review*

Kumar et al. [9] proposed modified LEACH protocol known as MaximuM-LEACH for increasing lifetime of WSN. The modified algorithm consisted of two phases: the setup phase and the steady state phase. In the setup phase, the base station knows the energy status and location of all the nodes. The base station evaluated the average energy of the network. All the nodes with energy greater than the average energy were selected as cluster heads. The steady state phase is similar to the steady state phase of the LEACH and LEACH-C protocols. The nodes send data to the cluster head. The study focused on improving LEACH performance to reduce the number of nodes stranded as the cluster heads die and on increasing network lifetime and throughput via load balancing.

Ez-zazi et al. [10] proposed an adaptive coding (AC) method that can be adapted with the channel state and inter-node distances so as to decode and correct the packets or request for retransmissions. The authors examined the energy performance of error control coding and proposed an energy efficient and adaptive coding framework for multi-hop WSN. The proposed method considered the trade-off between the decoding energy and transmission distance by taking into account the free space and multipath propagation to choose adaptively when to apply Forward Error Correction (FEC) decoding or request for retransmissions. The proposed AC method proved to be more energy efficient compared to Automatic Repeat request (ARQ) and FEC schemes in multi-hop WSN.

Shao et al. [11] proposed network coding aware energy efficient routing (NAER) for wireless sensor networks. In order to deal with the problem of network coding condition failure and neglecting of node energy, a network coding aware energy efficient routing for wireless sensor networks was proposed. In terms of the in-depth analysis of existing network coding condition, universal network coding condition (UCC) was presented to avoid network coding condition failure problem. Based on UCC, the cross layer network coding discovery method combined with coverage control and topology control was presented to further increase the number of network coding opportunities. Additionally, a network coding aware energy efficient routing metric (NERM) was presented, which took into account coding opportunity, node energy, and link quality jointly. Simulation results demonstrated that NAER improved the accuracy of coding discovery system, increases the number of coding opportunities, saves node's energy consumption, and extended network lifetime.

Ghaffari [12] presented an energy efficient routing protocol for wireless sensor networks (WSNs) using A-star algorithm. It proposed a new energy-efficient routing protocol (EERP) for WSNs using A-star algorithm. The proposed routing method improved the network lifetime by forwarding data packets via the optimal shortest path. The optimal path can be discovered with regard to the maximum residual energy of the next hop sensor node, high link quality, buffer occupancy and minimum hop counts. Simulation results indicate that the proposed scheme improves network lifetime in comparison with A-star and fuzzy logic protocol.

Liu et al. [13] presented an improved energy-efficient routing protocol for WSN. A low-energy adaptive clustering hierarchy (LEACH) was proposed as an application-specific protocol architecture for WSNs. Nevertheless, the authors stated that without considering the distribution of the cluster heads (CHs) in the rotation basis, the LEACH protocol would increase the energy consumption of the network. In order to improve the energy efficiency of the WSN, the authors proposed a novel modified routing protocol. The proposed scheme improved energy-efficient LEACH (IEE-LEACH) protocol considered the residual node energy and the average energy of the networks. In order to achieve reasonable performance in terms of reducing the sensor energy consumption, the proposed IEE-LEACH was responsible for the numbers of the optimal CHs and prohibits the nodes that were closer to the base station (BS) to join in the cluster formation. In addition, the proposed IEE-LEACH used a new level for electing CHs among the sensor nodes, and used single hop, multi-hop, and hybrid communications to further improve the energy efficiency of the networks. The simulation results demonstrated that, compared with some existing routing protocols, the proposed protocol substantially reduced the energy consumption of WSNs.

III. RESEARCH METHOD

It is quite challenging to model a wireless sensor network (WSN) to be used for simulation purpose. In this paper, effort has been made to develop a model that is practically feasible within the limits of simulation in MATLAB environment.

A. Modeling of Wireless Sensor Network

In order to safeguard the sink node and at the same time improve the energy efficiency of the network, a randomly distributed sensor nodes configuration over sink node is proposed. This helps to reduce distance of communication between sink node and the sensor nodes. The proposed system is represented by the block diagram in Fig. 1.

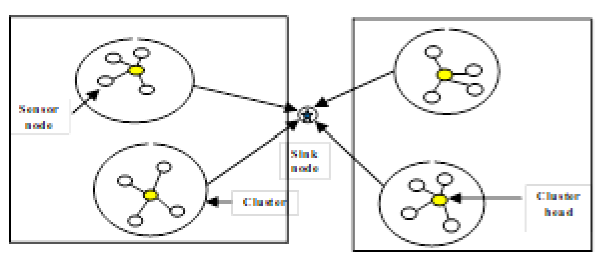

Fig. 1 Block diagram of propose WSN

B. MATLAB Model

In this work, modeling is carried out in MATLAB based on the following parameters.

- Simulation Setup: the model which will be used for simulation purpose in this work is a 100 by 100m in area. There are 100 sensor nodes in the model. This number can be adjusted. However, the number of 100 nodes is a reasonable number and can ensure enough coverage of the area of interest and connectivity of WSN.
- Nodes' Placement: in this work, the nodes are randomly distributed throughout the whole area.
- Sink Node Placement: the sink node is deliberately positioned in this work in the x and y coordinates given by: (x,y) = (25m,75m). It should be noted that sink node is not randomly placed.

The information provided for the modeling is coded in MATLAB and the model is shown in Fig. 2.

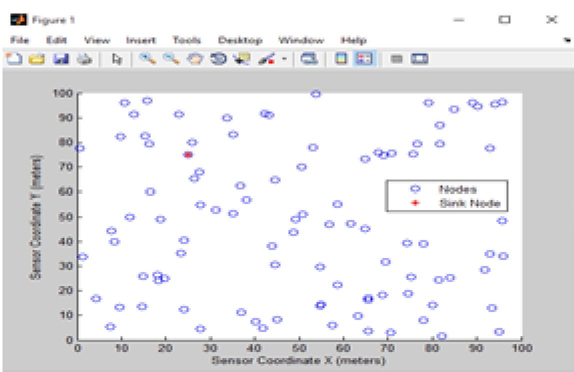

Fig. 2 Random Sensor Wireless Network coded in MATLAB

C. Cluster based Routing

In this work, to achieve energy-controlled anonymity, a routing algorithm based on node clustering which leads to having at least *n* other nodes that have related observable traffic statistics, and therefore confusing the location of the sink node is proposed.

The procedures that the wireless sensor network (WSN) takes when put into operation to route traffic are as follows:

i. Cluster Head (CH) election and cluster formation.
ii. Select a subset of the CHs to function as broadcast CHs.

- *Clustering:* Clustering is a normal process for achieving efficient and scalable performance in sensor networks. When nodes are clustered into groups, energy saved and aid distribution of control over the network [14]. In order to form clusters, sensor nodes must first elect a CH for each cluster. Nodes that are not CHs in the WSN find the closest CH within range and become cluster members. The nodes in a cluster only interact with one another and the CH. Data sensed by a node is transmitted to its CH. The CH is accountable for all routing and communication external to the cluster. This brings about energy savings over a "flat" topology, where every node must determine the route from source to sink node. As a result of this, the first procedure in the proposed algorithm is the initialization and formation of clusters. All the nodes in the WSN either choose to become a CH or join a cluster as a cluster member. An exception is the sink node. The sink node is always a cluster member in the WSN. It is never chosen to be a CH. This constraint has been forced on the sink node for the reason that, if the sink node is always a CH, then it becomes obvious to an attacker carrying out traffic analysis. Such that after a few CH rotations the sink node is the only node always re-elected to the function of CH. This will make the adversary to come into conclusion that the sink node (which is one of several CHs) has a more important role in the WSN.
- *Selection of Cluster Head:* Every sensor in the WSN may choose to become a CH with a predetermined probability *p* when the network is installed. There is not an optimal number of CHs for a WSN. For each topology the clustering process must guarantee that no nodes become separated and that there are no more clusters than required as surplus clusters decrease the energy savings produced from clustering.

An iterative process is used to balance the competing demands of preventing separation and accomplishing energy efficiency. In this work, the probability of a sensor node choosing to become a CH *p* is set at 0.20. This value was determined sothat most of the CHs are chosen in the first iteration, while the additional two iterations serve to guarantee that no sensor node is separated in the WSN.

The sink node has been mentioned earlier as never a CH. Thus, the sink node does not undergo the process of electing or choosing to become a CH. The sink node simply searches the nearest CH to join as a cluster member. The CH that serves the sink node is called the CH of the sink node. Over 1000 different topologies are intended to be determined where the mean number of likely sink node CHs is 40, with the minimum being 24 and the maximum being 54, so there will always be a node within range to serve as the CH of the sink node. If every one of these nodes chooses with a probability of 0.2 to become a CH, then there is a0.01% possibility (based on the average number of nodes) that none of these nodes elect or choose to become a CH. If this condition is met, then the network reinitializes and goes over the CH election process.

- *Cluster Head Rotation in WSN Topology:* The utilization of a clustering hierarchy enhances the general energy efficiency of the WSN. Only CHs evaluate routes and route traffic, which is a significant savings over every one of the node acting autonomously to route traffic. Clustering also imposes a substantial energy burden on the nodes that act as CHs; therefore, it is essential to rotate the role of CH within the WSN.

In this paper, the CHs are rotated for two reasons: load balancing and privacy. The CHs are reelected in the same way they were at first elected. The CHs are rotated at what time one of the two conditions is met. Either one of the CHs has exhausted a certain amount of energy or a given number of messages have been transmitted through the WSN. CHs are rotated if: 1) any CH used up one percent of its initial energy value $E_o/100$, where E_o represents the initial node energy or 2) the sink node's CH receives 1000 messages. The energy threshold is set at one percent because the costs of energy for routing traffic in the WSN are relatively low. If there is delay for more energy to be consumed, for instance 5%, the CHs would only rotate when the number of messages threshold was met. It is decided in this work to rotate fairly often because not doing so will make the cluster topology of the WSN to be static for long periods of time. With a static topology it is possible that the attacker could locate and inspect every one of the node for which traffic is broadcast to in an effort to locate the sink node [15]. The privacy of the sink node is increased by rotating the CHs. This so because randomizing the paths that traffic takes through the WSN will make it more difficult for an attacker to make any conclusions as to the sink node location.

- *Selection of Broadcast Cluster Head:* When selecting the broadcast CHs, two important considerations are made: 1) The amount of residual energy for the CH and 2) the number of cluster members of every one of the cluster. The overall number of broadcast cluster nodes is changeable based on the number of members in every one of the node. A lower threshold of 20 nodes broadcast is established in this algorithm to guarantee a minimum desired level of anonymity.

The CHs are structured by their residual energy levels. The CH with the most energy is selected to be the first broadcast CH. The number of cluster members which are broadcast to is then saved. Every one of the subsequent broadcast CH is selected sequentially based on the most residual energy.

D. Simulation Parameters

The values of the parameters used for simulation in MATLAB are shown in Table 2.

TABLE 2 Simulation parameters

Parameter	Value
No of sensors	100
Area	100m by 100m square
Transmit power	5.0×10^{-9}W
Receive power	5.0×10^{-9}W
Processing power	5.0×10^{-9}W
Initial Energy of sink node	2.0 J
Initial Energy of Each node	2.0 J
Traffic generation messages	5,000 to 20,000
No of threshold nodes	20
Sink node coordinate	(x,y) = (25m, 75m)

IV. RESULTS, ANALYSIS AND DISCUSSION

This section presents the outcome of the simulations carried out in MATLAB Simulink environment. In the simulation carried out in this study for wireless sensor network (WSN) sink node anonymity and energy efficient, each sensor in the network can elect or choose to become a cluster head (CH) with a given probability p when network is set up. However, there is no optimal number of CHs for a WSN. In this paper, the probability of a sensor node to become a CH was taken from 0.1 to 0.5. This was demonstrated by carrying out simulation to determine which value will ensure optimal performance with most of the CHs selected. Having obtained the probability that offered the most promising performance to be 0.2; further simulation was conducted in terms of the energy efficiency of the developed algorithm for different generated traffic (5000 to 20000) messages. Clustering is a standard to achieving efficient and scalable performance in WSN and that it is form when sensor nodes first elect a CH for each cluster. Figure 3 is the simulation plot showing the sensor node, sink node and cluster head.

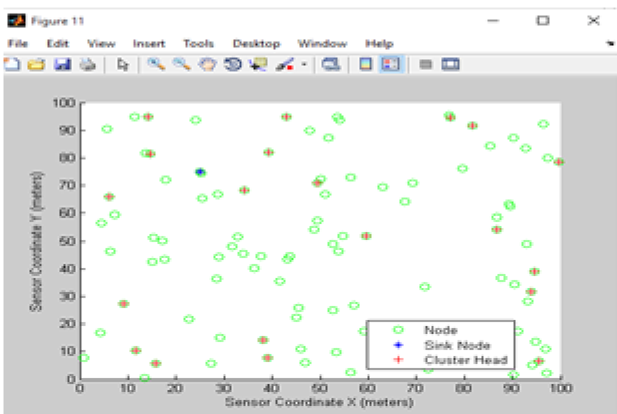

Fig. 3 simulation plot of sensor node, sink node and cluster head

The statistical results of simulations carried out in MATLAB for different traffic volume (or message, M). The MATLAB simulation reports graphs are presented in Fig. 4a to 7a. Tables 3 to 6 are the analysis reports, while Figures 4b to 7b are the statistical plots of the simulations.

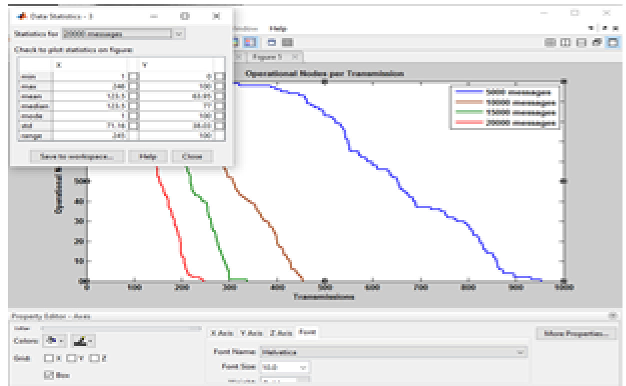

Fig. 4a Operational nodes per transmission with respect to messages

TABLE 3 Analysis of operational nodes per transmission for messages

Message	Transmission	Operational nodes
5000	953	100
10000	454	100
15000	337	100
20000	246	100

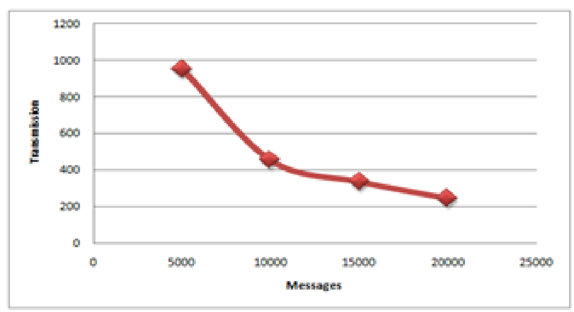

Fig. 4b Transmission against messages

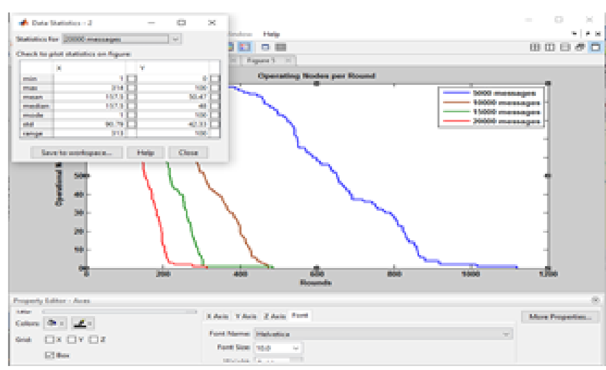

Fig. 5a Operational Nodes per Rounds with respect to messages

TABLE 4 Analysis of operational nodes per rounds for messages

Message	Round	Operational nodes
5000	1120	100
10000	473	100
15000	392	100
20000	314	100

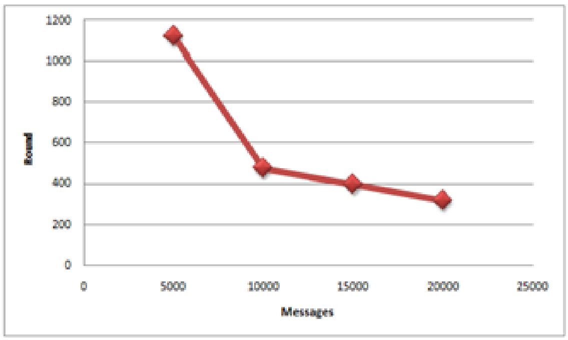

Fig. 5b Round against messages

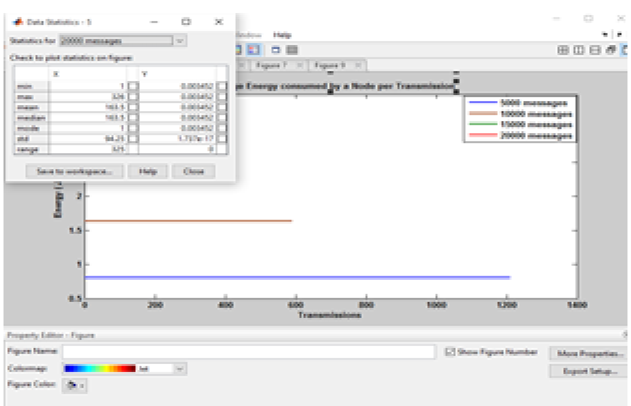

Fig. 6a Average energy consumed by a node per transmission with respect to messages

Table 5 Average energy consumed by a node per transmission for message

Message	Transmission	Average Energy (J)
5000	302	0.0008075
10000	160	0.00167
15000	122	0.00236
20000	92	0.003358

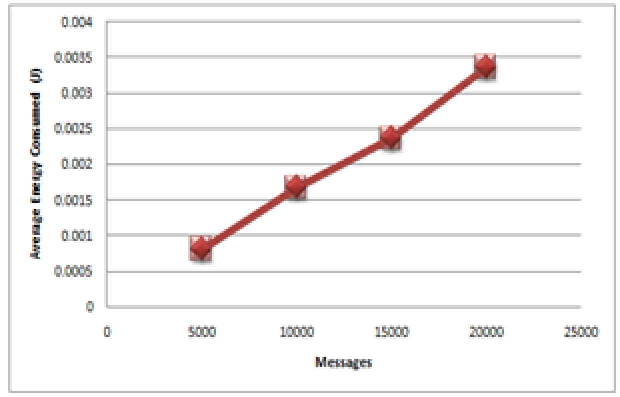

Fig. 6b Average energy consumed against messages

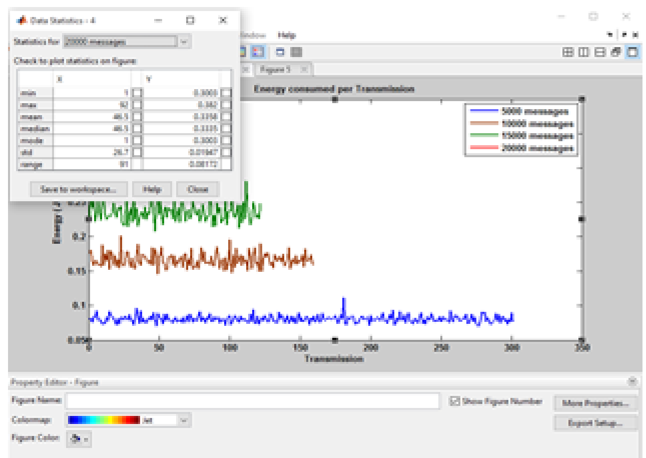

Fig. 7a Energy consumed per transmission with respect to messages

TABLE 6 Energy consumed per transmission for massages

Message	Transmission	Energy (J)
5000	302	0.1116
10000	160	0.2014
15000	122	0.2807
20000	92	0.3820

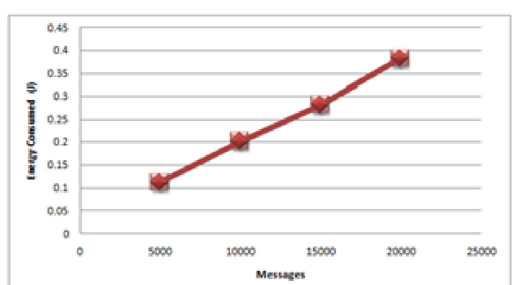

Figure 7b Energy consumed against messages

The numerical values for the average energy consumed by a node, and energy consumed by nodes in WSN are shown in Tables 5 and 6. As it can be seen in Fig. 4 and 5, transmission and rounds operation of WSN nodes decreases as the volume of traffic (or messages) increases. Also an obvious consistency of the average energy consumed by a node in the WSN can be seen based on the four simulation steps conducted and increases as the traffic volume increases across the WSN as shown in Fig. 6. Similar pattern is also followed for the energy consumed, which increases as the traffic volume increases across the WSN as shown in Fig. 7. Generally, the trend of increased energy consumed with increased messages holds for different simulation trial.

The number of messages the energy consumed node sends through the WSN is usual when compared to other values at the same traffic volume. The number of times the energy consumed node serves as a cluster head (CH), broadcast CH and the sink node's CH is the highest at the four simulations trial when 20,000 messages are sent and thereby driving energy consumed in the WSN higher. The second highest energy consumed node is registered during the transmission of 15,000 messages through the WSN and also carries out the role of cluster member, CH, broadcast CH and the sink node's CH in a similar way with 122 number of transmission time with less energy consumed compared with the 20,000 messages where number of transmission time was 92 with higher energy consumed node as shown in Table 6.

It can be said generally that the simulation results obtained in terms of average energy consumed by a node and the overall energy consumed by nodes in the WSN with respect to different traffic volume (or messages) as shown in Tables 5 and 6 indicate that at each simulation trial representing the operation of sensor nodes in the network, the average energy and energy consumed are less than initial energy value of sensor node which is 2.0 J (see Table 2). Thus it suffices to say that the developed algorithm has been able to provide energy efficiency for the operation of the WSN.

CONCLUSION

In this paper, a WSN model and routing algorithm has been presented for providing energy efficiency in WSN. The developed topology and routing algorithm for WSN was validated through simulation experiments conducted in MATLAB environment. Results obtained indicated that the overall energy consumed by the WSN topology was less than the initial energy of each node set as 2.0 J. In terms of the variation of energy consumed with respect to traffic volume, it was observed that as the number of messages transmitted across the WSN increases, the average energy consumed per node and energy consumed by the network increases.

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