Behavioral Analysis of Energy In Wireless Sensor Networks

Nikhil A. Chaudhari, Vivek S. Deshpande, J. B. Helonde, V. M. Wadhai

Abstract- Wireless sensor networking (WSN) is the greatest solution to many problems. It can be easily used in many applications prospectively. Sensor in the WSN is very important and a crucial part. The basic operation of a node in the network is to gather and transmit the information to base station for processing. The most critical question in WSN is to schedule the nodes properly according to time quantum. In this paper, it has been discussed how the nodes are scheduled to execute the data and how the cluster heads are formed in each cluster depending upon the calculated weight based on the energy of node and distance from its adjoining node. Different schemes of energy reduction have also been discussed.

Keywords - Wireless Sensor Networking, Energy consumption, TDMA, Scheduling, Clustering.

I. INTRODUCTION

Wireless Sensor Network has been very popular in the recent past. A WSN is a collection of sensing, computing and communication elements. A wireless sensor network consists of specially distributed sensors to monitor physical or environmental conditions, such as temperature, sound, pressure etc. and to pass their data through the network to a main location. A wired network is costlier than the wireless network. In case of a wireless network, we can easily replace the nodes in the event of node failure, but we cannot do the same thing in a wired network. If a node is replaced in a wireless network then it easily matches in network. Wireless sensor network depends upon resources i.e. sensor nodes and hence energy is an important factor in such a type of network in as much as all operations of nodes that depend upon energy constraints.

Fig. 1 shows the typical example of Wireless Sensor Network that captures the area it is installed in and sends the images to the base station i.e. sink. It consists of some nodes distributed over a certain area wherein some nodes have a camera attached to themselves to capture the images. Besides, the sink present in the network executes the data received from the nodes and gives the output accordingly.

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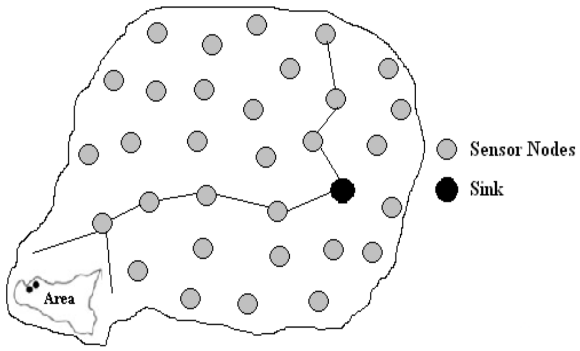

Fig. 1. Application of Wireless Sensor Network

The images captured by a node are sent to the sink through subsequent paths like transmitting the information via intermediate nodes. Finally, in this manner, all the captured data reaches the sink for further data execution. In this way, this technique finds its effective application in the surveillance of any particular location.

WSN sensors collect data and perform functions like modifying, aggregating etc. and then send that data to the sink. These sensors are event-sensitive. When any event occurs, the sensors gather the data and send it to the next logically connected node. This traffic may lead to congestion which means that when the buffer of nodes is full, the nodes cannot receive the next data from the previous node. It is important that crucial data must reach the sink at a higher priority. However, due to congestion, the data cannot reach the destination and hence the number of packet drops increases that may result in wasteful energy consumption. These numbers of packet drops also affect other parameters of WSN like throughput, delay and reliability.

WSN sensors have very low power. They cannot move from one place to another and are deployed so deeply in the network that it becomes hard to reach the sensors and recharge them every time. Therefore, energy is very significant in sensor networks [1].

Operations in a sensor network, like namely, data reception, data transmission, querying request processing etc. consumes energy. This energy consumption is also wasteful if collision and network overhead of packet occurs [5]. Sometimes energy consumption badly affects the network lifetime [1].

There are certain factors which affect the energy consumption of the entire WSN. These factors are transmitting and receiving power, processing power, buffer scheduling, delay minimization, throughput and caching.

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In sparse network, nodes are scattered over a large area which increases the distance between two adjoining nodes and hence it requires a great deal of energy for data transmission. On the contrary, in a dense network, since nodes are situated quite proximally to each other, the energy required for data transmission is also less. The processing power of the nodes is one of the significant factors which affect the energy consumption of the network. For instance, in a catastrophic situation like earthquakes, the data is extremely crucial and hence must reach the base station so that 100% throughput could be achieved. But, if any of the intermediate nodes in the path fails then the preceding node finds an alternative path to send the data. In this process, the summation of the energy generated by the earlier packets and the energy generated by the new packets is very large, which ultimately results in a large amount of energy consumption. Buffer Scheduling is all about sending any particular packet on a priority basis in the buffer of an individual node. Additional energy is required for scheduling any important packet. Suppose the buffer size of any individual node is large, in that case, to schedule those many packets, energy consumption is also very high. Caching constitutes the significant aspect of maintenance of the number of packets which have already been sent so this also requires additional energy.

There are a lot of techniques that have earlier been studied for reducing the energy consumption such as clustering, scheduling of nodes according to time quantum, duty cycling [15]. One of the techniques is to form clusters and then these clusters gather the data and send it to the cluster head which are chosen by the clusters itself [1]. After receiving the data from nodes, cluster heads modify it and send this data to the sink which results into substantial reduction of energy consumption [6]-[12]. Another technique is to schedule the nodes according to time quantum using Time Division Multiple Access (TDMA). According to time slots, nodes perform the operations of receiving and transmitting the data [2]. This technique also results in less energy consumption.

II. RELATED WORK

Ping Ding et al. [1] expounded the cluster-based Wireless Sensor Network. Here, clusters are formed in the network based on the Distributed weight-based energy-efficient hierarchical clustering (DWEHC) method for reduction in energy consumption. Thereafter, in each cluster, node finds its next logically connected node and performs weight calculation depending upon energy of that particular node and distance from its next node. On the basis of this, highest weight node is chosen as a cluster head. All these nodes gather the information in the cluster and send it to next parent node, which, in turn, sends it to the next parent node. Finally the data reaches the cluster head. Following this, the cluster head performs aggregation and modification of incoming data sent by all cluster nodes. The cluster head sends this modified data to the base station [13], [14]. This saves the energy consumption of the entire network. It also maintains the reliability, throughput, delay and congestion which are other significant parameters of Wireless Sensor Network. In this technique, every node of the network executes the DWEHC method individually. After execution, the hierarchical structure of clusters is formed. Then in the cluster, two types of nodes viz. either cluster head or sensor node are formed. In every cluster, they use TDMA for functioning. According to time allocated to sensor nodes, the data is sensed and forwarded to the parent node. This data then reaches to cluster head. Finally, cluster heads send the data to the base station. Overall energy consumption is very low in this entire process [1]. Advantage of this algorithm is that it generates the cluster head in O(1) time. However, after every time interval the cluster head changes. This could be considered as a drawback of this algorithm.

Another method of energy reduction is Energy-Efficient Wake-Up Scheduling for Data Collection and Aggregation [2]. The main challenge of WSN is to gather the information in proper format and transfer it to the base station for next functioning. When a node is not performing any function such as receiving and transmitting the data, it is in sleep mode. There is much more energy consumption to activate the node from its sleep mode. This issue has been addressed by the Energy-Efficient Wake-Up Scheduling for Data Collection and Aggregation algorithm. In this algorithm, the network is considered as a tree in which sink is root node and all others are child nodes which use TDMA. According to TDMA-assigned time slots, every node has to wake up twice, ones each for receiving and transmitting the data. However, in this protocol every node wakes up only once and finishes all the functionality continuously so that it minimizes the wake up energy consumption of every node, leading to less energy consumption of the whole network [2]. Benefit of this technique is that it reduces the energy cost for state switching. But since nodes use TDMA, the delay is relatively larger.

Zhi tan et al. [3] discussed all the parameters of WSN such as Reliability, Survivability, Connectivity, Coverage, Energy Efficiency, Low Cost, Security. This paper also describes security parameters such as Confidentiality, Integrity and Authenticity. It also explains various methods of energy reduction such as clustering, mobility, duty cycling. Clustering means to group the sensors and choose the cluster head, chosen by one of the election algorithms, and then transmit the data to the base station. Mobility is one of the techniques to reduce energy consumption of the network. In a static network, nodes near the sink consume more energy than other nodes in the network because every packet necessarily goes through those nodes. In mobility, some of the nodes are mobile including the sink in the network. So these mobile nodes contribute in the functioning of other nodes which are static which results in less consumption of energy. In a duty cycle, nodes are activated only in their stipulated time. Otherwise they stay in sleep mode as they do not have to send /receive information. Sensor becomes immediately active if new packets are generated. In this way, they consume less energy in the network [3]. Greater amount of delay is a major weakness of this technique.

III. PERFORMANCE ANALYSIS

For the purpose of performance analysis a scenario of 50 sensor nodes and one sink node has been simulated. Through the network initialization, 50 nodes are formed in the distribution of 1000 *1000 sq m region. IEEE 802.11 Media Access Control protocol and Ad-hoc on demand routing protocol has been used. Grid Topology, Chain Topology and Random Topology have been used herein. Packet size of up to 140 byte with variable generation rate has been used. The reporting rate has also been varied from 0 to 50.

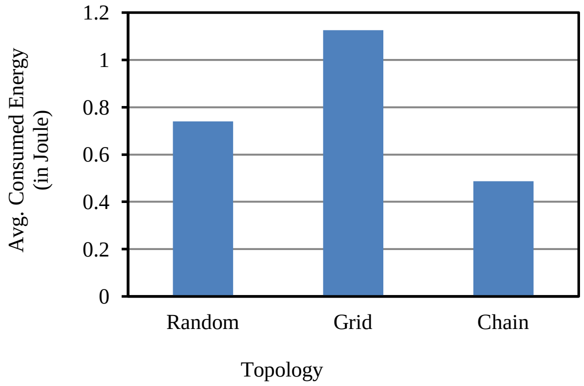

Fig. 2. Avg. Consumed Energy as a function of Topology

Fig. 2 shows Avg. energy consumed by the network against topology. Grid topology consumes maximum amount of energy than random topology and chain topology. In a regular grid topology, each node in the network is logically connected with more neighbors so that it consumes more energy. In random topology, nodes are randomly arranged in the network so that nodes transmit the data randomly to other nodes and hence random topology also consumes more energy for transmission. However, it still consumes less energy than grid topology does. In chain topology, nodes are arranged in a chain fashion .Every node sends the data to only next single node, so chain topology consumes very less energy as compared to both.

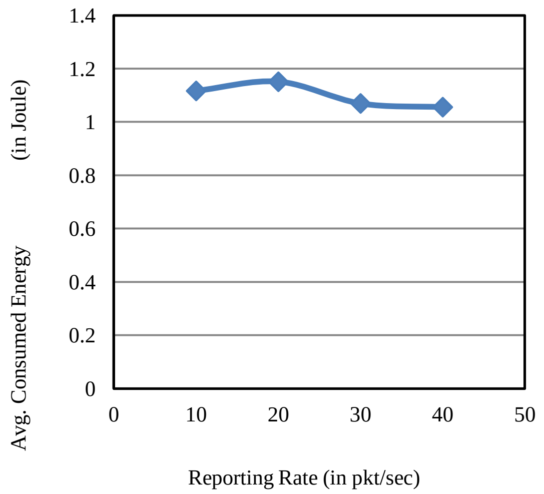

Fig. 3. Avg. Consumed Energy as function of Reporting Rate

Fig. 3 shows average energy consumption as function of reporting rate. Initially when reporting rate increases the avg. energy consumption also increases. After the specific threshold, as reporting rate increases avg. consumed energy starts decreasing due to congestion in the network. The packet loss ratio increases due to congestion and so the packet fails to reach the next node. As a consequence, average consumed energy of the network decreases.

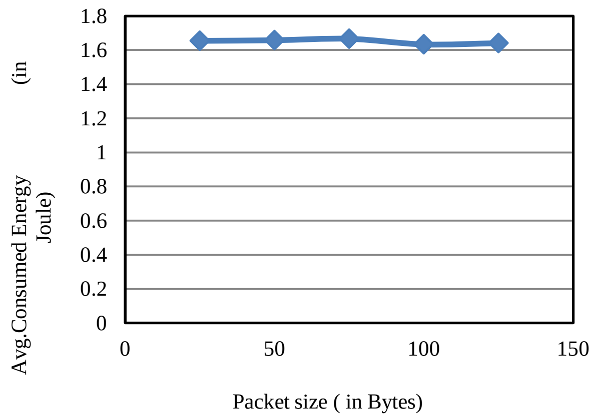

Fig. 4. Avg. Consumed Energy by the N/W as function of Packet Size

Fig. 4 shows Avg. consumed energy by the network against packet size. According to graph, consumed energy almost remains constant to all packet size. So packet size does not affect the avg. consumed energy.

IV. CONCLUSION AND FUTURE WORK

In this paper, on the basis of the study of various techniques of energy consumption in the network such as clustering, mobility, duty cycling, it can be concluded that that they play a pivotal role in less energy consumption which depends upon the network topology. Performance analysis clearly suggests that if chain topology is implemented then it can yield better results which imply that energy consumption could be substantially curtailed. Total energy consumption of the network is independent of packet size. It only varies from application to application.

In future, an algorithm will be so developed that will consume much less energy and hence greatly augment the life of the network. Other parameters of WSN like congestion, delay, throughput and reliability will also remain constant because of such an algorithm.

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