THROUGHPUT ANALYSIS OF ENERGY AWARE ROUTING PROTOCOL FOR REAL-TIME LOAD DISTRIBUTION IN WIRELESS SENSOR NETWORK (WSN)

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Abstract

Wireless sensor network (WSNs) are self-organized systems that depend on highly distributed and scattered low cost tiny devices. These devices have some limitations such as processing capability, memory size, communication distance coverage and energy capabilities. In order to maximize the autonomy of individual nodes and indirectly the lifetime of the network, most of the research work is done on power saving techniques. Hence, we propose energy-aware load distribution technique that can provide an excellent data transfer of packets from source to destination via hop by hop basis. Therefore, by making use of the cross-layer interactions between the physical layer and the network layer thus leads to an improvement in energy efficiency of the entire network when compared with other protocols and it also improves the response time in case of network change.

Keywords:- *wireless sensor network, energy-aware, load distribution, power saving, cross layer interactions.*

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1. INTRODUCTION

The advances in micro-electro-mechanical system technologies have made possible of embedding the system technology with wireless connectivity which has low power energy usage hence enabling sensing by using micro wireless sensors. Apart from that, wireless communication and information processing is also made possible. These power-efficient and inexpensive sensor nodes works together to form a network that can be used for monitoring the target region. Hence, WSNs sense and transmit different elements of message about the monitored/sensed environment such as temperature and humidity by utilizing the cooperation of sensor nodes to sink node which in turn processes the information and conveys it to the user. WSNs have attracted serious interest and attention from researchers from various field of study due to wide range of applications such as military surveillance, health monitoring, environment monitoring and many more.

Figure 1 depicts a standard wireless sensor network which consists of several sensor nodes where one act as the sink meaning that particular node maybe connected to a computer for processing purpose of data received/sensed. However, there lie some problems that require immediate attention such as reliable data delivery, congestion control, energy consumption, and data security to name a few. However, this study focus solely on energy conservation method only which will be discussed in later chapters.

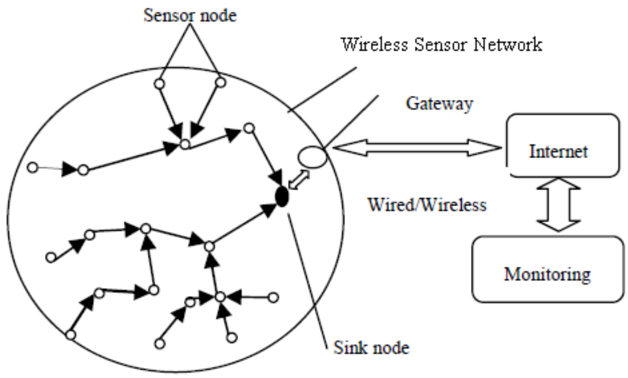

Fig 1: Typical Wireless Sensor Network

Mostly, applications utilizing sensor nodes are powered by batteries and must be able to work for several months or years without need to recharge or replace. Therefore, such expectation requires careful scheduling of the energy usage especially when sensors are densely deployed (up to 20 nodes/m3 [1]), which causes severe, unwanted problems such as scalability, redundancy, and radio channel contention [1]. Therefore, transmission of redundant data may occur due to complex density whereby multiple sensor nodes can generate and transmit about the same event to the sink node, causing higher than normal energy consumption and hence a significant reduction in network lifetime. Energy consumption in a sensor node can be divided into three modules consisting firstly data sensing module then data processing module and finally the data transmission/reception module of which the energy consumed for communication process is the most critical. Hence, large amount of energy used can be saved by reducing the amount of communication which can be done by eliminating or aggregating redundant sensed data and using the energy-saving link thus indirectly prolonging the lifetime of the WSNs.

In this paper, we proposed a real time load distribution system that takes into account the remaining battery level of the sensor nodes before deciding which of the sensor nodes to be used for creating the route towards destination or sink node. This method introduces an efficient manner of energy management system for WSN thus making full use of the available remaining energy of each sensor nodes.

The remainder of this paper is organized as follows with Section 2 reviews related works followed by Section 3 that describes the system model and the motivation of our work. Next, Section 4 presents the detailed design of the energy aware protocol. Finally, Section 5 concludes the paper.

2. RELATED WORK

The main task of the sensor network is to relay the sensed data gathered/sensed by sensor nodes to the base station. The WSN administrator may use direct transmission by controlling the transmission power. In this scenario, each sensor node within the network will send sensed data directly to the sink node. However, the node will be dead in short period of time due to excessive energy consumption used up for delivering data if the base station is far away from the sensor node. Therefore, some algorithms were developed to overcome this problem.

One of the protocols proposed is Low-Energy Adaptive Clustering Hierarchy (LEACH) by Heinzelman et al [2]. The authors in [2] proposed and suggested LEACH which is an alternative clustering-based algorithm. It assumes there exist a unique base station outside the sensor network and all the sensor nodes can communicate with this base station directly. Meanwhile, LEACH only chooses a fraction p of all sensor nodes to serve as cluster heads for the purpose of saving energy where p is a parameter that must be determined before deployment. The sensor nodes will then join the proper clusters according to the respective signal strength from cluster heads. The operation is divided into several rounds which ensure the cluster head rotate in each round in order to share the energy load. In LEACH, first phase is the cluster formation phase which is followed by the process of cluster heads aggregating the data received from cluster members and the aggregated data is sent to base station by single hop communication. Hence, this method is believed can effectively reduce the data needed to be transmitted to the base station indirectly saving some amount of power. LEACH's clustering algorithm assumes that sensor nodes are homogenous and equal which in reality it is hard to guarantee that. Moreover, according to the scale of the sensor network, the optimum percentage of cluster heads must be determined in advance. Therefore, LEACH cannot adapt to such changes as the addition, removal, and transfer of sensor nodes considerably affects the efficiency of data gathering. Finally, a cluster head must broadcast its own existence to the whole sensor network in cluster formation phase thus causing another inefficient use of energy.

Meanwhile, S. Lindsey et al. proposed an algorithm called PEGASIS [3] which has some relation to LEACH, The authors noticed that the energy consumed by transmission circuits is much higher when compared to that of amplifying circuits. Therefore, PEGASIS make use of the GREED algorithm to form the sensor nodes into a chain-like shape with intention to reduce energy consumption of sensor nodes in the system. The author’s findings show that PEGASIS performs better than LEACH in the case of sink node that is far from sensor nodes.
On the other hand, Sh. Lee et al proposed a new clustering algorithm called Congestion Detection and Avoidance (CODA) [4] in order to relieve the imbalance of energy depletion caused by different distances from the sink. CODA divides the whole network into a few groups based on distance of the node to the base station with each group has its own number of clusters and member nodes. The further the distance to the sink node then we require more creation of clusters in the case of single hop. The paper outcome shows that the CODA have better performance in terms of the network lifetime and the energy loss than those protocols that use the same probability to the entire network.

The authors in [5] proposed a hybrid with energy-efficient and distributed clustering algorithm (HEED) which selects the cluster head periodically according to two main parameters which are the node residual energy and proximity of the node to its neighbors. Low message overhead incurs in HEED thus achieving quite uniform cluster head distribution within the network. Meanwhile, the authors in [6] analyze the paper in relation to extending the network lifetime by which determining the optimal cluster size of WSN. They find that the maximum lifetime or minimum energy consumption can be achieved for certain optimal sizes of the cells. Hence, based on their result, they propose a location-aware hybrid transmission scheme that can minimize the energy consumption thus further prolong the network lifetime.

3. ENERGY AWARE METRICS

As mention earlier, sensor nodes are low-powered devices thus they have very limited energy hence it is necessary to maintain the high energy level to achieve maximum network lifetime. Loss of packets due to bit error or congestion can be considered as common in WSN [7]. Hence, we can calculate the packet loss ratio by using the equation below [7]:

$$\frac{\text{no of packets lost in the network}}{\text{no of packet generated by the sensing nodes}} \qquad (3.1)$$

Meanwhile, the number of packets successfully reach destination can be determined as success rate of transmission while packet latency is defined as time taken for a packet to reach its destination from the moment of the packet creation. Ratio of packet loss will result in energy loss per node and affect the entire network hence enhancing the importance of evaluating energy efficiency. Therefore, we assume that dropped packets are directly proportional to energy wastage, so the energy loss for each node can be measured by [7]:

$$E(i) = \frac{\text{no of packets dropped by node } i}{\text{total no packets received by node } i} \qquad (3.2)$$

On the other hand, the loss of energy for the entire network is found by using the equation below [7]:

$$E_{network} = \frac{\text{no of packets dropped by the network}}{\text{total no of packet received by the sink}} \qquad (3.3)$$

4. NETWORK SETUP

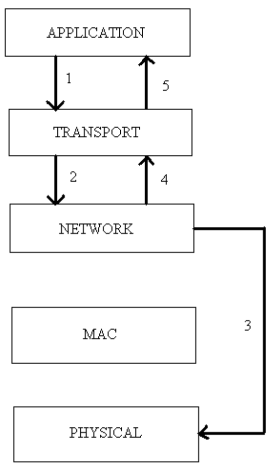

Fig 2: Layers involved

Figure 2 shows the layers involved in the development of the project. As we can see, the process starts with request from application layer which then invoke the transport layer to provide reliable data transfer mechanism. This in turn will invoke the network layer in order for best route selection. This is where the research work was focused on whereby the best route selection was determined by comparing remaining energy level. The node with higher remaining energy level will be chosen to form the route to destination. However, the routing protocol will need the remaining battery power from physical layer in order to compute the route selection. Hence, the need for inter layer interactions for the purpose of sharing information.

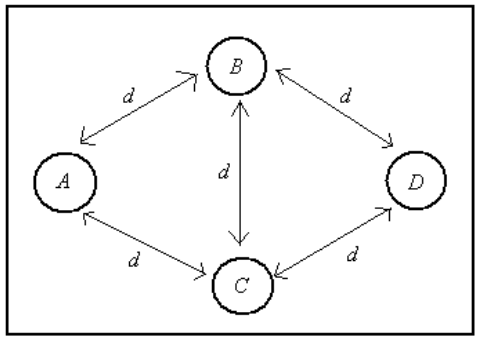

Fig 3: 4-node Network Setup

Figure 3 shows how the entire network is setup up where the network is configured as so having 4 nodes where node A is the source node and source D is the destination while node B and node C will act as intermediate nodes In this research work, we assume that node D is not within the vicinity of node A hence no direct transmission from node A to node D.

1 byte	2 byte	4 byte
Pkt Type	Dest Add	Remaining Battery

Fig 4: Request and reply packet format

When the network is set up, the source node will have to compute the best route to the destination when there are packets to be transmitted. However, before route is determined, the nodes will have to have prior knowledge of existing nodes within its vicinity. Hence, all the nodes in the entire network will invoke a request message as shown in Figure 4, containing its address and request for remaining battery level. The packet type column is to differentiate between request packet and reply packet. This request message will be broadcasted meaning that all the nodes within the vicinity of sender node will receive the request message. Then, these nodes will reply to the sender node with a reply packet (Figure 4) containing its address and its remaining battery level. Now, all the nodes in the network will have information about its neighboring nodes within its vicinity and the remaining battery levels. Then only can a route be determined using the remaining battery level information. As an example, in this setup, all the nodes will invoke the request message and reply to correspondent node. Then, node A will compare between node B and node C for higher remaining battery level. If node B is chosen as the one with higher level, then node A will transmit the data packet to node B. Once receiving the data packet, node B will check the destination address of the packet and determine whether to forward the packet or not. This process of inquiring neighborhood node's battery level for route creation is periodically done for better energy or battery management. If it is done every time a packet to be transmitted, then it will defeat the purpose of this research work which is for energy efficiency.

5. ANALYSIS

Once the protocol has been developed, it is then programmed into the sensor node for analysis purposes. The entire network is shown in Figure 3 which consist of 4 sensor nodes with one acting as source node (node A), two intermediate nodes (node B,C) for hopping purpose and one as the base station or sink node (node D). The test that was conducted covers the range of 1 meter to 15 meters as marked as d. 255 packets of dummy data of "HELLO" message were generated during the analysis and packet received by sink node were captured in order to measure the performance of proposed routing protocol in terms of the packet loss and energy loss. Table 1 below shows the packet received and packet loss for distance under test for the proposed routing while Figure 5 shows the captured packet and packet loss occurring.

Table 1: Analysis of proposed protocol

Distance (meter)	Packet Received By Proposed Protocol	Packet Loss of Proposed Protocol	Packet Received by Flooding Algorithm	Packet Loss of Flooding Algorithm
1	250	5	201	54
2	248	7	175	80
3	242	13	162	93
4	237	18	143	112
5	228	27	121	134
6	220	35	103	152
7	216	39	87	168
8	204	51	79	176
9	197	58	71	184
10	190	65	66	189
11	183	72	42	213
12	165	90	32	223
13	142	113	0	255
14	101	154	0	255
15	87	168	0	255

As we can see from both Table 1 and Figure 5 respectively, there are packet drops occurring even the sensor node are as near as 1 meter to each other. Though all the nodes collect their neighbor information and calculate the best route as soon as the entire network has been setup thus recognizing and reserving the path for data forwarding, but this path might change due to low battery of sensor node hence requiring the neighborhood table to be updated and recalculated. Hence, these processing may cause some packet loss to occur as can be seen in Figure 5.

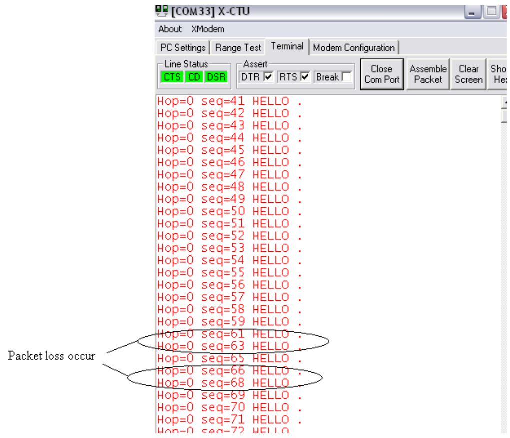

Fig 5: Packet loss occurring

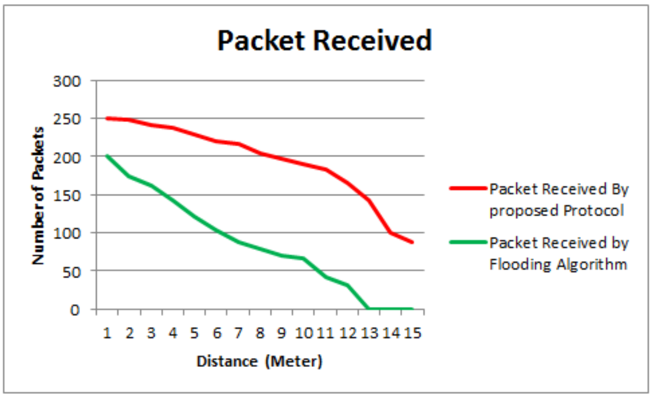

Fig 6: Packet Received

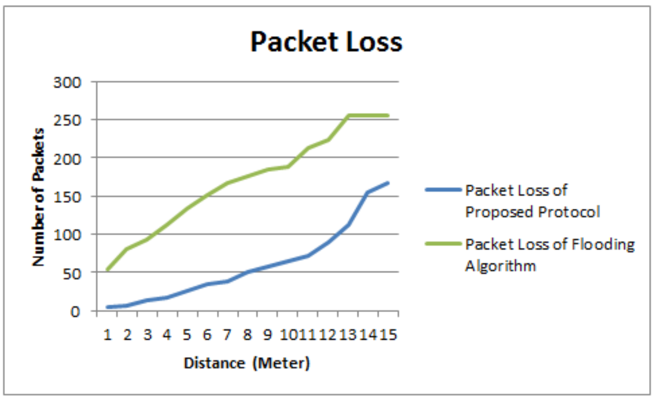

Fig 7: Packet Loss

Other than that, we also notice during the analysis that data collision happens when nodes transmit information at the same time to the node that requesting. Hence, the information is lost thus preventing data to be forwarded to node with higher remaining battery level. Meanwhile, we can notice increasing packet loss when the distance of the sensor nodes were more than 12 meters between each other. This might due to the capability of the xbee module itself and surrounding factor too. On the other hand, several issues were not taken into consideration such as the multipath fading effects, reflection or the optimum capability of xbee module transmission hence packet loss bound to occur. We can conclude that proper battery utilization or energy management is important in wireless sensor network in order to prolong the network life time.

6. FUTURE WORK

As stated before, some of the issues were not taken into consideration such as simultaneous transmission, link quality between nodes, delay and few more which hopefully can be covered in future analysis. Apart from that, comparison with similar protocols will also be conducted to compare the performance of proposed energy-aware protocol.

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