A New Routing Approach for Performance Improvement in Mobile Sensor Networks

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***Abstract*— Wireless sensor networks are operated with the aim of collecting data in a vast area. These constitute a large number of sensor nodes with limited energies which are dispersed throughout a geographical area. Wireless sensor networks are designed to work in tough outdoor conditions and harsh environment and they are always susceptible to potential faults and data transfer delays. Sensor nodes are susceptible to damages caused by discharge of energy and to disrupted communication lines. Network topology and transfer routes are designed to meet these imperatives and not to meet requirements such as energy efficiency, network functionality and eventually functional longevity.**

Fault tolerance and energy efficiency are thus among critical factors in wireless sensor networks. In this paper, we have offered a way for optimizing a routing protocol which may reduce network congestion and thus prevent loss of energy in nodes with very little cost and very little delay. Simulation results pertaining to the offered plan have been analyzed using MATLAB and the analysis has confirmed our solution.

Keywords*— *wireless sensor network; network longevity; energy efficiency; routing protocol.

I. INTRODUCTION

The idea of pervasive information gathering was first introduced with the aim of expanding environments with integrated communication and calculation capabilities [1, 2]. New advancements in the field of MEMS[1], smart sensors and wireless communications [3, 4] have made it possible to construct wireless sensor networks which can incorporate a large number of cheap sensory nodes with sensory, arithmetic and communicative capabilities. Each one of these nodes contains limited memory and a limited source of energy. Sensor nodes use self-organize protocols randomly to expand in the target area [5, 6]. These nodes are used for continual monitoring of a target event or a parameter and send collected data to central processing nodes called sink nodes or base stations using Radio waves [4]. Considering the fact that much of the energy is consumed by routing in sensors within the wireless sensor network and communication protocols. Communication protocols have important roles in enhancing efficiency and longevity in WSN. Preparing efficient protocols is thus a necessity when a wireless sensor network is being set up [1, 2]. Many plans have been offered with the aim of expanding wireless sensor networks and connecting mobile sensors together in an appropriate manner. These plans recommend solutions for enhancing energy efficiency, data delivery and fault tolerance while reducing delays within uncontested sensor networks with few connections (such as DFT-MSN) [1, 2]. It should be noted that DFT-MSN is an example of an opportunist network where communication links are present with certain probabilities.

II. RELATED WORKS

The idea behind DFT-MSN is derived from delay tolerant networks or DTN. DTN is an integrated and interconnected network which is at times ailed by fragmentation. Because there are no point to point connection within DTN, data delivery in these networks is a challenge.

The idea to use a protocol of cross layer delivering data through dynamic wireless sensor networks was offered by another article published in 2008. An asynchronous phase is used for setting up communication and identifying good communication and a synchronous phase is used for transferring data through selected links. It is possible to reach good data delivery rates by employing such method [7].

As stated in reference [8], problems of minimizing the cost were identified back in 2007. A data delivery algorithm based on linear programming was then offered for minimizing the cost. The algorithm included constraints such as canal band width, connection cost, delay budget and user mobility. In this algorithm, when there are many routes for reaching the intended target, the selection of route is done based on probabilities of data delivery.

A plan for delivering data packages in real time and with efficient energy consumption has been offered under the name PERT[2] by reference [13]. Such schemes are useful in time dependent wireless sensor networks and in applications such as

[1] Micro Electro Mechanical Systems

[2] Power Efficient Real Time Packet Delivery Scheme

High risk monitoring systems, etc. Here we have offered two solutions. The first solution is based on a new routing plan with balanced distribution of load among routes. This solution includes balanced distribution of data packages among nodes on the route to the sink node. The second solution includes a method for grouping smaller packages in large packages as well as delaying transfer of data from relay-nodes when the load is not critical.

III. AN OUTLINE OF DFT-MSN

DFT-MSN is comprised of a double-layer hierarchical architecture. The upper layer is the network backbone. It can be a wireless LAN or a wired network with a wireless access-point. The lower layer is comprised of two types of nodes. These are coverage sensor nodes and sink nodes.

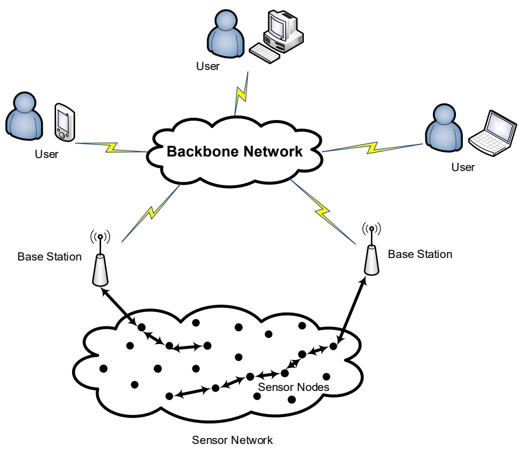


Fig.1. Wireless Sensor Network Architecture

DFT-MSN is distinct from other conventional sensor networks because of the following characteristics:

✓ Nodal Mobility: network topology will thus be very dynamic.

✓ Sparse connectivity: connections in a DFT-MSN network are sparse and a sensor is seldom connected to others.

✓ Delay Tolerability: in DFT- MSN, delay is caused by sparseness of connections between sensors. Such delays are acceptable for most users when the aim is to collect statistically relevant data.

✓ Fault Tolerability: redundancy may be incorporated in DFT-MSN at the time of data reception/delivery.

✓ Limited buffer: This limitation has a serious effect on DFT-MSN because sensor nodes need to store data messages inside their message queues for quite a long time before sending them to other sensors or to sink nodes.

Related problems and solutions to them are discussed under the field title of queue management [1, 2].

Main differences between DFT-MSN and conventional sensor networks are listed in Table-1.

The SPIN protocol is about sending data only to nodes in this way reducing energy consumption. Messages other than data messages are used by this protocol with the aim of reducing the general volume of information transaction and reducing the overload. This in turn will result in an overall increase in network efficiency.

IV. RECOMMENDED ROUTING PROTOCOL:

In the recommended protocol, data that generated by sensors are only dispatched to those nodes which are deemed fit to receive it. Almost all nodes can reduce their energy consumption in this way. This Protocol has been offered for prevention of unreasonable and unwanted data copying and multiplication within sensor networks.

The idea is that the recommended algorithm simultaneously evaluates three traits of nodes when evaluating them as recipients. First, the receiving node should have high energy level. So that it can emit data to the adjacent node while its energy level is lowered. Second, the distance between sending and receiving nodes should be optimal with regard to energy consumption. Eventually the overlapping area of different sink nodes within the radius of transfer should be as small as possible.

It is assumed here that each sensory node can regain its energy level while keeping and that it can store information on adjacent nodes. Information on location of adjacent nodes is also needed so that the energy needed for transferring data to each of them can be evaluated from the distance traveled by data. In this algorithm meta-data packages are sent and received, then the node of the highest merit is chosen, and finally data are sent to that node. Because the energy efficiency and network life time are to criteria for choosing we will discuss both of these parameters in the following. F_e is a portion of the remaining energy of the adjacent node, it is calculated as:

TABLE I. MAIN DIFFERENCES BETWEEN DFT-MSN & CONVENTIONAL SENSOR

	**Effect of Limited Buffer**	**Fault Tolerability**	**Delay Tolerability**	**Network Connectivity**	**Node Density**	**Network Topology**	**Nodal Mobility**
DFT-MSN	High	High	High	Sparse Connectivity	Sparse	Dynamic	Mobile Nodes
Conventional Sensor Networks	Low	Low	Low	Strong Connectivity	Numerous	Stable	Static

The first criterion is F_e which determines the remaining fraction of the energy of the neighboring node. It is calculated from the following relation:

$$F_e = \frac{(RemainingEnergyLevel)}{(OriginalEnergyLevel)} \quad (1)$$

Another criterion is F_d which is calculated in the following way:

$$F_d = \frac{(\delta - d)}{\delta} \quad (2)$$

Value of this parameter determines the way the distance between two nodes approaches the value of δ. This is the largest effective distance between two nodes or in other words the largest distance of transferring a message over which is economically feasible. To explain δ further, we will use the following energy model [10].

$$\begin{aligned} E_{tx} &= \alpha_{11} + \alpha_2 d^{\,p} \\ E_{rx} &= \alpha_{12} \end{aligned} \quad (3)$$

here E_{tx} and E_{rx} indicate the energy needed for sending a bit and for receiving a bit over the distance d respectively. α_{11} and α_{12} are the energy per bit consumed by the electronic sender and by the electronic receiver respectively. α_2 is the amount of energy lost in the transfer Op-Amp. Because E_{tx} increases exponentially with d; when the generated data are sent through direct transfer, it is possible that the energy consumption becomes too high. Estimating an Ideal distance will be an effective way of optimizing energy consumption.

In choosing the appropriate node, F_e and F_d as well as the weight values (w_e and w_d) as the condition of the network will be taken into account. The appropriate node is the one for which the value of F in the following relation is the highest.

$$F = w_e F_e + w_d F_d \leftrightarrow w_e + w_d = 1 \quad (4)$$

The offered protocol functions in three phases as follows:

In the first phase (The Advertise phase) the sensory node which contains data packages sends an advertisement message to its adjacent nodes.

In the second phase (The Request Phase) the neighboring nodes which have received the advertisement message analyze its content and decide to need the data packages, send back a request along with information on their remaining energy and their distance to the node which has the data packages to the sender node.

In the third phase, the sensory node which has received the Request message evaluates the parameters related to its remaining energy and its distance to the node which has sent the request. It then selects the appropriate node via equations 1, 2, 4 and sends data packages to that node. These three phases are constantly repeated until the data are transmitted throughout the network and eventually reaches a sink node.

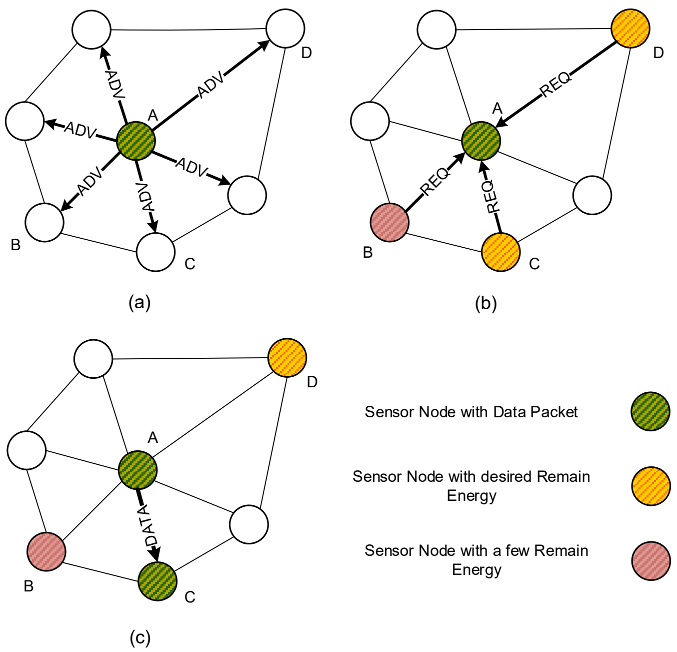


Fig.2. Function of the offered algorithm

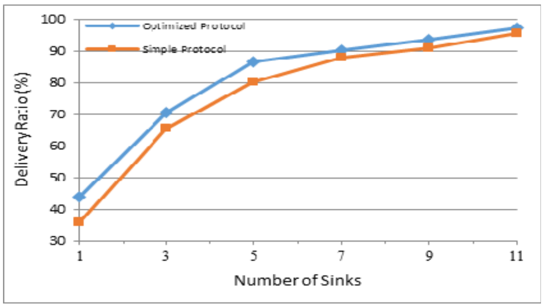
Fig. 2 shows the function of the recommended algorithm. As can be seen in (Fig.2-a) the node which contains data packages (node-A) sends an advertisement message to its neighboring nodes. In (Fig.2-b) those neighboring nodes which have received this message and want to receive the data packages send a request to the node which has them (B, C, D are the nodes which request data packages). The request message also contains information on the level of remaining energy of the requesting node as well as its distance from the node which has the data packages. The latter then analyzes the requests and chooses the best receiving node with regard to equation 4. As can be seen from (Fig.2-C), this best node is node C which will receive the data packages. It is better than node B because it has higher remaining energy and it is better than node D because its distance to the node which has the data packages is smaller.

V. Simulation and Assessment of the Recommended Plan

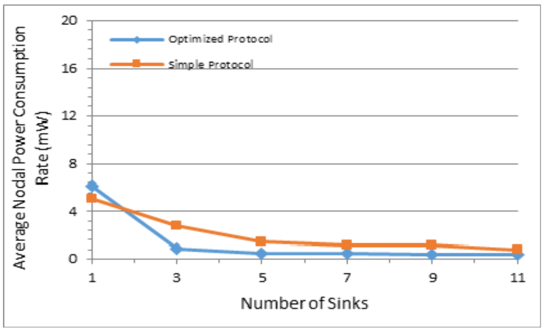
To access functionality of the Recommended Routing plan in DFT-MSN environments we have conducted a simulation of the plan. In the simulation of the recommended solution, many variable parameters have been included so that their effect on the functioning of the plan could be perceived. The simulation was done with the aim of arriving at an evaluation of the recommended solution as compilation of the related diagrams. The number of sink nodes was set at between 1 and 11 and the number of sensory nodes between 10 and 150 in different trials. The parameter nodal mobility speed was constant in different trials. Sensory nodes are randomly distributed in a 200×200 m^2 area. Sink nodes of our simulation are fixed while sensory nodes move at a fixed speed. Each sensory node has an optimum transfer range of 40 meters, an initial energy level of 100 Joules and a limited buffer queue. Each message has a fixed size of one byte and comprises only a single data block.

Data are generated randomly in sensory nodes and enough bandwidth is allocated to data transfer so that data could be transferred without any problem.

To compare the functionality of the recommended protocol against that of the Traditional Protocol, we have considered two variable parameters for their effect on the functionality of the plan. Diagram-1-a compares data delivery rate of the two approaches; it shows that data delivery rate increases with increasing number of sink nodes within the network. As can be seen from the diagram, increasing the number of sink nodes increases their availability and this in turn increases data delivery rate. We have higher data delivery rate with the recommended Protocol as well as smart node election. It is obvious that as the number of sink nodes is increased, the number of hops required for transferring a message decreases. This in turn results in a decrease in the average amount of energy consumed by nodes. Considering diagram 1-b, it can be said that in the first trial, when there is only one sink node, the optimal form of the recommended protocol makes more copies of each message among network nodes. This increases the average energy consumed by nodes, even beyond the amount consumed when the simple recommended protocol is used. As can be seen from diagram-1-b the number of copies made of each message decreases with increasing number of sink nodes. This is because the distance traveled by data messages (from sensory nodes to sink nodes) becomes shorter. This in turn would result in lower transfer loads and lower energy consumption in nodes.



(a)

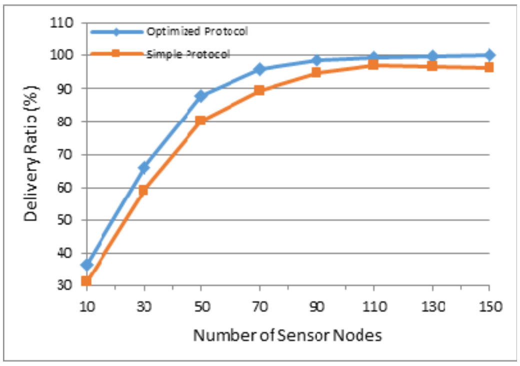


(b)

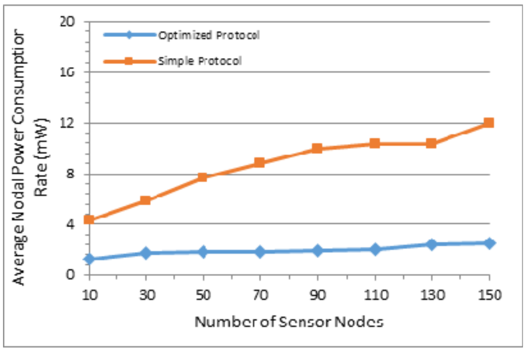
Diagram-1) Effect of number of sink nodes on data delivery rates (a) and on average energy consumption of nodes (b).

Diagram-2 shows the effect of density of sensory nodes within the network. As can be seen form diagram-2-a, data delivery rate of the recommended protocol first increases with increasing number of sensory nodes, then after a density of 110 sensory nodes is exceeded, it slowly decreases. This happens because of buffer overload as a result of too many sensory nodes being engaged in transferring messages to sink nodes. Sensory nodes which are in the vicinity of sink nodes transfer more messages and eventually would form a functionality bottleneck. Many messages would be lost and the data delivery rate would suffer as a result and decrease gradually.

In the improved version, however, due to the implementation of the combined data delivery plan and the prioritizing of messages on the basis of their importance which would prevent data from being lost, data delivery rate gradually increases with increasing number of sensory nodes. As can be seen from diagram-2-b, average energy consumption of nodes also increases with increasing number of sensory nodes. Hence the average energy consumption of nodes increases both in the simple recommended algorithm (the reason being high density of sensory nodes and Increased number of transfers within the network) and in the improved version (The reason being multiple copying of messages). It should be noted, though, that the increase in energy consumption for the improved version which is the result of buffering and copying a message repeatedly while preventing repeated transfer of data, is lower than the increase in energy consumption seen in the simple recommended algorithm.



(a)



(b)

Diagram-2) Effect of changing the number of sensory nodes in data delivery rate (a) and in average energy consumption of nodes (b)

In short, simulation results show that data delivery rate and energy consumption both are improved when we use recommended protocol. Although the improvement has achieved but there are more calculation overload and the transfer delay.

VI. CONCLUSION

Here we first discussed a basic navigation technique called SPIN, then used the idea behind it to recommend a protocol for alleviating network congestion. We have changed the multi-layered structure of the said protocol into a uni-layered structure with consider among the remain energy and distance between sensor nodes, while being inspired by the way a node is deemed fit and selected for data reception by cluster protocols.

We then used simulation to compare the functionality of the recommended protocol with Traditional protocol to verity the effect improved plan to the recommended protocol. What we saw was the possibility of better data delivery rates and less overloads.

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