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New Approach for Routing Algorithm with Mobile Agent for Reduce Energy Consumption in Wireless Sensor Networks

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ABSTRACT

Since Wireless Sensor Networks (WSNs) are commonly used for monitoring and controlling environments, data transmissions in these networks are done based on the content of data. One of the most renowned routing protocols in this field is the Directed Diffusion (DD) protocol. In this protocol, gathered data by the source nodes are transmitted to the sink. The data which is gathered from nodes is very similar, because density of the nodes is very high; therefore transmitting all them consumes much energy. To eliminate this, "in network processing" can be used which uses less energy to send and receive the packets. In some methods, Mobile Agents (MAs) are used to improve the "in network processing". Sink node generates MA(s) for any interest and forwards them to the network, or sends them to the source nodes that are located in the event area. The performance of these methods depends on MAs generator nodes. In this paper, a new method is presented in witch MA is generated locally in source nodes. As a result transmissions between the sink and source nodes are eliminated, which decreases the energy consumption and increase the lifetime of the network.

KEYWORDS: Wireless Sensor Nnetworks; Directed Diffusion; Mobile Agent; Data Aggregation.

I. INTRODUCTION

The Wireless Sensor Networks (WSNs) are commonly used for monitoring and controlling certain environments. Generally the sensor network nodes are source nodes that can receive the data from the environment, using sensors, and then forward this data to interest sink nodes and sink node[1,2,3]. Unlike common networks in which data transmission from one identifier (id) to another id (id-centric), in WSNs, the transmission is based on the content of data (data-centric)[4]. As a result, routing protocols which are used in WSNs should be data centric routing protocols. Directed Diffusion (DD) protocol is one of the most renowned routing protocols [5,6]. The gathered data will then be sent to the sink through the routes that DD has set by the gradients, only if it matches the interest. Considering the data density, many nodes will gather many similar data and send them to the sink which causes much energy to be consumed [7].

For a more efficient use of energy in DD, efforts have been done to make it possible for a more efficient rout selection[8,9], eliminating data redundancy and decreasing the amount of transmitted data to the sink [10-19]. Considering that the energy which is used for receiving and sending the packets is more than the required energy to run the process, "in network processing" is more advisable, to eliminate data redundancy. This was the main idea of other attempts in which data is gathered locally and after its redundancy is removed. Therefore the amount of forwarded data and number of data transmissions to the sink will both reduce.

To improve the in network functions, Mobile Agents (MAs) can be used. In one common method, the sink node distributes MAs containing interest to identify the area in which an event has happened. With these transmissions, some gradients will be generated in the network; when sensing some data which matches the interest, the node wills backward MA to the sink along the gradients. When the sink receives the discovered MAs, it will generate a list of source nodes that are located within the event area. Then it will generate another MA and send it to the nodes included in the list to gather the data [11].

In another similar method, the sink node will at firs use flooding to distribute the interest in the network, then using control messages, it will identify the area in which the event has happened. If we succeed to reduce these transmissions, we can highly improve energy consumption in the network [10].

In the proposed method in this article, which also uses MAs, the nodes will not send the messages to the sink while the event is taking place and the MA will be locally generated in the nodes located within the event area. The data will also be gathered locally by the MA; its redundancy will be removed and will then be sent to the sink. Therefore there will be much less transmissions in the network and the data size will be much smaller due to data integration. As a result, there will be less energy consumption and more lifetime of the network. Since in this method, the MA is locally generated within the event area, the title: "Local Mobile Agent Directed Diffusion (LMADD)" has been chosen for it.

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In the following part, in section 2, the related attempts will be introduced; in part 3, the proposed method will be explained; in part 4, the efficiency of this method will be studied and finally, in section 5, conclusion of the proposed algorithm will be discussed.

II. RELATED WORKS

Considering the WSNs applications, data centric approaches are recommended for them. This will cause the data centric routing methods to be presented. In this part some of the commonest of these methods such as DD method will be explained. Also other methods which can decrease overhead of flooding and select suitable rout to forward data-for example EAR and GBR-are introduced; then other methods that use MAs to solve these problems -such as Rumor Routing- are explained. Finally methods that use MAs to aggregate data-such as MADD and ABDD-are introduced.

In DD protocol, when the operator sends a request to the sink to gather data about a certain event, the sink floods this request which is called an “interest” to each of its neighbors. When the neighbor nodes receive an interest, they will add it to their cache and a gradient will be set between the two nodes. In this step, data transmission is done in a low rate until the network is well identified and a rout is set between the nodes. If the nodes don't have any content matched with the requested interest, they will forward the interest to the next neighbor. Consequently the interest will be flooded in the whole network, until it reaches the nodes that are located within the event area and source nodes are found. In this step, the source node will find the highest rate of data transmission among its gradients, and finally send the data messages to the sink [7,18]. According to this protocol it can be observed that the overhead which is generated because of flooding the interests in the network, and the overhead of sending every single data to the sink, while there is much similar data will lead to a considerable energy consumption that will reduce the network's lifetime.

Recently agent based approaches are replaced with client/server approaches to distributed the data in sensor networks. In wireless sensor networks based on client/server model, the nodes will first gather the data; as soon as an event occurs, the data is sent to the central processor based on an appropriate routing protocol. In agent based model, there is an agent that is a specific code and can process the data automatically; it can also travel through the whole network to find the source nodes; that's why it is called the Mobile Agent (MA). The advantages of MA which makes them useful in main tasks such as electronic business to military tasks are: 1) optimum use of network's bandwidth; 2) allowing the agents to run after they leave the node even if they lose contact with the node that has generated them; 3) Decreasing the traffic in the network and more speed of data transfer; 4) Mobility and independence makes it possible for the MAs to move toward another point in network and perform pre-planned tasks or services [15-18].

The Rumor Routing approach which is another modified protocol of the DD. The main idea in this protocol is distributing the interests by flooding them and routing takes place in the nodes that have received a specific event. For flooding the interests in the network, the Rumor Routing protocol uses agents. This agent is then distributed in the network to transfer information about the local events to nodes. When a node generates an interest, other nodes may respond to it; therefore there will be no need to flooding the whole network. On the other hand, rumor routing uses one route to transfer the data while DD uses a number of routes to transfer data with a low rate of data transfer. The results of simulations prove that rumor routing uses less energy. When the nodes get informed about the events by the agents, selecting the rout by exploration has a great effect on the efficiency of the next step. The probable problems of this protocol are that there is much delay [8].

To solve the problem of delay in Rumor protocol, the Agent Based Directed Diffusion (ABDD) protocol has been proposed. Any node which receives the MA sets a gradient along the receiving path. If the node includes some data matching the interest in its cache, it will be backward it to the sink along of the gradient. If not, it will add the interest to its cache and will send the MA to its neighbors. When the sink receive all the discovered MAs again, it will process the data and provides a sequence list of the source's nodes which are located within the event area and stores it in the MA with a processing code for data aggregation. After that the collected data from the last node in the list will be sent to the sink. Thus, in this method, it is necessary to send some data to the sink to set the order of the movements between the nodes. This transmissions will use up the middle nodes' energy [11].

In another protocol mentioned in [10] which is much similar to ABDD protocol, first flood the interests in the network, if the flooding overhead can be tolerated, the whole network and the hops to the sink can be detected [10].

Considering all the advantages and disadvantages of each of the existing protocols presented in this paper, using in network processing and MAs, and also by eliminating redundant data, energy consumption can be reduced and the network's durability be improved.

III. PROPOSED METHOD

Considering the pros and cons of each of the mentioned methods in previous section, a new method which can decrease energy consumption, will be presented.

In this method, first flooding the interests are in the network. By tolerating the overhead caused by flooding, the whole network can be well identified and it will be cleared that how many hops is the minimum distance of each nodes to the sink. Then the source nodes that are located in the event area should get informed from each other. After that a node is selected as the virtual sink which is the most remote node to the sink. Finally the virtual sink node generates an MA to travel through the nodes based on the list and to gather the data in these nodes and aggregate them. When getting to the last node, the gathered data will be sent to the sink. Figure 1 shows one example to how this method works.

According to the explanation above, the steps of this method can be presented in four phases below.

Phase 1) flooding the interests: in this phase, the interests and processing code flooded in the network. By tolerating the overhead caused by flooding, the whole network can be well identified and it will be cleared that how many hops is the minimum distance of each nodes to the sink. When the interest matches the gathered data in a node, a copy of the processing code will be stored in the node. This is for eliminating the redundant data according to a function based on the interest. For example to know the maximum temperature, this function will find the maximum temperature and will delete lower temperatures as redundant data.

Phase 2) Identifying the event area: in this phase, when node sense an event, it triggers a timer in itself and sets it with $k.\sqrt{m}.t_{packet}$, in which m is the number of nodes in event area, t_{packet} is needed time to send one packet and k is a coefficient that is estimated in various experiments each of the nodes will first make a list in themselves which can be called the "levent", the node stores its locations and the number of hops to the sink (x,y,h) in this list. This list is sorted based on the h, then x and then y on a descending basis. After that it will store a copy of levent as "lpacket" in a packet and sends it to all neighbor nodes. Only the neighbor nodes that include a data matching the interest can open the packet. When a node receives this packet, it will compare it with its levent. If there is a new data in the lpacket, it will be added to the node; then a new lpacket is made from the node's levent which will be sent to the neighbor nodes. This will be continued between all the nodes in the event area which are a kind of locally flooding. This way, all the nodes can get informed from other nodes in the event area. This will go on for each node until the node's timer expires.

Phase 3) data aggregation: in this phase each node considers its levent, if it has the maximum number of hops, in the nodes' list, to the sink; it will be chosen as the virtual sink. If several nodes have the maximum hops, the second criteria for choosing the virtual sink will be more x value and the third, more y value which are location parameters. In other words the farthest node to the sink, of both the number of hops and location aspects, will be chosen as the virtual sink. When MA travels between source nodes in event area, the size of aggregated data increases, this way data transmission can occur in lager amounts, from closer distances, so it will cost less. The virtual sink node also provides another list, called the "vlist" to keep the nodes which are met for the first time. Then the virtual sink makes an MA to gather the data, and stores a copy of levent and put vlist and levent in the MA. The MA will gather and aggregate the data and data travel according to the levent and a traversal algorithm between the source nodes including in the list. In this traversal algorithm which is similar to level order traversal in graphs [20], each node searches among the levent and the neighbor nodes and chooses the first node which has the maximum hops to the sink and is included in the neighbor nodes list, will be selected. If this node is not included in the vlist, it is selected and the MA is sent to this node. Otherwise, the next node will be selected from the levent and the algorithm will be continued. If none of the nodes is selected, the algorithm will be back for on hop and will be run again.

Phase 4) Sending data to the sink: when the MA travels all the nodes in the list and aggregates their data, the aggregated data will be sent to the sink from the last node that has been met.

Considering the steps of this algorithm, it is observed that there will be no need to send and receive data to the sink in order to identify the event area, and the nodes can perform this task locally. Therefore by eliminating these transfers, more energy will be saved and the network can live longer. The pseudo code for each operation in nodes is presented in figure 2.

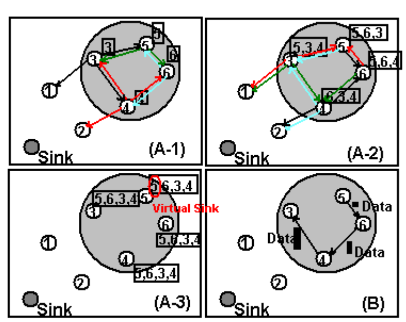

Figure 1. An example to show transfers between source nodes in event area to identify this area(A1-3) and gathering data within source nodes in event area(B)

```
//levent: list of nodes' positions in event area  that sorted by hop
// of count to sink, then to sink, then x then y as descending.
on sensed an event:{
        generate a levent (h,x,y)
        broadcast the levent as a lpacket
        start timer }
on recieve a lpacket:{
        if the lpacket have new elements then   {
           add new elements of the lpacket to the levent
           rebroadcast the levent as the lpacket   } }
on timer expired: {
   if the node is the first element in the levent then  {
        set this node as virtual sink
        generate a vlist (x,y)
        generate a MA (levent, vlist)
        find next node that the MA should be visit by traversal algorithm
       send the MA to the next node } }
on recieve a MA: {
      if the number of vlist and thw levent not equal then {
         aggregate data in the node and the MA
         add the x and the y of this node to the vlist
         find next node that the MA should be visit by traversal algorithm
         send the MA to the next node }
                                                                                          Else     {
        forward aggregated data in the MA to the sink  } }
```

Figure 2. LMADD protocol's pseudo code in one node

IV. PERFORMANCE EVALUATION

To evaluate the performance of the proposed LMADD method, it can be compared with the three other protocols, basic DD [7], MADD [10] and ABDD [11]. To do the experiments the NS2 network simulator software is used. The criteria which are considered in this evaluation are as follows:

Delay: in this criterion, the time between an event occurred and the time in which the first data is delivered to the sink, is studied.

The number of live nodes: the number of live nodes is an appropriate criterion to estimate the network's lifetime. By studying this criterion in the period of time, the networks lifetime can be measured.

The periphery of simulation is modeled with a fixed sink and a number of source nodes that are used in different experiments. The simulation parameters are as listed in table 1.

TABLE I. PARAMETERS QUALITY SETTING IN SIMULATION

Network's size	2500m * 2500m
Data rate MAC layer	1Mbps
Initial energy of each node	1 (J)
Transfer's power	0.660 (w)
Receiving power	0.395 (w)

In the next experiment, the criterion of the number of live nodes within the simulation time is studied (figure 4) to observe the network's condition after doing a specific task. In this experiment the nodes density is 1000. From the beginning until the seventh simulation, because of flooding, none of the nodes' batteries is exhausted, but after that the nodes energy is exhausting gradually and makes the nodes to be eliminated from the network. As this follows, there will be a more number of eliminated nodes. In the proposed method, because of elimination the extra transfers between the sink and source nodes, more nodes can stay alive in a long time in the network and this will cause the network's durability to increase which is a major objective in sensor networks.

In figure 5, the criterion of delay in delivering the data packet to the sink comparing the network's density is studied. It can obviously be seen that as the number of the nodes in the network, increases, the DD protocol has the least delay because in this protocol every source node transfers the data to the sink by itself as soon as it receives every interest. In the proposed method and the two other protocols, because of the needed time to processes or transfers the sinks, a criterion delay is unavoidable. In our method, though since extra transfers to the sink are eliminated, this delay will be much less and equals a few hundredths of a second which is acceptable considering the sensor network's functions.

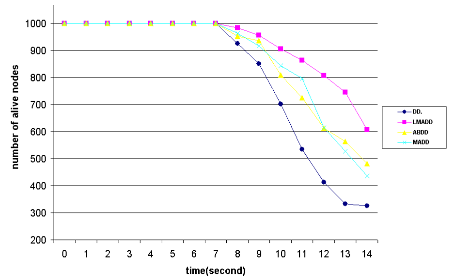

Figure 3. **The number of live nodes comparing the simulation time**

In figure 6 and 7, the superiority of the proposed method to the previous algorithms is well illustrated. By eliminating the extra transfers between the source nodes and the sink, our method will function even better when the event area is farther. Also if the number of the nodes within the event area is less, the number of transfers to identify the event area and also the transfers to gather the data will be less. In these experiments, the number of the nodes in the network is 1000 and there are 10 nodes within the event area to make it possible for the method capabilities to be shown better. The distance between the event areas to the sink is increased to observe the quality of the algorithm's function.

In figure 6, the criterion of consumed energy when the event area is close to the sink is shown, ABDD protocol which moves the MA in the network, can find the source nodes faster and send the data to the sink, therefore less energy will be consumed. But as we get far from the sink the probability of finding the source nodes will be less, consequently more energy is consumed to perform this task. When the event area gets far from the sink, in MADD, the extra transfers between the middle nodes increases and as a result, more energy is consumed. In our proposed method by eliminating these extra transfers, as you get far from the sink, the energy consumption will only change slightly.

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In figure 7, to show the needed time to do the in network processing which causes to delay in delivering the data to the sink, the diagram of delay based on the distance between the event areas to the sink is presented. About the MADD protocol which is much similar to our method, this delay is pretty much, because it needs both processing and extra transfers. As we get far from the sink there will be more of these transfers and therefore more delay. It is also seen that our method has more delay than the DD, but as long as we are not far from the sink, the ABDD has less delay, because it has more chance to find the source nodes, but as you get far from the sink, there is less chance for this and more delay in the protocol. About the mentioned difference between our method and DD, it is seen that as you get farther from the sink, this difference is less and less, and it shows that as you get far from the sink, since most of the time, is spent for sending the data to the sink and also because the number of nodes in event area is less, the process time is insignificant, comparing the needed time for this. This delay is negligible, considering the less energy consumption. Therefore the main goal of sensor networks which is more life time has been achieved by this algorithm.

As it is seen in the result of the experiments, in our algorithm, because of elimination of extra nodes between the source nodes and the sink node and local generation of MAs, there will be fewer numbers of packets and therefore the energy is used more efficiently. Elimination of redundant data using the MAs will also decrease the amount of data. Altogether it can be clearly concluded that the proposed method can highly improve the functioning quality of WSNs.

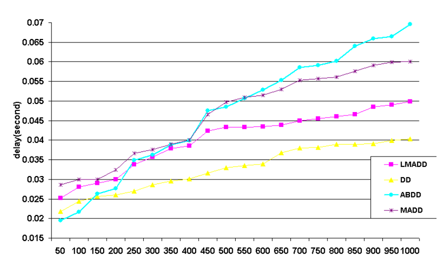

Figure 4. The average delay of data delivery to sink comparing the network's size

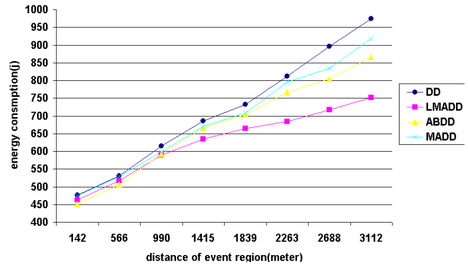

Figure 5. The used energy into the distance of event to the sink

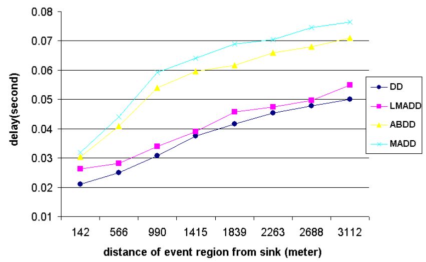

Figure 6. The average delay to deliver data to the sink into the distance of event to the sink

V. Conclusion

Our goal in this work is improving the energy consumption in DD protocol, using MAs. To do the generator of MAs has been replaced from the sink node to be locally generated in the event area. This way a set of transfers between the source nodes and the sink node which are necessary to identify the event area is eliminated and the middle nodes energy will be saved. Using this algorithm will cause to less consumption of energy and more life time of the network. The experiments also prove when the number of source nodes in the event area is few, and when the sink is far from the event area, LMADD method uses the energy more efficiently and increases durability. In return, to run the in network processing, there is a little more delay than DD protocol which is insignificant considering the functions of WSNs.

Since the virtual sink nodes, use more energy than nodes in the networks, their energy will finish sooner and this will eliminate them from the network. To solve this problem, we can use the proposed solutions for cooperation of the nodes in sensor networks and by using certain strategies, this can be avoided. In the next work we will focus on this problem, to prevent the probable holes in the network.

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