A QoS Based Data Dissemination Protocol for Wireless Multimedia Sensor Networks

Amir Hossein Mohajerzadeh, Mohammad Hossein Yaghmaee, Reza Monsefi

Department of Computer Engineering, Ferdowsi University of Mashhad
Mashhad, Iran
ah.mohajerzadeh@stu-mail.um.ac.ir, {hyaghmae,monsefi}@ferdowsi.um.ac.ir

Abstract—In this paper, we are going to present a data dissemination protocol for wireless multimedia sensor networks (WMSN). The proposed protocol entitled as MLAF (Multimedia Location Aided Flooding) is used for packet dissemination in WMSN. MLAF considers network as a virtual grid. Depending on its geographical position, each node is placed in one of network cells. We prevent sending redundant packets, and as a result, network's consumed energy will be reduced. Proposed protocol considers priority for traffics. Depending on packet's priority, MLAF makes decision about its routing. Consumed energy and end to end delay are two main parameters in protocol design. The proposed protocol uses LAF as base. Different aspects of MLAF efficiency have been evaluated. Performed simulations show that MLAF has achieved all of its goals.

Keywords—data dissemination protocol, quality of service, traffic priority, Wireless multimedia sensor networks.

I. INTRODUCTION

This Following wireless sensor networks, wireless multimedia sensor networks have been recently considered [1]. The ever-increasing applications of these networks make them important. The availability of low cost hardwares such as, CMOS cameras and microphones is the reason of expanding wireless multimedia sensor networks; A Network of wireless nodes which can sense multimedia data in addition to ordinary data. Hardware developing makes equipping small nodes with necessary tools (that gather multimedia data) easier. It’s impossible to use protocols which are designed for wireless sensor networks for wireless multimedia sensor networks.

Considering wireless sensor network features, protocols should usually be designed cross layer. These are some of suitable protocols’ features for wireless multimedia sensor networks:

- Energy consumption efficiency: like wireless sensor networks nodes, nodes which are designed for wireless multimedia sensor networks also have limited primary energy resources and they mostly can’t be recharged so energy consumption is still mentioned as a basic parameter.
- Self configuration: usually there is no way to monitor wireless sensor networks nodes, so nodes should be designed in a way that they have the ability to continue their function without user interference.
- Capability of sending data with different real time requirements: for different reasons traffics with different priorities are forwarded in wireless multimedia sensor networks. Protocols should have the ability to send the traffics simultaneously and as a result each traffic receives its own real time requirements.
- The ability of sending data with different reliabilities: wireless multimedia sensor networks’ traffics need different reliabilities. These networks protocols should have the ability of sending these traffics.

In proposed protocol, 3 basic parameters are considered about wireless multimedia sensor networks: energy, end to end delay and reliability. The proposed protocol is designed on basis of LAF [2]. LAF protocol is designed for wireless sensor networks and it is not efficient enough for wireless multimedia sensor networks. The proposed protocol reduces consumed energy by changing LAF routing mechanism and also it provides sending different traffics with different requirements. MLAF is designed for WMSN therefore, End to end delay and reliability are considered in it. Depending on the application, delay parameter for wireless multimedia sensor networks is important in different ranges. In real time applications data should arrive to the destination in definite time interval, otherwise they lose their importance (In hard real time, receiving data out of the interval is valueless). Moreover, different data _depending on their type_ can have different delay threshold, so network’s reaction to different data should be proportional to their type. Depending on data type, it needs different reliabilities. for example in an specific application like controlling a forest temperature, loss of sent data _which declare normal temperature_ lower than specified threshold is acceptable; but data declaring critical temperature should certainly reach the destination in appropriate time and high reliability.

LAF and MLAF are used for data dissemination in network. In most applications sink should give its data to network’s nodes. So the sink node should send its data to all network nodes; in other words, data dissemination phase is
used as the first step in many different routing protocols which are designed for WSN and WMSN. In this case many different algorithms are presented for wireless sensor networks; the first one is flooding. LAF reduces number of useless forwarding, using grid. One of the main aims in data dissemination algorithms is to reduce number of useless forwarding. For example in flooding algorithm, each node sends its packet to all of its neighbors and so each node receives a large number of packets with similar data from each of them. Except the first packet, the rest are useless. Reducing number of useless packets leads to protocol’s efficiency increase in energy consumption.

In the rest of the paper, in second part related works are discussed, and then in section 3, MLAF (in detail) is explained. What’s more, in 4th section, MLAF efficiency using simulations will be studied and finally we will conclude the paper.

II. RELATED WORKS

Flooding algorithm has a simple function in which each node sends received packet to all of its neighbors irregularly. Each node stores a copy of packet and again sends the packet to all of its neighbors. This procedure continues until all network nodes receive this data. On one hand flooding algorithm consumes high amount of energy because of large number of redundant forwarded packets, on the other hand, it provides a high reliability. Different algorithms have tried to improve the efficiency of flooding, using different methods. For example gossiping algorithm, extends flooding efficiency (not in a high level). In gossiping algorithm each node forwards the received packet to one of its randomly chosen neighbors. Efficiency of gossiping and flooding has been compared in [3]. Also there are other different presented protocols with this subject for dissemination data in wireless sensor networks. For example [4] data received by the node from their neighbors causes a decrease in sending redundant packets. The more a protocol decreases sending redundant packets, the more it becomes efficient.

Different algorithms disseminate data using information of node positions. Generally one of the important groups in wireless sensor networks’ routing is location aware algorithms. These algorithms use node position data, directly or implicitly. GEAR [5], GAF [6] and HGR [7] are examples of this group of protocols. GEAR defines the routes cost specification using remained energy and distance between each node and sink. GAF uses virtual grid in routing. GAF activates some nodes in each grid cell and inactivates the rest, in this way, it reduces energy consuming. HGR defines the rout between node and sink considering the distance between each node and its neighbors and also angle of each of nodes’ neighbors.

LAF [2] is a protocol that uses node location information to propagate data in network. LAF considers network as a virtual grid. Network nodes are divided into 2 types: internal and edge nodes. Some of edge nodes’ neighbors are in another grid cell but for internal nodes, all their neighbors are located in node’s own cell. Each packet has a field in which list of node IDs that receive packet is saved. Therefore if packet arrives a node which has received it before, packet will be destroyed.

III. PROPOSED PROTOCOL

Before MLAF protocol is designed for data dissemination in wireless multimedia sensor networks. To send sink node’s data to all of network nodes is the main aim of data propagation algorithms. For instance, in different protocols of wireless sensor network like REEP [8], there is a phase to propagate data. In this phase, sink broadcasts its query to network nodes. All of network nodes should receive the request, so that they can provide requested data for sink.

MLAF protocol follows 3 main goals:
1- Sending data to all of network nodes using proper energy consumption.
2- Sending data with different delays based on its priorities.
3- Considering different reliabilities for data with different priorities.

MLAF considers network as a virtual grid. Network nodes are aware of their own geographical position. Considering network’s boundary we can simply form virtual grid. For instance if a 400 * 400 bounded network needs a 16_cell grid, cells with 100 * 100 bounded will be formed. So each cell’s width should be 100. Each node can find its own cell knowing its geographical position and width of grid cells. 2 types of nodes are defined in each cell. Nodes with all their neighbors inside its own cell are called internal nodes, and those with at least one neighbor in another cell are entitled as edge nodes. Each MLAF packet has a field in which list of node IDs that receive packet is saved. By the time each node intends to send a packet to its neighbors, it stores their IDs in the mentioned field. Each node evaluates this field after receiving a packet. If it finds its ID in foresaid list, it will destroy the packet; otherwise it forwards the packet to its neighbors, as mentioned above. Using the routine method explained in this paragraph, the number of forwarded redundant packets decreases.

Data propagation performed by LAF is an applied method to decrease sending useless packets, but not a suitable one for wireless multimedia sensor networks. Here are some of LAF’s weaknesses:
- LAF reduces number of redundant packets, but not satisfactorily.
- Forenamed protocol considers no reliability based priorities; it has considered just one routine for all packet types.
- Like previous case, LAF protocol doesn’t have a routine to send data with different priority, so it can not consider different delays for different traffics.

In MLAF protocol we try to cover weak points in an efficient way. In figure 1, we can see structure of a grid cell and its 4 neighbors. Each grid cell has 2, 3 or 4 neighbors.

Qualifications of 2_edge or 3-edge cells are subset of 4_edge cells, so in the rest of paper we just consider 4_edge cells.
A. Directional forwarding

As you see in figure 1, the 4 neighbors of a grid cell are identified with E, N, S and W. normally data enter the cell from 4 directions. In data propagation as done in LAF, packets with redundant data enter the cell from 4 directions. In MLAF protocol, we can consider traffics with different priorities. Performed simulations which are evaluated in the rest of the paper, lead to the idea of restricting arrived data to grid cells. So 2 priorities are needed:

1. For low priority data, each grid cell should receive data only from the southern(S) cell and other data entering from other side cells should be destroyed. It happens when sink node is one of the southern nodes of network.

2. For high priority data, each grid cell receives data from all its neighbor cells.

Considering two rules above, network is capable of sending two types of data: low priority traffic and high priority traffic. Facing packet loss, Low priority traffic has less sensitiveness rather than that of high priority traffic. In other works, low priority traffic has a more flexible packet loss threshold in comparison to high priority traffics. MLAF sends data with high priority using method 2 and the ones with low priority using method 1.

The more redundant packets results in the more reliability which are expected.

The more increment we have in number of redundant packets, the more reliability we expect.

In method 1, each grid cell receives data from only one direction, while in method 2 each cell does it from 4 sides. So method 2 is expected to have more reliability than method 1. Reliability evaluation depends on the packet loss rate in network. In LAF implementation packet lost rate is considered zero. In this state using method 1 is much more efficient than method 2. Because although the number of useless sent packets is reduced, it doesn’t affect reliability. The reason is that there is no packet lost in path and all of packets will arrive to the destination. But, as we know, in real world, packet loss rate is more than zero in networks. In the case that packet loss rate is more than one, not all of packets reach the destination. Therefore difference between method 1 and method 2 is distinguished better. When packet enters grid cell from 4 sides, in a case of packet loss related to one side, packets of other sides will distribute in the cell and will deliver data to grid nodes. In other words method 2 is more reliable than method 1 because of sending more redundant packets. But, as we know, this reliability costs more consumed energy. Compounding these 2 methods leads to MLAF, which is an efficient protocol. Each time that there is a need of high reliability, although it consumes more energy, MLAF uses method 2, but when lower reliability is acceptable, packets are sent using method 1. Reliability of method 2 is a bit more than that of method 1. Simulation results which are presented in section 4 will support this claim.

B. Delay sensitive forwarding

Delay in wireless multimedia sensor networks depends on the number of hops. Generally, in computer networks, delay parameter is consists of two parts: link propagation delay and intermediate nodes delay. Link propagation delay is the time spent on sending packet from one node to its neighbor node. Intermediate node delay is the time that one packet spends in each of intermediate nodes. Due to ad hoc structure of sensor networks, each of network nodes acts also as router, in addition to its normal function. Nodes use other network nodes to send their own data to each other. Delay is occurred in each intermediate node due to processing and queuing. Due to limited bound of wireless sensor network, we can overlook links propagation delay comparing to intermediate nodes delay.

In MLAF, different traffics with different threshold delay can be sent; So Two priorities are considered for traffics; high priority and low priority. Packet with high priority belongs to the traffic which needs less delay_ comparing to low priority traffic_ (there is no relation between these priorities and the ones defined in section 3.1). To send high priority packets, MLAF reduces the number of hops between receiver and transmitter by reducing the number of intermediate nodes. As mentioned in previous paragraph, reducing the number of intermediate nodes, leads to end to end delay reduction. Reducing hop numbers is a result of an increase in grid radio range. Actually, MLAF increases nodes radio range to send packets with high priority, so the nodes are capable of sending their packets to further nodes and as a result the number of intermediate nodes between source and destination will decrease. If we want to double radio range, we should increase transmission power fourfold.

Increasing radio range is not acceptable itself because it increases network energy consumption; but in MLAF, this mechanism is used with directional forwarding (the one explained in section 1-3). Using these 2 mechanisms simultaneously causes suitable efficiency of protocol in both fields.

We consider 2 priorities for directional forwarding and 2 for delay sensitive forwarding so 4 priorities can be defined for MLAF. Priority definitions depend on network application. In other words we can use different priorities based on the application which wants to use wireless multimedia sensor networks, and on the features of traffic which is forwarded in network.

IV. PERFORMANCE EVALUATION

In this section, performance of proposed protocol is evaluated from different aspects using performed simulations.
We use Opnet [9] for simulations. In performed simulations we have considered 4 protocols:

- **LAF (G=1):** in this state LAF with only one grid cell have been considered.
- **LAF:** in this state LAF have been considered.
- **PLAF:** in this state proposed protocol have been considered which uses only directional forwarding.
- **MLAF:** in this state proposed protocol is fully considered. In other words we have implemented both directional and delay based forwarding.

Simulation parameters are shown in table 1.

**TABLE I. SIMULATION PARAMETERS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio Range</td>
<td>10, 20 meters</td>
</tr>
<tr>
<td>Transmission energy for Radio Range =10</td>
<td>12 unit</td>
</tr>
<tr>
<td>Forwarding energy for Radio Range =20</td>
<td>48 unit</td>
</tr>
<tr>
<td>Receiving Energy</td>
<td>10 unit</td>
</tr>
<tr>
<td>Network size</td>
<td>A 100<em>100 and 40</em>40 square</td>
</tr>
<tr>
<td>Packet type</td>
<td>Low priority, High priority</td>
</tr>
<tr>
<td>Packet loss ratio in environment</td>
<td>Varies between 0 and 30</td>
</tr>
<tr>
<td>Input rate</td>
<td>Poisson between [0.5-1.5]</td>
</tr>
</tbody>
</table>

First, nodes are distributed uniformly and randomly in environment. As discussed in sections 3, nodes know their positions. After determining number of cells, (number of cells can be determined easily, by determining cell width), each node can easily find its own cell. In real world, nodes find their position using GPS or position finding algorithms.

Simulation results confirm our expectation about decreasing network energy consumption. In figure 2, node’s energy consumption is presented for protocols which were discussed before. Initial energy of nodes is 2000 units.

**Figure 2.** network nodes energy consumption,a-LAF(G=1), b-LAF, c-PLAF

In figure2-a, a graph related to LAF(G=1) energy consumption is depicted. As you see, network lifetime is about 7 seconds. Lifetime is the time between simulation beginning and death of first node. When energy of a node is fully depleted, it will die. Figure2-b presents network nodes energy consumption for LAF. Network lifetime is about 9 seconds. Figure2-c presents network nodes energy consumption for PLAF. For PLAF network lifetime is about 17.8 seconds. For plotting figure 2 graphs, traffics with different priorities are injected to network; 50 percent of packets have high priority and the rest have low priority. In figure3 network lifetime for all the protocols is depicted.

**Figure 3.** Lifetime versus Loss Rate

In figure3 lifetime is plotted versus loss rate. Loss rate is the rate of packets lost in network links. Packet generation rate in sink is considered constant. As you see in figure3, when packet loss rate increases, network lifetime for all protocols increases too. These lead to a decrease in energy consumption of each packet. For example, when loss rate is zero, all the packets reach the destination, but when loss rate is more than zero, some of packets are dropped in the path and it causes a decrement in consumed energy.

It is observable in figure3 that network lifetime for PLAF is more than LAF and LAF (G=1). Obtained results show that PLAF is more successful in decreasing number of redundant packets. Whenever sending forwarded packets is prevented, you can save much more energy.

As discussed in section 3-1, decrement in number of redundant packets may leads to decrease reliability. In figure4, average portion of network nodes which receive packets are shown. In performed simulation, for example when 200 packets are distributed in network, one packet may reach to all the nodes and another packet may reach only to 50 percent of nodes. In figure4 average of the values has been shown.

**Figure 4.** Broadcast rate versus Loss Rate

As observable in figure4, when loss rate is zero, all of packets of all protocols reach to all nodes of network. When loss rate increases, number of nodes which receive packets (we call this parameter, broadcast rate) decrease. Based on results of figure4, PLAF in comparison with LAF is a little less successful in mentioned parameters. If results of both figure3 and 4 are evaluated at the same time, we can make decision more precise. When loss rate in network is zero, number of nodes which receive packets are the same for both protocol, but it is observable in figure3 that PLAF saves energy 50 percent.
better than LAF. In table2 energy consumption and broadcast rate are presented for PLAF and LAF.

<table>
<thead>
<tr>
<th>Loss rate</th>
<th>Energy consumption difference between PLAF and LAF</th>
<th>Broadcast rate difference between PLAF and LAF</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>+50</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>+57</td>
<td>-4</td>
</tr>
<tr>
<td>10</td>
<td>+59</td>
<td>-11</td>
</tr>
<tr>
<td>20</td>
<td>+62</td>
<td>-18</td>
</tr>
<tr>
<td>30</td>
<td>+33</td>
<td>-10</td>
</tr>
</tbody>
</table>

Difference between PLAF and LAF are fully visible in table2. As discussed before, for acquiring simulation results, 50 percent low priority and 50 percent high priority traffics are injected to network.

In figure5 overall residual energy for both PLAF and LAF is presented. As observable in figure5, when network uses PLAF network lifetime is about 103 second and for LAF network lifetime is about 74 second. Overall residual energy is calculated by sum of residual energy of all network nodes. Using figure5, we can understand that PLAF performs fairness more efficient than that of LAF. To perform fairness, nodes’ energy should be used equally. If one part of a network is used more than other parts, its energy will drop sooner than others and then the network will be partitioned. If a network partitioned, its energy consumption increases severely.

![Figure 5. Total residual energy versus Time](image)

In figure6, influence of grid size in PLAF efficiency is evaluated. As observable in figure6, when number of grid cells increases network lifetime increases too. We have evaluated grids with 4, 9 and 36 cells. When number of grid cells increases, number of forwarded redundant packets decreases, therefore energy consumption decreases and network lifetime will be prolonged.

![Figure 6. Lifetime versus Loss rate](image)

In the rest of the paper MLAF and LAF are compared from delay point of view. As discussed in section 3, one of main goals of MLAF is to reduce end to end delay. Delay sensitive forwarding is explained in section 2-3. We will evaluate its performance here. In performed simulations we consider two network types, network with 16 and 36 nodes. Based on related works, in both states, 90 percent of traffic is low priority and remained 10 percent of traffic is high priority. In figure8, delay is compared for MLAF and LAF. Horizontal axis is loss rate and vertical axis is delay.

![Figure 7. Broadcast rate versus Loss rate](image)
In figure 8, two delay types are presented: the least and the most delay. For determining delay, we consider the node with longest distance to sink as criterion. With respect to data dissemination mechanism in wireless multimedia sensor networks, in spite of decrease of number of forwarded redundant packets, totally more than one packet will arrive at destination in both protocols. Each of packets which arrive to criterion node has particular delay (difference between sending packet time and the time which packet arrives at destination). We use the least and the most delay for comparing protocols. As observable in figure 8 the least delay for MLAF packets is almost half of LAF packets delay. Simulation results are depicted for different loss rates. Packets which arrive at destination using shortest path, have the least delay. Therefore the least delay is constant, because the shortest path is constant too. But loss rate influences on the most delay. When number of packets decreases, queuing delay decreases too. In figure 8 you can see the least and the most delays for MLAF are less than that of LAF.

One of the advantages of MLAF is its ability to send traffics with different priorities. Traffic priority is determined based on its own packets priority. Traffic delay requirements are determined based on their traits. In figure 9 delay is presented for both high priority and low priority traffics. In figure 9 similar graphs are depicted for the network with 36 cells. Both figures 8 and 9 have same analysis. By comparing figures 8 and 9, it is observable that from delay point of view, difference between LAF and MLAF decreases when number of nodes reduces.

In figure 10 MLAF and LAF is compared from energy point of view. In section 2-3 delay sensitive forwarding is explained in details. Simulation results which are shown in figure 10 show that MLAF energy efficiency is more than LAF. MLAF is more energy efficient due to following reasons:

- MLAF uses directional forwarding as explained for PLAF
- MLAF uses longer radio range in comparison with LAF, therefore it can prevent sending redundant packets better.

Figure 11 shows number of packets which are reached to criterion node. It is observable that criterion node receives less number of packets when it uses MLAF rather than LAF. It can prove that MLAF is more successful in decreasing number of forwarded redundant packets.

V. CONCLUSION

In this paper a QoS and energy aware data dissemination protocol for wireless sensor networks entitled MLAF is presented. Three parameters are considered for protocol design: energy, reliability and end to end forwarding delay. Performed simulations show that proposed protocol achieved the goals. MLAF uses 2 mechanisms: directional forwarding and delay sensitive forwarding. In directional forwarding, considering virtual grid structure, number of neighbour cells for each grid cell is restricted. This leads to save significant more energy. In delay sensitive forwarding, high priority packets are forwarded with lower delay using different radio range for nodes; Of course protocol’s energy efficiency is preserved. For future works, we will adopt MLAF for more specialized multimedia application by considering new parameters.
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