An Energy Efficient Data Dissemination Protocol for Wireless Multimedia Sensor Networks

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***Abstract*—In this paper, we are going to present a data dissemination protocol for wireless multimedia sensor networks (WMSN). The proposed protocol entitled as PLAF (Priority based Location Aided Flooding) is used for packet dissemination in WMSN. PLAF 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, PLAF makes decision about its routing. Consumed energy the main parameters in protocol design. The proposed protocol uses LAF as base. Different aspects of PLAF efficiency have been evaluated. Performed simulations show that PLAF has achieved all of its goals.**

Keywords-data dissemination protocol, energy efficiency, traffic priority, Wireless multimedia sensor networks .

I. INTRODUCTION

Following wireless sensor networks, wireless multimedia sensor networks have been recently considered. 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 [1]; 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 [2]. These are some of important protocol 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 [3].
- 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, 2 basic parameters are considered about wireless multimedia sensor networks: energy and reliability. The proposed protocol is designed on basis of LAF. 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. 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 [4] and PLAF 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 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 it's 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, PLAF (in detail) is explained. What's more, in 4th section, PLAF 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 [5]. Also there are other different presented protocols with this subject for dissemination data in wireless sensor networks. For example in [6] information 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 [7], GAF [8] and HGR [9] 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 [4] 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 neighbours 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

As explained before, PLAF 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 dissemination algorithms. For instance, in different protocols of wireless sensor network like REEP [10], 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.

PLAF protocol follows 2 main goals:

1- Sending data to all of network nodes using proper energy consumption.

2- 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 disseminating 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 weaknesses:

- LAF reduces number of redundant packets, but not satisfactorily.

- LAF considers no reliability based priorities; it has considered just one routine for all packet types.

In PLAF 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.

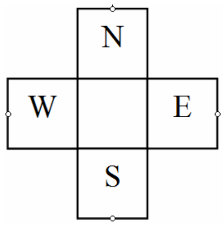

Figure 1. A grid cell.

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.

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 3 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 intermediate priority data, each grid cell receives data from 2 direction based on sink position. In our simulations cells receive data from southern and eastern neighbors.

3. 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 words, low priority traffic has a more flexible packet loss threshold in comparison to high priority traffics. PLAF sends data with high priority using method 3 and the ones with low priority using method 1.

Method 2 is not energy efficient as method 1 and is not reliable as method 3. To send ordinary traffic we can use method 2.

Method 2 energy efficiency is admissible, and it is enough reliable for mentioned traffic.

In method 1, each grid cell receives data from only one direction, while in method 3 each cell does it from 4 sides. So method 3 is expected to have more reliability than method 1. The more increment we have in number of redundant packets, the more reliability we expect. 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 3, 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 PLAF, 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.

Generally, based on points which are mentioned in previous paragraphs, we use method 1 for sending low priority traffic, method 2 for sending ordinary traffic and method 3 for sending high priority traffic.

IV. PERFORMANCE EVALUATION

In this section, performance of proposed protocol is evaluated from different aspects using performed simulations. We use Opnet[11] 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.

Simulation parameters are shown in table 1.

TABLE I. SIMULATION PARAMETERS

Radio Range	10, 20 meters
transmission energy	12 unit
Receive Energy	10 unit
Network size	A 100*100 and 400*400 square
Packet type	Low priority, High priority
Packet loss ratio in environment	Varies between 0 and 30
Input rate	Poisson between[0.5-1.5]

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.

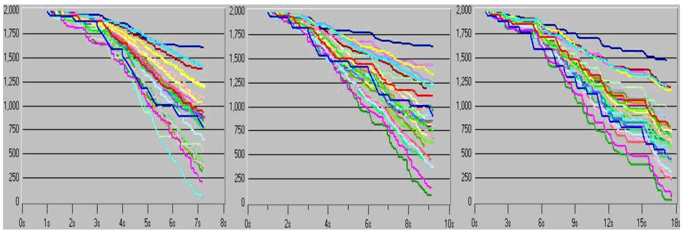

Figure 2. network nodes energy consumption, left-LAF(G=1), mid-LAF, right-PLAF

In figure2, you can see a graph related to LAF(G=1) energy consumption. 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. In this traffic, 50 percent of packets have high priority and the rest have low priority. In figure3 network lifetime for all the protocols is depicted.

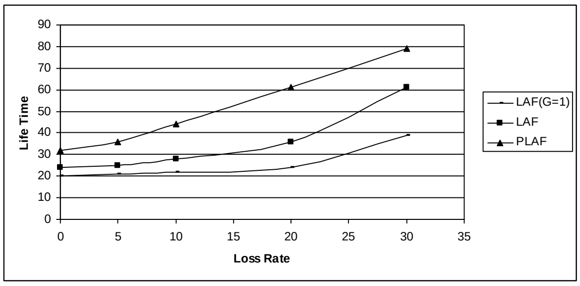

Figure 3. Lifetime versus Loss Rate for defferent protocols

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 route 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 result shows that PLAF is more successful in decreasing number of redundant packets. Each time that sending forwarded packets is prevented, you can save much more energy.

As discussed in section 3-1, decrease number of redundant packets may leads to decrease reliability. In figure4, average portion of network nodes which receive packets are shown. In performing simulation, for example when 200 packets are distributed in network, a 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.

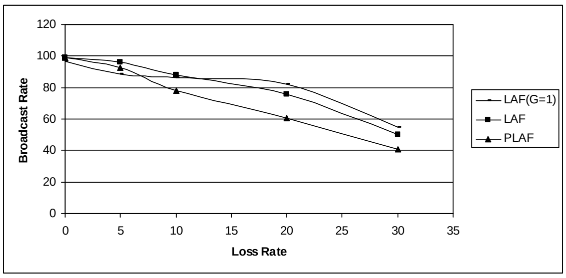

Figure 4. Broadcast rate versus Loss Rate for defferent protocols

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 II. COMPARING PLAF AND LAF

Loss rate	Energy consumption difference between PLAF and LAF	Broadcast rate difference between PLAF and LAF
0	+50	0
5	+57	-4
10	+59	-11
20	+62	-18
30	+33	-10

Difference between PLAF and LAF are fully visible in table2. Although difference between PLAF and LAF in broadcast rate is acceptable, PLAF is much more efficient in energy consumption.

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.

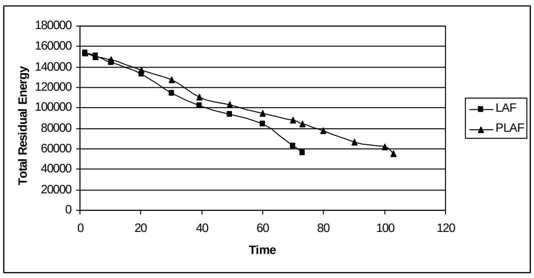

Figure 5. Total residual energy versus Time for PLAF and LAF

In figure6, influence of grid size in PLAF results 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.

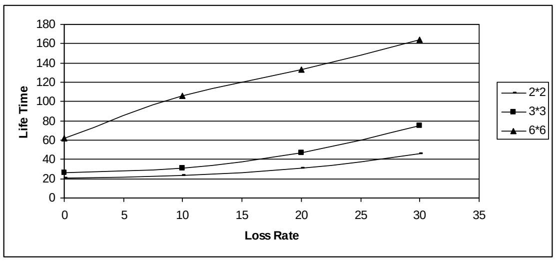

Figure 6. Lifetime versus Loss rate for different gris sizes

We can not increase number of grid cell without limitation. The most number of grid cells is the same with number of network nodes. Network performance severely decreases when number of grid cells approaching to number of network nodes. As observable in figure9, when a network with 36 nodes uses grid with 36 cells, network performance decreases severely. Network performance is decreased due to broadcast rate reduction. When loss rate is zero, grid nodes with 36 cells only receive 56 percent of sent packets. Low energy consumption of grid with 36 cells is due to its much less broadcast rate. In other words due to unsuccessful send of packets energy consumption is reduced. Regarding to results of figure6, about 36 cells grid, results which are obtained from figure7 about its energy consumption is invalid and seducer. But for 4 and 9 cells grids, results are valuable and important. Broadcast rate for grid with 9 cells is 10 percent less than grid with 4 cells, but its network lifetime is 78 percent better. Mentioned results show that 9 cell grid is more efficient than 4 cell grid.

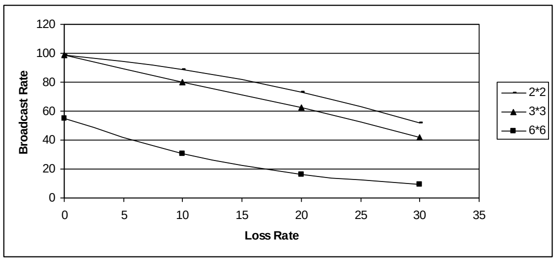

Figure 7. Broadcast rate versus Loss rate for different grid sizes

Here we will evaluate effect of directional forwarding on PLAF efficiency. 3 states are considered for performed simulations. In first state grid cells only receive packets from their right (east) neighbours. As discussed in section 3-1 side selection for forwarding packets is depended on sink position rather than other network nodes. In performed simulations, sink is located on south-east of network. In next state grid cells only receive packets from their southern neighbours. In third state grid cells receive packets from all directions neighbours. Figure8 shows network lifetime for mentioned states.

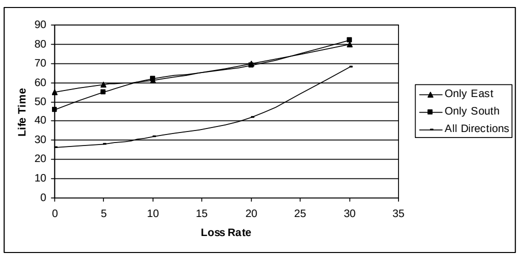

Figure 8. Lifetime versus Loss rate for different methods

Number of neighbours which send packets to the cell is important in directional forwarding. If number of sender neighbour increases energy consumption increases too, but in other side reliability decreases. As observable in figure8 simulation results for state 1 and 2 are the same; this confirms our idea. Even though state 1 and 2 accept packets from different directions, but they consider the same number of directions. State 3 consumes energy more than that of two other states, therefore its lifetime is less than two other states in the same condition.

In figure9 broadcast rate is presented for 3 mentioned states. For loss rate zero, performance of 3 states is the same. Even loss rate increases, difference between 3 state performance increases too. Results which are presented in figures8 and 9 make clear directional forwarding performance. Based on network application and traffic priority different states are selected. For example if an application is loss intolerant, it should use state 3; because state 3 is more reliable. For loss tolerant applications state 1 and 2 is more efficient; state 1 and 2 are less reliable but they are more efficient in energy consumption.

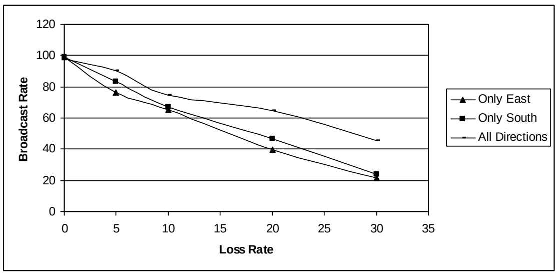

Figure 9. Broadcast rate versus Time for different methods

In figure 10 and 11 the same simulations are done for methods which are presented in section 3. Method 1 is used to send low priority traffic, method 2 is used to send intermediate priority traffic and method 3 is used to send high priority traffic. WSN application use one of mentioned methods based on their goal. In recent applications, due to cost efficiency of network, different traffics are forwarded through network. If WSN data dissemination protocol uses PLAF, 3 different choices exist for data forwarding. Based on results which are shown in figure 10 and 11, and also based on traffic characteristics, one the methods is used to send traffic packets.

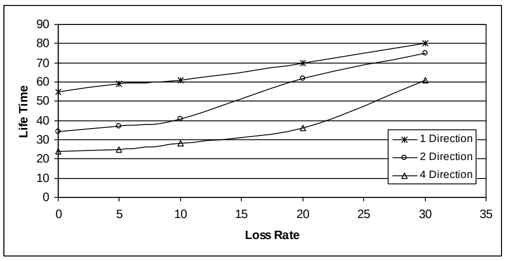

Figure 10. Life Time versus Loss Rate for different methods

As observable in figures 10 and 11, there is a trade off between energy efficiency and reliability. More energy efficiency leads to less reliability and vice versa. User should choose one of methods based on traffic characteristics. For reliable transmission method 3 should be selected, for energy efficient transmission method 1 should be selected and for ordinary traffic method 2 is the best choice.

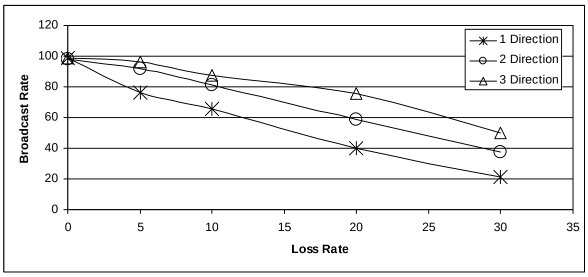

Figure 11. Broadcasr rate versus Loss rate for different methods

V. Conclusion

In this paper an energy efficient data dissemination protocol for wireless multimedia sensor networks entitled PLAF is presented. Two parameters are considered for protocol design: energy and reliability. Performed simulations show that proposed protocol achieved the goals. PLAF uses directional forwarding mechanism. In directional forwarding, considering virtual grid structure, number of neighbour cells for each grid cell is restricted. This leads to save significant more energy. Furthermore, PLAF can send traffic with different reliabilities based on their priority. For future works, we will adopt PLAF for more specialized multimedia application by considering new parameters.

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