

## MULTI PHASE, QoS AWARE ROUTING PROTOCOL FOR WIRELESS MULTIMEDIA SENSOR NETWORKS

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*In this paper, we present a novel data centric routing protocol for Wireless Multimedia Sensor Networks (WMSN) called Multi phase, QoS aware Routing Protocol (MQRP). It performs data delivery in WMSN considering crucial parameters, energy consumption, timeliness (delay), reliability, lifetime and fairness. Multiple QoS priorities are provided and the routing is performed based on the provided constraints. Simulation results show that MQRP provides QoS differentiation in mentioned parameters, as a result, achieves its goal which is improvement in the efficiency of a WMSN.*

**Keywords:** Data Dissemination Protocol, Routing Protocol, Phase Based Protocol, Quality of Service, Wireless Multimedia Sensor Networks

### 1. Introduction

Wireless multimedia sensor networks (WMSN) following by wireless sensor networks have received great attention nowadays. Additive applications of these networks lead to an increase in their importance. Accessibility to low cost hardware such as CMOS cameras and microphones has expanded wireless multimedia sensor networks. WMSN consists of wireless nodes, which can transmit multimedia traffic in addition to sensing multimedia events. By developing hardware, equipping small nodes with necessary multimedia devices is possible now [1].

Protocols which are designed for WSN, lose their efficiency to some extent, if directly used for WMSN. But, they still have so many similar characteristics. With respect to WMSN characteristics, their protocols should be designed in cross layer manner [2]. Many of those characteristics are: 1) energy consumption efficiency, 2) self-configuration, 3) sending data with different real time requirements, 4) sending data with different reliabilities [3, 4].

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In this paper, we propose QoS based Routing protocol for WMSN that is called MQRP (Multi phase, QoS aware Routing Protocol). The proposed protocol is a data centric routing protocol that takes end to end delay, reliability, energy consumption, network lifetime and fairness into consideration. As it is obvious, all of the aforementioned parameters are dependent; for example: energy consumption and network lifetime are inversely related. The main goal of the proposed protocol is to control these parameters using constraint based routing process.

Depending on their application, the delay parameter has different importance for WMSNs. Different data types have different delay thresholds; therefore, network reaction should be commensurate with data types. Energy consumption, lifetime and fairness are relevant parameters to protocol's energy efficiency. Indeed, increasing lifetime is the essential goal; two main elements for increasing lifetime are consuming energy efficiently and providing fairness [5]. The aim of providing fairness is consuming energy of the network nodes fairly. When the network nodes' energies are less than the variance, the network lifetime will be prolonged. To provide fairness, nodes' energies should be used equally. If one part of a network is used more than other parts, its energy will decrease sooner than others then the network will be partitioned. If a network is partitioned, its energy consumption will increase severely. Using different paths to send data to sink makes the fairness performance better. When the network lifetime is prolonged, apparently we can use its services longer.

Many successful routing protocols are presented for WSNs and WMSNs hitherto. Directed Diffusion [8] and SPIN [9] are two famous routing protocols for WSNs. In both protocols, requests are disseminated in the network and then routing is done based on data type. Each of the aforementioned protocols is improved many times, as they are known as family [10]. SPIN has many flaws; for example, it is not scalable, it is not energy efficient and etc. [11,12] are two famous WMSN routing protocols.

MQRP makes routes based on network conditions and traffic requirements at the same time. The proposed protocol has used many of ideas that are pointed to in REEP [13]. REEP protocol has different phases like other data centric protocols. These phases are: Sense event propagation, Information event propagation and Request event propagation. MQRP is a data centric protocol. Data centric protocols are a major part in routing protocols in wireless sensor networks [7]. MQRP is composed of different phases. Details about phases, will be presented in section 2. In the first phase, the sink must disseminate its requests in the entire network. Forming this phase in the best manner is one of the major goals of the proposed protocol. REEP uses Flooding to perform first phase. Due to the huge amount of redundant packets, Flooding is not energy efficient, but on the other hand, it is a reliable protocol. Different routing protocols try to improve

Flooding efficiency by using different methods. For example, in Gossiping [14] algorithm every node chooses one of its neighbors randomly and then sends the received packet to it [15]. Many other routing protocols with vary purposes have been proposed for wireless sensor networks, GKAR [16], GEAR [17], GAF [18] and HGR [19]. For example, HGR defines the route from the nodes to the sink considering the distance between each node and its neighbors and angle of the node's neighbors. LAF [6] is a protocol that uses node location information to propagate data in the network.

The proposed protocol includes the following 4 phases; request dissemination, event occurrence report, route establishment and data forwarding. A new data dissemination algorithm named MLAF (Multimedia Location Aided Flooding) which is a modified version of traditional LAF [6] protocol is proposed in order to be used in the MQRP first phase. MLAF also can be used independently in other routing protocols as a data dissemination algorithm.

The rest of the paper is organized as follows: in section 2, the proposed MQRP protocol is presented in detail. In section 3, we will evaluate proposed protocol efficiency and finally in section 4, we conclude the paper.

## 2. Proposed Protocol

In this section, we describe the proposed MQRP in detail. MQRP is a data centric protocol, which is composed of the following phases: request dissemination, event occurrence report, route establishment and data forwarding. The proposed protocol structure is presented in Fig. 1. In phase 1, MQRP uses the proposed dissemination algorithm called MLAF (Multimedia Location Aided Flooding). MLAF is specially designed for data dissemination in wireless multimedia sensor networks. MLAF will be discussed in detail in section 2.1. Then three other phases, event occurrence report, route establishment and data forwarding, are presented in sections 2.2, 2.3 and 2.4 respectively.

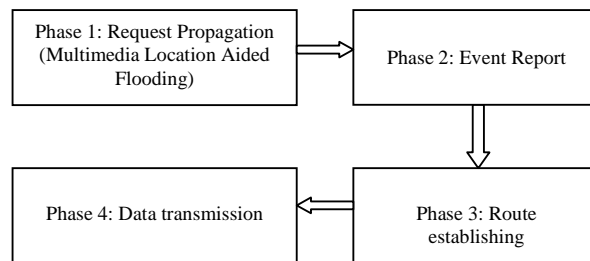


Fig. 1. Proposed protocol structure

The main goal of the proposed protocol is to provide a QoS aware routing protocol for wireless multimedia sensor networks. The proposed protocol is designed based on wireless multimedia sensor networks characteristics. These

networks are used for different applications [20]. Using one network for variety of applications is economical because different applications are performed using one hardware infrastructure and this leads to a decrease in cost. So, proposed protocol can send traffic with different QoS requirements.

### **2.1. Request dissemination phase**

In this phase, sink sends its desirable requests to the entire network nodes. The proposed protocol MQRP uses the MLAF protocol to perform this phase. Many of other data centric routing protocols such as REEP use deficient data dissemination algorithms (for example flooding). The MLAF algorithm not only decreases energy consumption, also provides disseminating data with different priorities. Following points should be considered for this phase packets: 1) priority of used application; 2) time; 3) destination nodes geographical confine; 4) request specification; each request contains destination nodes task and the way they should react to the event.

MLAF considers network as a virtual grid. The network nodes are aware of their own geographical position. Considering network's boundaries, we can simply form a virtual grid. For instance, if a 400 \* 400 network needs a 16 cell grid, 100 \* 100 cells will be formed. The more the network density is, the smaller cell is acceptable. Two types of nodes are defined in each cell. Nodes with all their neighbors in its own cell are called internal nodes, and those with at least one neighbor in another cell are titled edge nodes. Each MLAF packet has a field in which a list of nodes IDs that have received packet is saved. By the time each node intends to send a packet to its neighbors, it stores their IDs in the given field. Each node evaluates this field after receiving a packet. If it finds its ID in the foresaid list, it will destroy the packet; otherwise, it forwards the packet to its neighbors.

#### **2.1.1. Directional Forwarding**

Normally, each cell has four neighbors, E (east), N (north), S (south) and W (west). Data enter the cell from four directions. In traditional data propagation as it is done in LAF, packets enter the cell from all four directions. In MLAF protocol, we try to control the redundancy as follows:

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. This happens when a sink node is one of the southern nodes of the network (See Fig. 2).
2. For high priority data, each grid cell receives data from all its neighbor cells.

Low priority traffic is the type that has lower sensitivity regarding packet loss compared to high priority traffic.

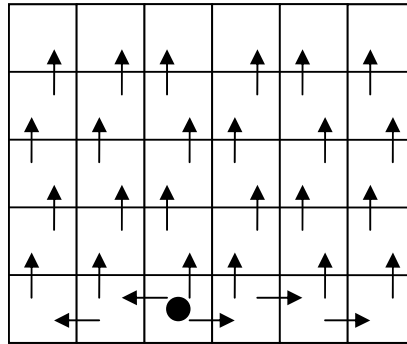


Fig. 2. Directional forwarding when sink stands in the south

The more redundant packets send to a cell, the more reliability is expected; however, energy consumption grows. In method 1, each grid cell receives data from only one direction, while in method 2 each cell receives from 4 sides. Therefore, method 2 is expected to have more reliability than method 1. Simulation results that are presented in section 3 support this claim.

### 2.1.2. Delay Sensitive Forwarding

Delay in wireless multimedia sensor networks depends on the number of hops. Generally, in computer networks, the delay parameter consists of two parts; link propagation delay and intermediate nodes delay (the queuing delay). Link propagation delay is the time spent sending packet from one node to its neighbor node. Intermediate node delay is the time that one packet spends in each of intermediate nodes. In MLAF, different traffic with different delay threshold can be sent; therefore, two priorities are considered for different types of traffic; high priority and low priority. Packet with high priority belongs to the traffic, which needs less delay compared to low priority traffic (there is no relation between these priorities and the ones defined in section 2-1-1). 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 the previous paragraph, reducing the number of intermediate nodes, leads to reducing end to end delay. 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.

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 2-1-1). Using these two mechanisms simultaneously improves efficiency of the protocol in both fields. Fig. 3 clarifies the aforementioned procedure.

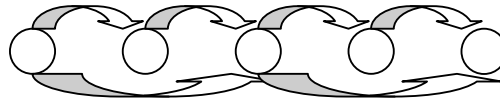


Fig. 3. Delay sensitive forwarding

We consider two priorities for directional forwarding and two for delay sensitive forwarding. Therefore, four priorities can be defined for MLAF as presented in table 1.

Table 1

Four different priorities for traffics		
Traffic types	High reliability	Low reliability
Low delay	2	1
High delay	4	3

## 2.2. Event Occurrence Report Phase

When request dissemination phase is done, the entire network nodes know their tasks. When a node senses an event relevant to its task, it should report the sensed event features to the sink. In this phase, the relevant information (metadata) to the event that has occurred will be sent to the sink, but sending the fundamental information relevant to the event will be done in data sending phase. Furthermore, the phase paves the way for providing packet routing. The nodes that sensed the event create packets and put relevant information in them. Through sending the packet to sink, the necessary routing tables will be provided for the aim of data routing in the intermediate nodes. The final routing will be executed in the route establishment phase. Indeed, in the second phase the completion of the final routing will be done by gathering all the essential information in each node in the form of a permanent routing table. This act will finish by creating of routing tables for each specific node in the third phase.

When a node senses an event, according to the node's task, the event should be reported to the sink through sending packets. The node will send the packet to all its neighbors by the time it is created (this packet is called the second phase packet). If the nodes are aware of their situations, the packet will be sent to the neighbors who are far closer to the sink than the sending node. Although this matter leads to a decrease in the protocol's energy consumption, considering the need for localization process, it can't be implemented everywhere. It is worth mentioning that, in the application in which the request should be sent to one part of the network, the nodes are certainly aware of their situations.

By receiving the second phase packet, each node creates a record in its routing table (which is called the second phase table). In this record the packet's priority (compatible with traffic priority and the specified event), source node, sending node, the length of the traversed path and the numbers of traversed hops

are kept. In the proposed protocol, each node owns an ID that is put in all sent packets. The traversed route is the sum of the routes the packet has taken from the source node to the current node. After inserting a record, the node will send the packet to all its neighbors. This procedure will continue until the packet reaches the sink. At the end of the second phase, each node owns a routing table named the second phase table, which will be used for determining the final route in the third phase. The records of the second phase table dictate the possible ways between the specified node and the source node which has sensed the event.

In the Fig. 4 part <a> the pseudo code of the second phase for the event sensor node and in part <b> pseudo code in the second phase for other nodes (the packet transmitting scheme) are illustrated.

```

<a>
/* Phase 2 pseudocode for sensor node */
/* when a node sense an event */
If (is this event relevant to node's task)
    Then continue;
    Else ignore event;
Collect necessary information as determined in request packets;
Send packet to all nodes' neighbors;

<b>
/* Phase 2 pseudo code for relay nodes */
/* the node got packet from its neighbor */
If (the node is closer to sink than sender node)
    Then continue;
    Else ignore packet;
If (the packet is not repetitive)
    Then create a record for it in proposed routing table;
    Else ignore packet;
Send packet to all nodes' neighbors;

```

Fig. 4. Second phase pseudo code

### 2.3. Route Establishment Phase

After the sink has received all the second phase packets, it sends back an acknowledge packet (this packet is called the third phase packet) to the source node announcing that, source should send all its gathered data to the sink. It is possible for an event to be sensed by more than one sensor node. At this stage, according to the sent data by the source node, the sink chooses one or more nodes for the final data sending. In the second phase packet, each packet specifies its own sensing accuracy. As the third phase packet traverses the path, it creates the third phase table in the middle nodes. The third phase routing table is the final routing table which is used in forwarding packets. Forwarding acknowledgement depends on the sensed event priority. Two different acknowledgements are considered, the acknowledgement for high priority (real time traffic) and priority (non real time traffic). The shortest path (considering second phase routing table) will be selected to forward high priority packets.

Every node constructs two tables in the second phase. These two tables are: routing table in phase three with high priority and with low priority. During

this phase, these two tables are completed. When a node receives a packet with high priority in phase three, a record for that in the routing table of phase three with a high priority is created. In this table, the following parameters are placed: the sending node, the receiving node, the source node and the type of function. According to the points mentioned above, every node chooses the first record from the routing table in the second phase as the next hop, in order to send third phase packet. This process continues until the packet arrives at its sink. In fact, at the end of the third phase, non real time routing table will be created on each node.

Concepts which mentioned before in this section concerned traffic with high priority. In the rest of the section, creating low priority table in the third phase will be elucidated. The sink considers the records which are related to the source. For each of the records the Selection Interest  $SI_i$  is calculated through the equation (1):

$$HC/TD = SI_i \quad (1)$$

TD is the field that includes the length of the record path and HC is the number of the hops of each record.  $SI_i$  is the selection interest of  $i^{\text{th}}$  record as the next hop, in order to forward the third phase packet with low priority. After determining SI for each record with the specified source node, two records with the highest value of SI will be chosen. Assume the  $j^{\text{th}}$  and  $k^{\text{th}}$  records are selected. Then between each  $[SI_j + SI_k]$  incoming packets,  $[SI_j / (SI_j + SI_k)]$  packets are sent based on  $j^{\text{th}}$  record and other  $[SI_k / (SI_j + SI_k)]$  packets will sent based on  $k^{\text{th}}$  record entry. Selecting different paths is done to achieve fairness in energy consumption of network nodes. Without considering the priority, all the traffic will be sent via one fixed path; similar to the mechanism which is used in REEP protocol. This prevents achieving fairness regarding energy consumption of network nodes. In each record of the third phase table for non real time traffic, all the characteristics of the packet will be registered.

#### **2.4. Data Forwarding Phase**

At the end of the third phase, the real time and non real time routing tables will be created. Each node owns a real time and non real time third phase routing table. The source node, depending on the type of sensed event can send its data to the sink, whether it has received real time acknowledgement or non real time acknowledgement. As it was mentioned earlier, all the nodes, including the source nodes have both types of routing tables. The third phase real time routing table is used to send real time data and the third phase non real time routing table to send non real time data.

In the third phase routing table for real time traffic, there is only one record for each source. By receiving the real time traffic from the specified node, every node sends the data to the next hop using corresponding record. However,



in the non real time routing table of the third phase (for every source) there will be more than one record in the table for each source. Every record has one  $P_j$ . The choice of the next hop depends on the  $P_j$ . The larger the  $P_j$  record is, the higher the chances of its selection are. Ultimately, one record will be selected as the next hop and the data will be sent to it.

### 3. Performance Evaluation

In this section, the performance of the proposed protocol is examined. As it was pointed out earlier, there are two components to the notion of the proposed protocol, each of which will be assessed separately below. MLAF algorithm is one of the central ideas in this article, which is scrutinized in section 3-1. MLAF is used in the first phase of the routing MQRP as a disseminated algorithm. In sections 3-2 the performance of the MQRP protocol will be evaluated in comparison to the REEP protocol. We simulated our proposed protocol by OPNET simulator. The topology which is used in our simulations is presented in Fig. 5.

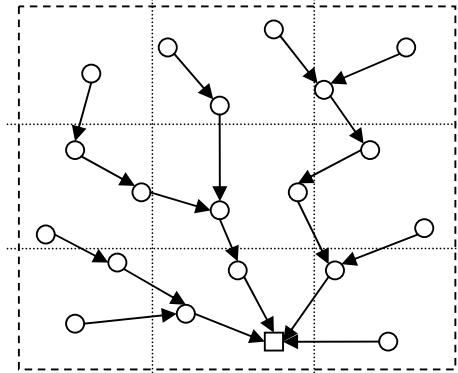


Fig. 5. Network topology

We have used 20 nodes. Links in Fig. 5 are not permanent; they will be changed during network lifetime according to the nodes' status. Also, simulation parameters which are taken into consideration are presented in table 2.

Table 2

Simulation parameters

Radio range	10 and 20 meters
Energy required for sending a unit of data (20 meter)	12 $\mu$ J
Energy required for sending a unit of data (20 meter)	48 $\mu$ J
Consumed energy for receiving data	10 $\mu$ J
Network size	100*100
Packet type	Low priority, high priority
Loss rate	Vary in [0-30]
Input rate	Poisson process, rate: [0.5-1.5]

### 3.1. Performance evaluation of the proposed data dissemination algorithm MLAF

At first, we examine the efficiency of the proposed algorithm MALF, which is used to disseminate data in the network in the first phase of MQRP protocol. For the purposes of simulation, the Opnet simulator has been utilized [21].

We continue to compare the MLAF protocol with LAF in terms of delay parameter. As mentioned in the section 2-1-2, one of the main goals of MLAF is to consider the delay parameter in transmitting data in the network. The mechanism of delay sensitive forwarding is explained in section 2-1-2. We continue to examine the performance of the aforementioned mechanism. In the simulations, 90 percent of the transferred traffic has low priority and remained 10 percent of it enjoys high priority. In Fig. 6, the delay experienced by data while transmitting for the two protocols MLAF and LAF are compared. The horizontal axis is the loss rate of packets in the network and the vertical axis is the delay.

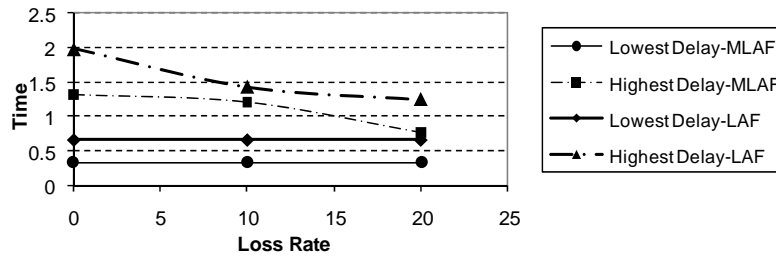


Fig. 6. Comparison parameter delay for MLAF and LAF

In the graph in Fig. 6, two types of delay have been measured: The minimum and the maximum delay. For measuring delay, the furthest node from the sink is taken to be the yardstick. In spite of using efficient algorithms, it is possible to receive more than one instant of a packet by the sink. Each of the packets which arrive at the node has a certain delay, so the shortest time is called the minimum and the longest time is maximum. As it can be observed in Fig. 6, the minimum delay for MLAF is almost half as much as the delay for LAF. The results of simulation are obtained for the different amounts of loss rate. The packets that arrive at the destination through the shortest possible route have the minimum delay; thus, the minimum delay is constant, but on the other hand, the loss rate affects the maximum delay.

In Fig. 7, MLAF and LAF are compared in terms of energy with the aforementioned simulation conditions. The obtained results in Fig. 7 demonstrate that the performance of energy consumption is higher for MLAF than LAF.

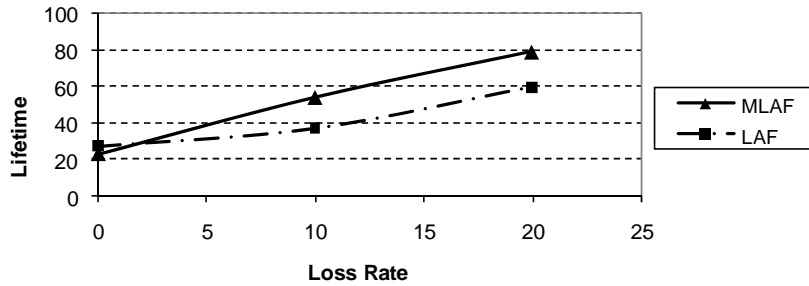


Fig. 7. Lifetime difference between MLAF and LAF

Fig. 8 shows the average number of redundant packets that arrive at their destination. As it is demonstrated in Fig. 8, in MLAF packets which carry the same data arrive at their destination more appropriate. In fact, the performance of MLAF in terms of the number of received packets at the destination had been more balanced.

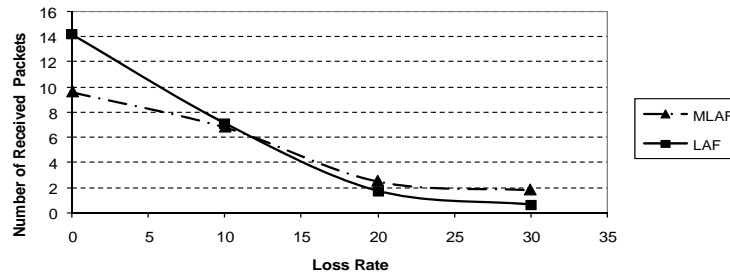


Fig. 8. Number of redundant packets which arrive at the same destination

### 3.2. The evaluation of MQRP alongside MLAF

The primary effect of MLAF on MQRP is that it diminishes energy consumption. In Figs. 9, the energy consumption of MQRP and REEP protocols are compared.

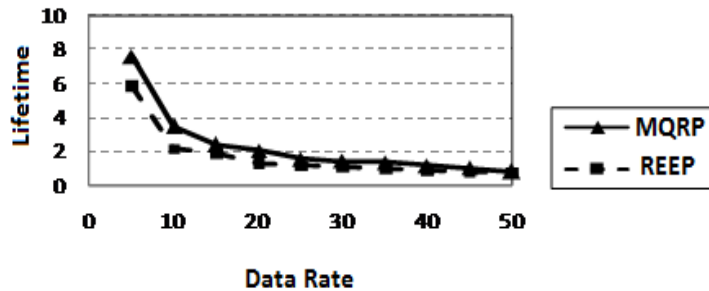


Fig. 9. Lifetime comparison between MQRP and REEP

As it was mentioned earlier, MQRP and REEP protocols are performed step by step, according to the requests from the sink. We continue to demonstrate that the more the role of the first phase grows, the more the performance of MQRP protocol will be.

In Figs. 9, the lifetime graph of networks for REEP and MQRP is presented. In this scenario, the amount of first phase packets is taken to be 10 percent of all the forwarded packets. This means that the first phase uses 10 percent of primary nodes energy. In Fig. 10, the role of the first phase is taken to be 50 percent.

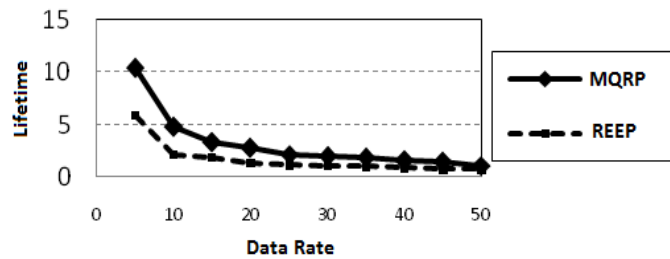


Fig. 10. Lifetime comparison between MQRP and REEP (role of the first phase is taken to be 50 percent)

In Figs. 9 and 10, the horizontal axis is the sending rate of data and the vertical axis is the lifetime of the network. The superiority of MQRP is obvious in the graphs. For instance, the lifetime of the network for MQRP when the amount of first phase packets is 10 percent is approximately 7.8 (Fig. 9), but when the amount of first phase packets is 50 percent, it is approximately 10.4 (Fig. 10).

Another fundamental parameter that is considered in this protocol is end to end delay. Delay is a parameter which is crucially important for the wireless multimedia sensor networks. In Fig. 11, MQRP and REEP are compared in terms of delay (vertical axis is the average end to end delay and horizontal axis is the simulation time). The delay presented in Fig. 11 and other figures in this section are related to the sensed data and do not include control data. As can be seen in Fig. 11, the end to end delay of real time traffic in MQRP (MQRP\_RT) is much less than that of non real time traffic (MQRP\_NRT) and REEP.

The behavior of the protocols in the beginning of the graphs shows the marked increase of delay for REEP and MQRP-NRT. The reason for this phenomenon is the congestion which occurs in intermediate nodes, which is the result of sending the remained packets of phase two. When all packets of the second phase are sent, the delay becomes stable. In a stable condition the delay of REEP and MQRP-NRT are seen to be very close. But, the delay of MQRP-RT is significantly less than them. RT traffic or real time traffic is the kind of traffic,

which requires low delay, but NRT traffic has considerably lower sensitivity to delay than RT. Considering the performance of proposed protocol presented in this section, it has achieved its goal.

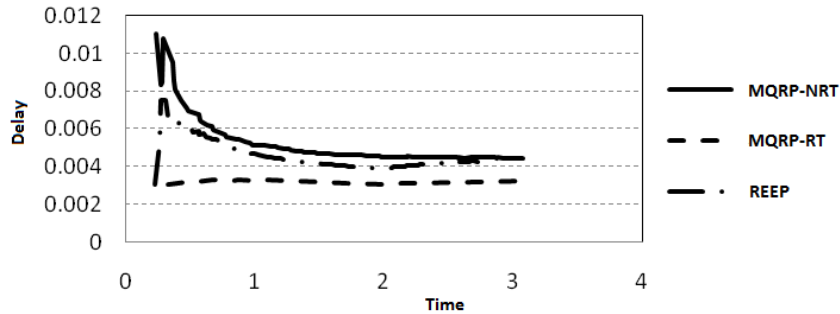


Fig. 11. Delay comparison between MQRP and REEP

#### 4. Conclusions

In this article, a QoS aware routing protocol for wireless multimedia sensor networks is presented. The proposed protocol is data-driven and comprises four phases. The first phase of proposed protocol (MQRP) has been designed to disseminate the demands of the sink. To execute this phase a new data dissemination algorithm named MLAF is proposed. The other phases of MQRP are respectively event occurrence report, the route establishment and data forwarding. Generally, the proposed protocols have taken into account several parameters including end to end delay, reliability, energy consumption, the lifetime of the network and fairness regarding energy consumption. Finally, utilizing simulation, the performance of data dissemination and MQRP protocols were evaluated. The results of the simulations show that both data dissemination algorithm and routing protocol have achieved their goals, which are controlling the aforementioned parameters.

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