MREEP: A QoS based Routing Protocol for Wireless Multimedia Sensor Networks

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***Abstract*—Use of general and efficient routing protocols for wireless multimedia sensor networks (WMSN) is of crucial significance Similar to other traditional networks, in WMSN a noticeable proportion of energy is consumed due to communications. In addition to energy, depending on network's application, many other parameters are also considered. In this paper, a data centric routing protocol which considers end to end delay, reliability, energy consumption, lifetime and fairness have been taken into account. The Proposed protocol which is called MREEP (Multimedia Reliable Energy Efficient routing Protocol) provides sending traffics with different priorities and QoS requirements based on constraint based routing. We study the performance of MREEP using different scenarios. Simulation results show that MREEP has achieved its goals.**

Keywords-component; Data Centric; QoS; Routing Protocol; Wireless Multimedia Sensor Networks

I. INTRODUCTION

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

Protocols which are designed for WSN lose a proportion of their efficiency 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 mentioned below [3]:

- Energy consumption efficiency
- Self configuration
- Capability of sending data with different real time requirements.
- The ability of sending data with different reliabilities

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 is known, all of the aforementioned parameters are not independent; 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. Parameters which are important for MREEP are also important for wireless sensor networks, too. But with respect to the fact that WMSNs are a subset of WSNs, parameters are more commensurate with WMSN.

Depending on their application, the delay parameter has different importance for WMSNs [4]. In real time applications, information should reach destination in an appropriate time otherwise its importance decreases (in hard real time application receiving data out of legal interval is valueless). Another point worth mentioning is that different data types have different delay thresholds; therefore network reaction should be commensurated with data types. Energy consumption, lifetime and fairness are relevant parameters to protocol's energy efficiency. Indeed life time increasing is the essential goal; however two main elements for increasing lifetime is consuming energy efficiently and performing fairness [5]. The aim to perform fairness is consuming energy of network nodes fairly. When network node's energy has less variance, network lifetime will be prolonged. To perform fairness, nodes' energy should be used equally. If one part of a network is used more than other parts, its energy will decrease sooner than others and then the network will be partitioned. If a network is partitioned, its energy consumption increases severely. Using different paths to send data to sink makes the fairness performance better. When network lifetime is prolonged, apparently we can use its services longer [6].

The rest of the paper is organized as follows: in section 2 related works will be discussed. In section 3, the proposed MREEP protocol is presented in detail. In section 4, we will evaluate proposed protocol efficiency and finally in section 5 we conclude the paper.

II. RELATED WORKS

MREEP is a data centric protocol. Data centric protocols are a major part in different routing protocols in wireless sensor networks [7]. Many successful routing protocols are presented for WSNs and WMSNs hitherto. Directed Diffusion [8] and SPIN [9] are two famous routing protocols for WSNs, which have received attention. In both protocols, requests are disseminated in network and routing is done based on data type. Each of the aforementioned protocols is improved many times, as they are known as family; for example [10,11]. SPIN has many flows; for example it is not scalable, it is not energy efficient and etc. Wireless multimedia sensor networks routing protocols are divided in different ways [12]. MREEP makes routes based on network conditions and traffic requirements at the same time. The Proposed protocol has used many of ideas which are pointed to in REEP [13]. REEP protocol has different phases like other data centric protocols. The Mentioned phases are: Sense event propagation, Information event propagation and Request event propagation. In Sense event propagation phase sink sends its requests to all of the network nodes. In Information event propagation phase each node sends its sensed data to the sink. In next phase which is entitled Request event propagation sink responses to all of the nodes which send their sensed data and during this communications routes are established. This plan phasing is almost similar to data centric routing protocols.

III. Proposed Multimedia Energy Efficcient Routing Protocol

In this section we describe the proposed MREEP in detail. MREEP is a data centric protocol which is composed of the following 4 different phases: request dissemination, event occurrence report, route establishment and data forwarding. The proposed protocol structure is shown in Fig.1. In phase 1, MREEP uses the proposed dissemination algorithm called MLAF (Multimedia location aided flooding) [14] which is discussed in section 3.a. Then three other phases, event occurrence report, route establishment and data forwarding, are presented in details in sections 3.b, 3.c and 3.d respectively.

We have designed the proposed protocol based on wireless multimedia sensor networks characteristics. These networks are used for different applications [15]. Using one network for different applications is economical, because different applications are performed using one hardware infrastructure and this leads to a decrease in cost. Proposed protocol can send traffics with different QoS requirements. For more tangible discussion, we will present an example. Assume that WMSN is used to monitor one building [16]. There are two traffics in the mentioned network. When a suspicious is sensed, a high priority report should send to sink through network. But for other events (for example periodical events), network nodes use low priority traffic.

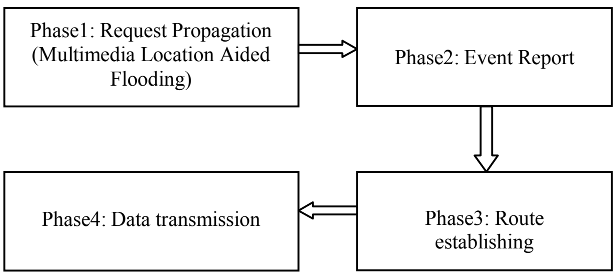

Figure1. Proposed protocol structure

A. Data dissemination phase

Across MREEP phases this phase is done first. In this phase sink sends its desirable requests to the entire network nodes. In other words, sink requests are propagated through entire networks using a data dissemination algorithm. The mentioned data dissemination algorithm is very significant here. In many applications one request should be sent to all nodes (broadcast), but in other applications request will be sent to nodes based on their position (multicast). For example in firing application, ignition threshold should be sent to all of network nodes. But in tracking application, node's task should be sent based on their position (node's task is similar to sink request).

This phase is begun by the sink. All the packets which are used in this phase have the same format. The proposed protocol MREEP uses the MLAF [14] 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 decreases energy consumption and also provides disseminating data with different priorities by considering special methods.

B. Event occurrence report phase

When request dissemination phase is done, the entire network nodes know their task. When a node senses an event relevant to its task, it should report the sensed event features to the sink. Node should necessarily regard all the specifications which are outlined in task characteristics in its report so that the sink can react properly.

In this phase the relevant information to the occurred event will be sent to the sink but sending of the fundamental information relevant to the event will be done in the data sending phase. Furthermore the very phase paves the way for providing packet routing. With this end in mind a packet will be created by a node and the relevant data to the sensed event will be located there. Through sending the packet to the sink the necessary routing tables will be provided for the aim of data routing in the nodes. The final routing will be executed in the route establishment phase. Indeed in the second phase in each node the completion of the final routing will be done by gathering all the essential information in each node in the form of permanent routing table. This act will end in the creation of routing tables for each specific node in the third phase.

When an event is sensed by a node, according to its task it should be reported to the sink. 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 than the sending node to the sink. 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 to be noted that in the application 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 a routing table which is titled 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, the numbers of traversed hops are kept. In the proposed protocol each node owns an ID which is located in all the sent packet. 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 a packet to all its neighbors. This procedure will continue until the packet reaches the sink. We have to bear in mind having more than one record is more likely from one certain source node in the second phase table. This is due to the different routes which a node can be reached by the second phase packet but the packets which have the same field will be ignored.

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 event sensor source node.

In the figure 2 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 packet) are illustrated.

```
<a>
/* Phase 2 pseudo code 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 node's 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 node's neighbors;
```

Figure 2. Pseudo code for event occurrence report phase

C. *Route establishment phase*

After the sink received all the second phase packets, it sends back and acknowledge packet (this packet is called the third packet phase) to the source node announcing to send all its gathered data to the sink. It is possible for an event to be sensed by more than a 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. For instance, in the applications of firing, the received temperature's degree specifies the sensing accuracy (if a node is closer to fire source it should sense higher temperature than other nodes). According to it a sensor can be chosen for reporting the location situations. After choosing the source node, the third phase packet will be sent to its destination.

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 made the sent data routing possible from the source node. The sending acknowledgement depends on the sensed event priority. Two different acknowledgements are considered, acknowledgement for high priority (real time traffic) and acknowledgement for low priority (non real time traffic).

The sink evaluates the second phase routing table for sending the acknowledgement with high priority. The first record will be chosen for the sending acknowledgement. The second phase packets will be located in the second phase routing table according to the time. Whenever a node receives the second type packet, it will locate it in the first available record. In fact the order of records´ numbers in the second phase routing table specifies the order of the time which they were received. Due to the great importance of time for real time applications the first record of the second phase table will be chosen. It is worth mentioning that the first record was first created in terms of time. But records selection in the source node is always of great importance. The only records will be considered that their source node is the very node which is chosen by the sink.

Every node constitutes two tables in the second phase. Routing table in phase three with high priority and routing table in phase three with low priority. During this phase, these two tables are completed. When a node in phase three receives a package with high priority, a record for that in the routing table of phase 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 what was mentioned, every node chooses the first record from the routing table in phase two as the next hop for the package in phase three with high priority. This process continues until the package arrives at its source. In fact, at the end of the third phase in the third phase non real time routing table, for every source one record is placed.

Concepts which were mentioned in current section concerned traffic with a high priority. In the rest of the section finding low priority table in phase 3 will be elucidated. The sink considers the records relating to the source, among the routing records of phase two. For each of the records the probability of P_i is calculated through the equation (1):

$$\frac{TD}{HC} = P_i \qquad (1)$$

TD is the field which includes the length of the record path and HC is the number of the path hops of the record. P_i is the probability of record selection as the next hop, for the third phase packet with low priority. After determining P_i for each record with the specified source node, two records will be chosen randomly (according to the probability) then the third phase packet with low priority will be sent for them. Selecting different ways is 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 mechanism which is used in REEP protocol. This prevents the fairness from being achieved in energy consumption of network nodes.

Each node registers the node in the routing table with low priority and in the next stage by the use of the same procedure with the sink the next two hops will be chosen and the third phase packet will be sent to them. In the record of non real time third phase table all the packet characteristics will be registered.

Figure 3 shows Pseudo code for event occurrence report phase.

```
/* sink receives packet type 2 */
Sink determines packet information type;
If ( packet information is high priority )
                Then do high priority module;
                Else do low priority module;

<a>
/* high priority module */
Find packet source;
Look up proposed routing table for determined source;
Select first relevant row;
Add a record for selected source in RT-routing-table;
Send packet type 3 to node which is declared in selected row;

<b>
/* low priority module */
Find packet source;
Look up proposed routing table for determined source;
/* for each record, variable X is calculated as (path length/hop count) */
Select two records with highest value X;
Add a record for source, based on each selected record in NRT-routing-table;
Send packet type 3 to nodes which are declared in two selected records;
```

Figure 3. Pseudo code for route establishment phase

D. The data forwarding phase

At the end of the third phase the real time and non real time routing table will be created. Each node owns a real time and non real time third phase routing table.

The source node (the event sensor node) depending on the type of event sensed can send its data to the sink once it has received real time acknowledgement (the real time third phase packet) and non real time acknowledgement (the non real time acknowledgement). As 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 data.

For every source in the third phase real time routing table in the direction of the sink, there is only one record. Every node by receiving the real time traffic from the specified node sends the data to the next hop using that record. However, in the non real time routing table of phase three for every source there will be more than one record in the table. Every record has one P_j, the choice of the next hop depends on the P_j. The larger the P_j of a 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.

IV. PERFORMANCE EVALUATION OF MREEP

The protocol REEP is a known protocol in the area of wireless sensor networks. Both the protocols MREEP and REEP have been implemented in the Opnet [17] simulator and their effectiveness depending on various scenarios were investigated. Firstly we will examine two protocols in terms of the effectiveness of energy. In figure 4 the lifetime of the network for different rates has been drawn. The rates of the vertical axis relate to the production rate by the source node. In other words, in the fourth phase the sending rate of data is taken to be different and for every rate the lifetime of the network has been calculated.

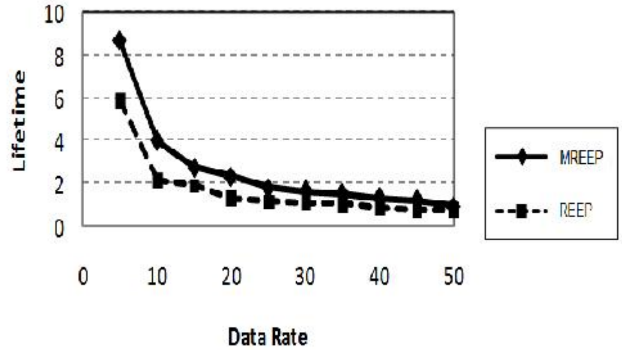

Figure 4. Lifetime comparison between MREEP and REEP

As can been seen in figure 4, for the rates under 50(packet/sec) the difference between the lifetimes of the networks is noteworthy. For example the life time of the network using MREEP equals 8.8 time unit, while using REEP equals 5.9 time unit. This means prolonging the lifetime of the network by 49 percent. However, in the high rates there is not a remarkable difference between the performance of the two protocols. Figure 4 has been drawn for a network of 20 nodes and figure 5 for a network of 50 nodes.

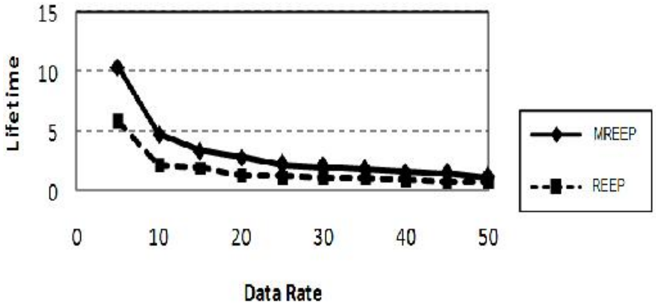

Figure 5. Lifetime comparison between MREEP and REEP for 50 nodes network

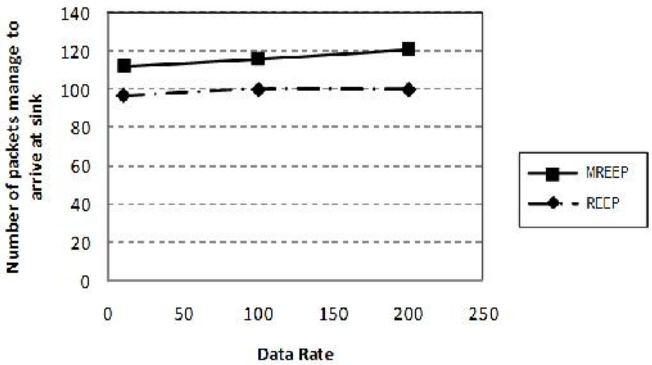

Figure 6. Number of packets manages to arrive at sink

As is demonstrated in figure 6, the number of packets received at sink for the protocol MREEP exceeds that of REEP. Examining the two graphs in figures 5 and 6, it is easily understandable that MREEP is more energy efficient than REEP despite it has sent higher number of packet.

The better performance of MREEP is reasonable for two reasons. First, on the basis of the selection of various routes, less congestion has occurred in the middle routes and in the simulation period a larger number of packets arrive at their destination (packets that arrive at the destination consumes more energy than a packet which has not arrived at the destination) The second is the longer lifetime of the network. The lifetime of the network begins from when the simulation starts to the first node loses its energy completely. The longer lifetime of the network causes more packets to have the opportunity to transfer to their destination.

In figure 7, fairness in the consumption of energy of the network nodes is examined.

The vertical axis is the sending rate of data and the horizontal axis is the parameter which calculates the variance of the energy of network nodes through equation (2).

$$Dev = \sum_{i=1}^{n} \left(Energy_i - Ave\right)^2 \quad (2)$$

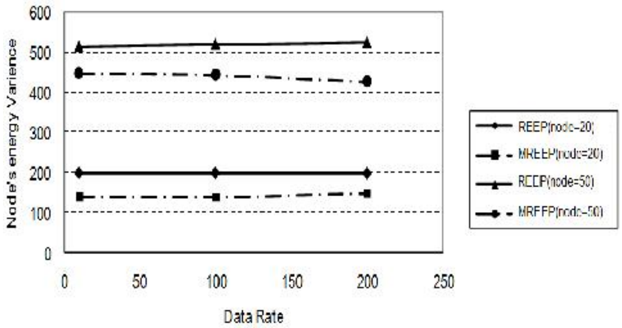

Figure 7. Comparison fairness between MREEP and REEP

The higher the amount of the Dev for a protocol, the less success the protocol has achieved success in maintaining balance in the energy consumption of nodes since the variance of energy nodes has increased. As can be seen in figure 7 in both two scenarios, the MREEP has a lower variance. Where the number of nodes is 20 the variance of MREEP shows a 30 percent decrement in variance. The parameters of network lifetime and variance are in some way dependent. If we can keep better balance in the energy consumption of nodes the lifetime of the network increases under the same conditions.

Another fundamental parameter which is considered in this protocol is the end to end delay. Delay is a parameter which is crucially important for the wireless multimedia sensor networks. In figure 8, MREEP and REEP are compared in terms of delay. The delay presented in figure 8 and the other figures concerning this section are related to the sensed data delay and do not include control data. As can be seen in the figure 8, the end to end delay for real time traffic in MREEP (MREEP_RT) is much less than the end to end delay for non real time traffic (MREEP_NRT) and REEP.

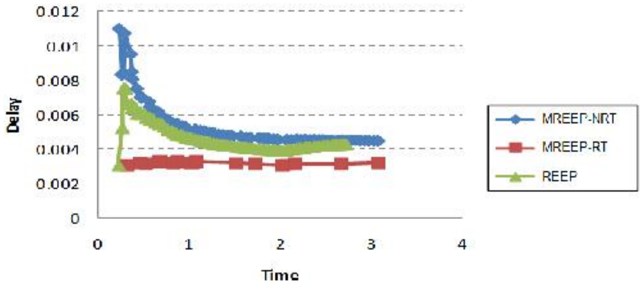

Figure 8. Delay comparison between MREEP and REEP

The reaction of protocols in the beginning of the graphs shows the marked increase of delay for REEP and MREEP-NRT. This event occurs because of congestion in routers for the purpose of sending the remaining packets of phase two. When all the packets of phase 2 sent, the delay approaches stability. In a stable condition the delay of REEP and MREEP-NRT are seen to be very close. And the delay of MREEP-RT is significantly lower 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. The goal of the protocol is to send the real time traffic with as low delay as possible and to send the non real time traffic with an acceptable level of delay. Given the performance of REEP in figures 8-10 the proposed protocol has achieved its goal. The vertical axis relates to time and the horizontal axis to the end to end delay.

In figure 8 the graph of delay for a network with 20 nodes and the sending rate of 10 is drawn. In figure 9 the delay graph for a network with 20 nodes and the sending rate of 200 is drawn.

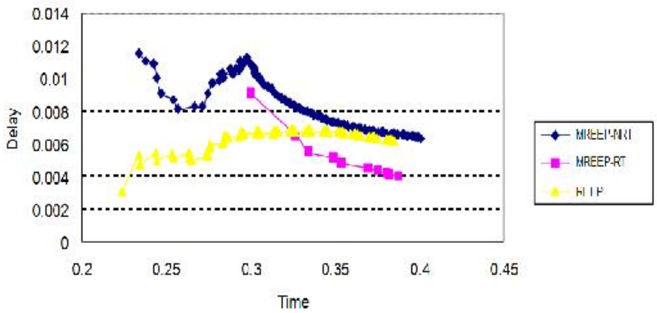

Figure 9. Delay comparison between MREEP and REEP for sending rate=200

In figure 9 the initial time of the simulation is presented. Initially, the delay for MREEP-RT and MREEP-NRT is more than REEP. As discussed before it is due to the presence of phase two packets. The number of phase two packets in the proposed protocol exceeds that of phase 2 REEP, hence their presence increases the delay in initial moments for MREEP. But with the time lengthened and the stabilization of the conditions, the delay of MREEP-RT and MREEP-NRT decreases and becomes similar to the graph in figure 8 so that ultimately the delay of MREEP-RT becomes less than MREEP-NRT and REEP and the amounts of MREEP_NRT and REEP obtain similar amounts.

The figure 8 presents the average delay; in figure 10 the delay based on every single packet is shown. Figure 10 clears the variance of delay.

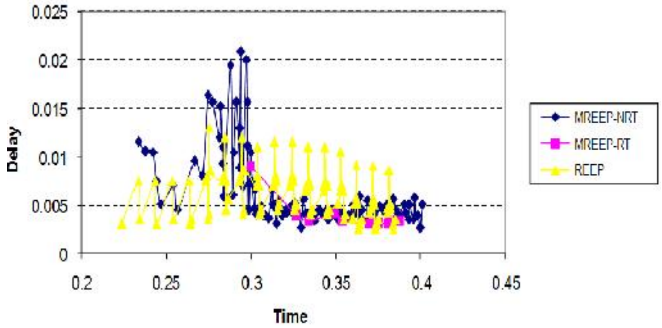

Figure 10. Wee delay for MREEP and REEP

In figure 11 the end to end delay graph for a network with 50 nodes while sending data with rate of 100 packets per time unit is illustrated.

What is observed in figure 11 resembles greatly what we have in figures 8 and 9. In fact, the objective of the inclusion of figure 11 is to demonstrate that protocol MREEP performs well in various scenarios. However, it is worth mentioning that the end to end delay is similar to figure 10; in other figures including figure 11 the initial time of simulation is presented. As a matter of fact, with the continuation of time in figure 11, a graph resembling that of figure 8 emerge.

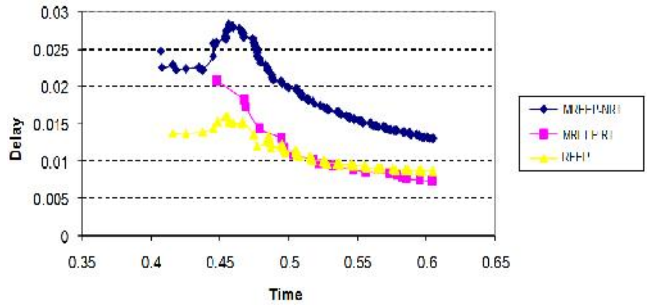

Figure 11. Delay graph for a network of 50 nodes

V. CONCLUSION

In this article a QoS aware routing protocol for the wireless multimedia sensor networks was presented. The proposed protocol was data-driven and comprised several various phases. The first phase of MREEP was designed to disseminate the demands of the sink. To execute this phase a new data dissemination algorithm named MLAF [14] was used. The other phases of MREEP are respectively event occurrence report, the route establishment and data forwarding. Generally, the proposed protocols have taken into account several parameters including the parameters of end to end delay, reliability, energy consumption, the lifetime of the network and fairness in energy consumption. Finally, utilizing simulation, the effectiveness of algorithm of data dissemination and MREEP protocol were evaluated. The results of the simulation show that MREEP conscious of the proposed service quality have achieved its goals, which were to control the aforementioned parameters.

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