QoS Routing Method for Wireless Multimedia Sensor Networks

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***Abstract*— The advent of wireless multimedia sensor networks has opened a new perspective on existing wireless sensor networks by upgrading its existing capabilities (due to the integration of visual sensor and high-computing engines) and applications such as intelligent transportation systems, wireless multimedia sensors networks (WMSN), and so on. However, there are many challenges in these networks that require attention and finding an appropriate approach to address them. Transferring multimedia data while considering the parameters of service quality and the issue of resource limitation can be mentioned as one of the most important of these challenges. Therefore, routing in wireless multimedia sensor networks has long been considered as one of the most important and crucial problems, and the network optimal performance is not possible without a proper routing approach. In this paper, a novel approach is proposed for routing in wireless multimedia sensor networks using intelligent capabilities and using meta-exploration algorithms in such a way to improve the overall network performance. The goal is to optimize some service quality parameters, such as energy consumption, network lifetime and energy consumption balancing. We have achieved all these three goals. Especially in order to reach our third goal, we have defined a new criterion called the ratio of the instability period and shown that the duration of the instability period is short in the proposed method. In fact, the nodes have balanced energy consumption in the proposed method and they die almost together..**

***Index Terms*— Wireless Sensor Network (WSN), Wireless Multimedia Sensor Network (WMSN), Clustering of nodes, Particle Swarm Algorithm (PSO).**

[1] INTRODUCTION

Advances in CMOS technology for creating low-power chips made it possible to build single-chip cameras that can easily be embedded in cheap transmitters/receivers. Before that, microphones have been necessary components of wireless sensor nodes for a long time. The affordable connection among multimedia resources and communication tools has strengthened performing researches into multimedia sensor networking, which is considered a particular type of wireless sensor networks. As a result, wireless multimedia sensor networks (WMSNs) have been widely researched in a variety of fields such as digital signal processing, communications, networking, control and statistics during the recent years [1]. The collection of experiences gained from each of these fields has facilitated the creation and development of WMSNs that can provide the ability to restore audio, video (or animated images) and still images and Transfer them in real time[2][3].

Since the volume of multimedia data is much greater than numerical data (including temperature, pressure, etc.), transmitting these data requires more bandwidth, lower latency, higher throughput, continuous transmission and other quality service parameters in order to ensure that the data reaches its destination accurately and with high reliability[4]. Therefore, the proper routing for transferring these data is one of the most important and challenging issues in wireless multimedia sensor networks. An effective and efficient routing is a method that can optimize service quality as much as possible. On the other hand, it should be able to reduce the most important concern for the durability and survival of all types of sensor networks, namely energy consumption, thus increasing the network lifetime [5].

In the proposed method, we initially consider the nodes to be heterogeneous, and three node types with different battery charging capabilities are placed in the network such that the energy consumption of the nodes is balanced. Also, in order to balance energy consumption, we divide the network into nine regions, the size of them is determined according to their distance from the sink, such that the farther region from the sink would be larger. In order to reduce route overhead, a new idea is considered in the proposed method that the routing process is performed only between cluster heads. A simple PSO model is used in order to increase the speed of the routing process.

The remainder of this paper is organized as follows: The first section introduces and reviews the routing methods in WMSN networks as well as the works done so far in this field. The second section provides a categorization of energy-effective routing algorithms for WMSN. Then in the third section, we introduce the proposed method. In the fourth section, the implementation, evaluation and comparison of the proposed method are addressed. The fifth section contains the conclusion.

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[2] TYPES OF ENERGY-EFFECTIVE ROUTING ALGORITHMS FOR WMSN

Since many years, a lot of research has been done to create an appropriate solution for routing these networks, and different methods and techniques have been proposed based on ensuring service quality, high bandwidth, energy consumption reduction, and so on. In the following we consider some them. Figure 1 illustrates a comprehensive categorization of energy-effective routing algorithms for WMSN.

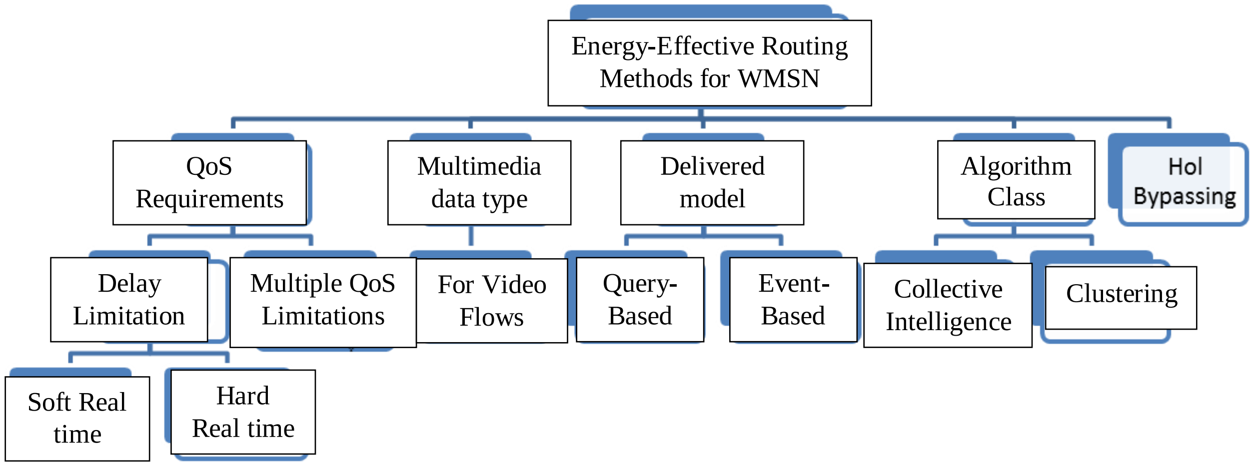

Fig1. Categorization of energy-effective routing algorithms for WMSN.

[3] *Methods based on Evolutionary Processing*

In [6], a QoS routing algorithm has been proposed based on ant colony optimization that can satisfy parameters such as bandwidth, latency and packet loss in WMSN and increase network lifetime. This method involves two stages; route detection and route confirmation, thus introducing two types of ants. The evaluation function is introduced in a way that all service quality parameters are taken into account. However, the network traffic and data produced by nodes are considered constant, which is far from reality.

[4] *Methods based on Clustering*

path multi constraint routing protocol (AMPMCR) in multimedia sensor networks has been proposed [7]. This protocol focuses on multi-path routing for supporting service quality. The proposed protocol is based on clustering and minimizes the loss rate, energy consumption, and latency between clusters using the criterion of communication quality. The cost function between connections is calculated using the proposed parameters. This protocol uses path tables in the sensor nodes. The sink informs the whole network by a request until the sensor causes the requested data to be obtained. Sensor nodes are classified based on their role in routing process to be active or passive.

The node that does not play a routing role becomes passive and turns into idle or even sleep state in order to save energy for increasing the network lifetime. Each sensor is able to create, maintain and update a path table that records different paths to the sink. Simulation results prove that the proposed protocol is better than single-path routing for energy efficiency, latency and packet delivery rate.

[5] *Methods based on Service Quality*

In [8], a new strategy based on collaborative service quality routing in WMSN has been proposed in order to optimize and improve network bandwidth efficiency for real-time flow, which is referred to as CQR algorithm. It seems that the cooperation between different flows in routing and bandwidth reservation is beneficial for the overall resource efficiency of the network, and this is the main subject in the CQR strategy. The idea of CQR leads to a common optimization of path selection of multiple flows. Therefore, this strategy is used to achieve higher acceptance rates for real-time flows and delivery at a lower cost. The core of CQR is how to describe the competition and connection contribution between different flows. The energy consumption in this method is relatively high and the energy consumption of the nodes is unbalanced.

[6] RESEARCH

[7] *Methodology*

In this paper, a routing method is proposed to increase and improve lifetime nodes and thus increasing the lifetime of sensor networks. A new solution is introduced to achieve this goal. The work that energy consumption can be uniformly distributed between sensor nodes. Also, a heterogeneous distribution method for nodes is introduced for this purpose. In the second stage, a clustering method is introduced for data aggregation. In the third stage, a hierarchical tree is proposed by the PSO algorithm for sending multiple-steps data from the aggregation nodes to the base station.

[8] *The Heterogeneous Distribution of Nodes*

There are two methods, homogeneous and heterogeneous, for distributing nodes on the network area. In the homogeneous method, the initial energies and the structure of all nodes are equal, but in the heterogeneous method, the initial energies of the nodes are not equal. For this purpose, three types of nodes are considered with different initial energies. According to the distance from

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the base station (BS), three regions are considered, where the nodes with the lowest energy are placed in the closest region, the nodes with medium energy are placed in the middle region and the nodes with the highest energy are placed in the farthest region. Since farther nodes consume more energy to send data, the energy consumption of the nodes becomes more balanced and causes the nodes to die almost simultaneously.

[9] Network Partitioning

In addition to the heterogeneous distribution of nodes, another way is proposed also to reduce energy consumption of nodes. The network environment is divided through two stages into different parts called grids, each of which has a different number of nodes and a different distance from the base station. The farther grid from the BS has more nodes too, which makes it possible for these grids to have more nodes participating in the head clustering, thus making the energy consumption more uniform. In each round, the cluster heads are selected again to prevent more loads to be on just a few specific nodes. Initially, the network is divided into similar sized rectangles, called swimlanes, and for each region an id is assigned. Then each swimlane is divided into smaller rectangles. The farther regions from the BS are considered to be larger and the clusters of these regions have more nodes. Assuming that the BS is above the square of the network area, we divide the region along the x-axis to S regions. The array A is defined to contain S elements, in which the k-th element specifies the number of grids in k-th swimlane. Each grid is represented by a pair (i, j), where i specifies the swimlane number and j specifies the grid number. Also, S arrays are defined to determine the lengths of the grid, where the v-th array defines Hv the length of the v-th swimlane grids, and the w-th element of Hv, hvw, specifies the length of the grid (v, w). Figure 2 shows how the partitioning is organized. The vertical lines identify the swimlanes and the dotted horizontal lines determine the grids.

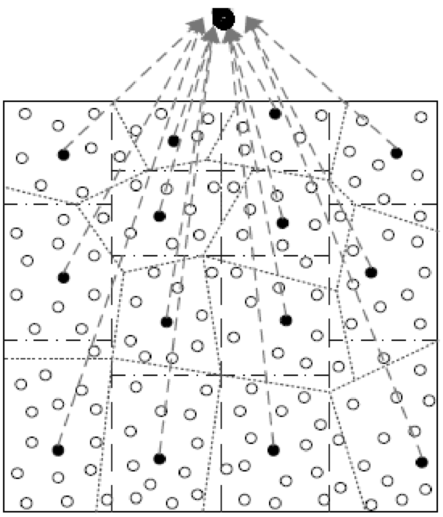

Fig 2. Organize portions

The purpose of network partitioning is that farther nodes from the BS have less work load. The energy consumption is directly related to the distance between the two nodes, and farther cluster heads from the BS consume far more energy. Partitioning the network in the above form makes the nearer clusters to the BS smaller and the farther clusters larger. Because clustering and determining cluster heads are done in each cycle, it is possible that a different node becomes a cluster head in each stage.

[10] Determining Cluster Heads

At each stage of the implementation of the proposed method, a cluster head is selected for each grid. From the nodes of a grid, the node that has the most remaining energy is selected as the cluster head. In the first stage where the initial energies of all nodes are equal, the node selected as a cluster head is the closest node to the BS with a sum of distances to the other nodes in the same cluster less than that of the other nodes. In the next stages, if several nodes have the same energy, then the closest one to the BS is selected as the cluster header. In the first stage, the cluster head is selected by the collaboration of all nodes in a grid. Initially, each node sends a message containing NODE_MSG (k, (v, w), Er, (x, y)) to the other nodes in the grid, where k is the id of the node, (v, w) is the grid number, Er is the remaining energy of the node and (x, y) is the node location. Through this message, each node can receive the information of the other nodes in a grid, and thus the node with the most remaining energy is selected as the cluster head.

In each subsequent stage after the first one, the cluster head is selected by the cluster head of the previous stage. In this way, all the nodes send their information to the cluster head of the previous stage in order to select the new cluster header. The cluster head of the previous stage sorts all the nodes according to the amount of remaining energy and selects the new cluster head based on this amount. To inform the other nodes of the new cluster header, the cluster head of the previous stage sends a message containing the id of the selected cluster head to all the nodes in that grid.

[11] Clustering

After selecting the cluster heads, given that there are 14 different grids in the network, there will be 14 cluster heads and 14 clusters. But this does not mean that all the nodes of a grid belong to the same cluster. For each node in each grid, the distance to each cluster head is calculated, and finally, the node will belong to the cluster that the head of which is the closest to it

[12] Routing between Cluster Heads using the PSO Algorithm

In the proposed method, the PSO algorithm is used to create a hierarchical tree. The main issue in using PSO is the proper modeling of the system in such a way that PSO can be implemented on that model. The main purpose of the proposed method is to find an appropriate hierarchical path such that it has the lowest energy consumption. To create a suitable particle model, we consider a path as a particle. A particle can be defined as $X_i = (x_{i1}, x_{i2}, ..., x_{in})$. For example, a particle X_i(0,0,0,1,2,3,1,0,0,0,0,0,0,0) may be selected as a path, which specifies that the best choice for nodes "4, 5, 6", and "7" in the next step is to send for the nodes" 1, 2, 3", and "1".

[13] The Fitness function

At each stage of implementing the PSO algorithm, the proximity to the final solution should be measured by a suitable criterion for each particle. To select the optimal path in the hierarchical clustering, the two criteria that are most considered are: 1. the amount of remaining energy for a node, 2. the distance of the node to the BS. These two criteria are used to select the appropriate fitness function.

In simple PSO, the inertia coefficient (w) plays an important role in the convergence of the results. A larger value of w can prevent falling in the best local choice, and a smaller value of w will result in faster convergence. Therefore, by increasing the number of repetitions, w should decrease. In old methods [9], equation (1) is used to determine the value of w. In this study, an exponential method is used to determine the value of w to achieve better efficiency. Equations (1) and (2) show how w is calculated.

$$f_{iteration} = \frac{P_{id}}{P_{gd}} \tag{1}$$

$$w = w_{max} - (w_{max} - w_{min}) \times \exp\left(-\frac{f_{iteration}}{iteration}\right) \tag{2}$$

Where, P_{id} is the best choice for the i-th particle until now, and P_{gd} is the best choice for all particles until now. According to the definition of the fitness function in wireless sensor networks, P_{id} is greater than P_{gd}. Therefore, by increasing the number of repetitions, w decreases. Also, this improves the efficiency of the algorithm and achieves better convergence, since both the best local and global choices are effective.

In every round, the value of fi is calculated for all particles using equation (3), where Emax is the initial energy of the nodes, dmin is the minimum distance from cluster heads to the BS, d (i, s) is the distance from the i-th cluster head to the BS, Eri is the amount of remaining energy of the i-th cluster head in the r-th round, and n is the number of cluster heads. According to equation (3), the nodes with high remaining energy and less distance to the BS will have a greater value of fi.

$$f_i = \sum_{i=1}^{n} \frac{E_{ri}}{E_{max}} + \frac{d_{min}}{d_{(i,s)}} \tag{3}$$

In the next stage, the cluster heads are sorted according to the weight fi from down to up. The main goal at this stage is to find the parent nodes for each cluster head. It is likely that cluster heads with less fi are the main candidates to be leaf nodes in the tree structure. For this reason, we start with the cluster head having the least fi, and we select the parent cluster head for each cluster head. A node is chosen as the parent node when it has greater fi value and it is closer to the BS than its child node. Once the parent node is chosen for each cluster head, a tree structure is created. To send data from each node, nodes send data to the cluster head first. And each cluster head sends the data to its parent node to be sent hierarchically to the BS. In the proposed method, we try to reduce the number of steps to the BS. Because if the number of steps increases, there will be a delay in each step, and this delay will be large overall, which may cause the data not to be ready in one stage and not to reach the destination thus making it postponed to the next round. Finally, the number of packets sent to the BS will be reduced.

[14] FINDINGS, COMPARISON AND EVALUATION

In this section, the proposed network model and the energy consumption model are introduced and the simulation steps are presented. Then, we compare the performed simulation with other methods and present the comparison results with different criteria. The results show that the proposed method has better performance than other methods.

[15] Network Model

To simulate the algorithm, we consider an area of 200 by 200 meters in which 400 nodes are randomly located. We represent the lower right vertex by (O_x, O_y) and the upper right vertex by (OW_x, OW_y). We consider the following assumptions for the network.

[16] BS and other nodes are stationary after being deployed and BS is located outside the nodes' area.

[17] The nodes and their distances are considered to be symmetric.

[18] BS and other nodes are aware of each other's location

[19] Energy Consumption Model

In this model, a value d0 is chosen as a threshold, and the energy needed to transmit an l-bit message to distance d is calculated using equation (4) according to whether the distance between the transmitter and the receiver nodes is less or greater than d0.

$$E_{Tx}(l,d) = \begin{cases} l \times E_{elec} + l \times \varepsilon_{fs} \times d^2 & if\ d < d_0 \\ l \times E_{elec} + l \times \varepsilon_{mp} \times d^4 & if\ d \geq d_0 \end{cases} \tag{4}$$

The value of d0 is calculated from equation (5).

$$d_0 = sqrt\left(\frac{E_{fs}}{E_{mp}}\right) \tag{5}$$

In equation (4), Eelec is the amount of energy required to run the transmitter or receiver circuitry, εfs and εmp are the amount of energy needed to run the transfer through the amplifier, and the amount of energy needed to receive the message is obtained by equation (6).

$$E_{Rx}(l) = l \times E_{elec} \tag{6}$$

The amount of energy needed to aggregate m messages with l bits is obtained from equation (7).

$$E_A(m,l) = m \times l \times E_{DA} \tag{7}$$

[20] Simulation Results

The efficiency of the proposed routing method is evaluated against the parameters of the average number of path steps, end-to-end delay, and network lifetime and instability period.

The Average Number of Path Steps

The average number of steps in the proposed method is compared with that of TPGF method [10], NI method [11] and GEAM method [12]. The mean number of steps in the proposed method is higher than that of TPGF and NI methods, but less than that of GEAM method. The reason for the number of steps to be less in both TPGF and NI methods is that they use almost-stationary routing methods and have not performed the clustering process. However, as is shown, the low number of steps cannot be by itself the

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strength point of a method. Chart 1 shows the comparison of the number of path steps.

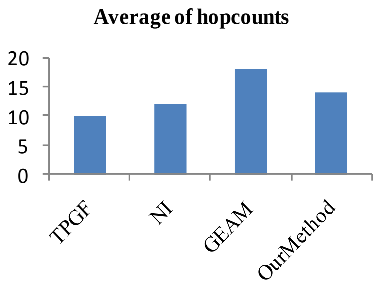

Chart 1. Comparison of the average number of path steps.

End-to-End Delay

The average delay of the proposed method may not be less than that of all other methods when the speed is less than 300 kbps. In the TPGF method, two selected paths are considered for each source and destination such that the one with less traffic is chosen at each stage. This works very well for speeds less than 300 kbps, but its delay is high at high speeds. The NI method lets the packets pass through two different routes that have less traffic. For this reason, its delay is low at low speeds. However, its delay will increase for speeds greater than 300 kbps. The GEAM method also uses several different paths. Its delay is less than that of TPGF but more than that of NI. The delay of the proposed method is moderate for low speeds, but it is less than that of other methods for speeds more than 300 kbps. Figure 3 compares our method with the abovementioned methods.

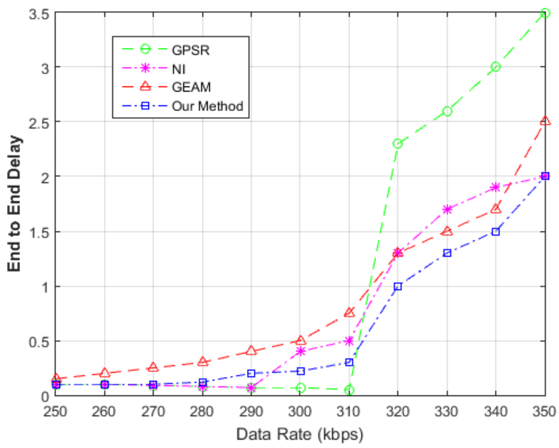

Fig 3. Comparison of end-to-end delay.

Network Lifetime

In the proposed method, all nodes die after 52 stages, but they die after 38 stages in the GPSR method, after 44 stages in the NI method, and after 46 stages in the GEAM method. Figure 4 compares our method with the three mentioned methods.

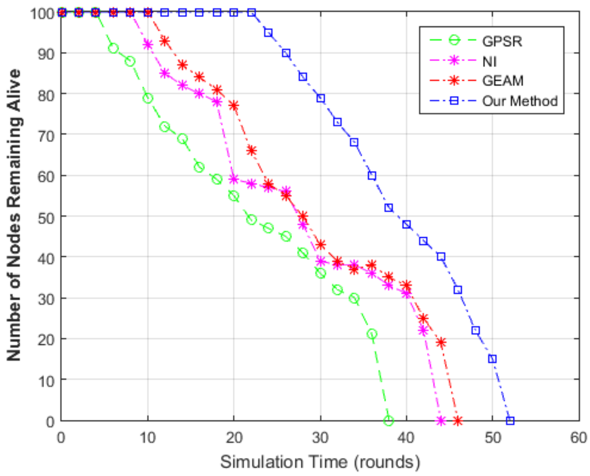

Fig 4. Comparison of network lifetime.

The Ratio of Instability Period

In this research we introduce a new evaluation criterion, which is used for the first time in evaluating wireless multimedia sensor networks. In the calculation of network lifetimes, the last stage is usually considered when all nodes have drained their energy. This problem gets clearer by an example. Suppose that in an entirely identical evaluation, in one method, the last node dies in the 50th stage and the first node dies in the 10th stage. But in another method, the last node dies in the 45th stage and the first node dies in the 35th stage. By only considering the network lifetime, one might argue from the first glance that the first method has worked better, but this argument is not fair, since the second method has worked for longer time with more nodes. This time period is calculated from equation (8), in which **Error! Reference source not found.** is the number of the stage in which the first node has drained its energy and **Error! Reference source not found.** is the number of the stage in which the last node in the network has drained its energy. The lower this amount is, the more efficient the method is. Table 1 compares our method with the other methods.

$$rate = \frac{\#TotalNodesDead - \#FirstNodeDead}{\#TotalNodesDead} \quad (8)$$

Table I. Comparison of the ratio of instability period.

The method	The ratio of instability period
GPSR	89%
NI	80%
GEAM	80%
The proposed method	57%

[2] Conclusion

Network lifetime is one of the most important criteria for evaluating a routing method in wireless multimedia sensor networks. Network lifetime is directly related to the correct management of node energy consumption. Of course, if the selected paths have the least amount of distance, the energy consumption of the nodes will overall decrease. According to the results of this experiment, it was determined that the proposed method has lower and more balanced energy consumption and has a longer overall network lifetime. Due to the fact that under certain conditions, network lifetime cannot be a fair criterion for comparing two methods, therefore, this research has introduced a new evaluation criterion, which is used for the first time in the evaluation of multimedia wireless sensor networks. In network lifetime calculation, usually the last stage is considered only when all nodes have drained their energy.

Several standard parameters were considered for evaluating the proposed method, and this method was compared with some other algorithms based on these parameters. One of the evaluation parameters is the end-to-end delay. It was shown in this experiment that the delay time is negligible when the transmission speed is less than the bandwidth limit. However, by increasing the speed upper than some threshold, the time delay increased sharply. It was shown that the time delay of the proposed method is moderate at low speeds, and it is less than that of the other methods at high speeds.

As simulation results showed, the ratio of instability period in the proposed method is much lower than that of the other methods, which indicates that the proposed method is more stable or, in other words, provides longer activity duration with the maximum number of nodes. The reason for this superiority is the fair distribution of load on the nodes. When the network structure was partitioned in the proposed method into a number of unequal regions, the goal was to make the nodes consume energy in a balanced manner and to drain their energy at approximately the same time. According to these results, we can say that we have achieved the desired result.

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