

# An Energy-Efficient QoS-aware Routing Algorithm for Wireless Multimedia Sensor Networks

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## Abstract

*Sensor nodes in WMSNs should be able to collect various forms of sensing data, prioritize each form of data based on the application service request conditions, and provide a certain degree of Quality of Service (QoS) guarantee. In order for sensor nodes to provide QoS, they must maintain routing information based on delay, reliability, and energy efficiency. Existing routing algorithms transmit many routing control messages to reflect dynamic network conditions. In this paper, we propose a routing protocol that can provide QoS that appropriately reflects changes in network status regarding reliability and delay, even in circumstances with a deficiency in sensor node resources. Our algorithm has the advantage of minimizing the routing control messages and therefore can safely operate from an energy-efficient perspective, as the algorithm utilizes broadcast messages regularly transmitted by the sink node. We observe that the sensor node establishes a routing table based on the shortest route towards a sink, the energy efficiency of the foothold, and the least amount of congestion*

**Keywords:** *Wireless multimedia sensor network, QoS-aware Routing protocols, Periodic Broadcast message, Energy efficiency*

## 1. Introduction

Recently, many researches have been conducted on WMSN (Wireless Multimedia Sensor Networks) based on WSN which delivers multimedia information [1, 2, 3]. WMSNs are networks of wireless embedded devices that allow retrieving video and audio streams, still images, and scalar sensor data from the physical environment. In addition to the ability to retrieve multimedia data, WMSNs will also be able to store, process in real-time, correlate, and fuse multimedia data originating from heterogeneous sources. Wireless multimedia sensor networks have the potential to enable new applications such as traffic monitoring, border surveillance, smart homes, and environment and habitat monitoring. The various applications of WMSNs are formed into various network traffic patterns. Quality of service (QoS) characteristics such as delay, error rate, and throughput necessary for these data patterns become different. Thus, sensor nodes should be able to collect various forms of sensing data, prioritize each form of data based on the application service request conditions, and provide a certain degree of QoS guarantee [4, 5]. In order for each sensor node to provide QoS, it must maintain routing information based on delay, reliability, and energy efficiency. Thus, a routing protocol that can reflect QoS information will be necessary. In order to efficiently manage the frequently changing network, dynamic routing protocols are used. However, these dynamic routing protocols are not suitable because of the limited resources of

a sensor node. In order to quickly reflect the network status, many control messages are transmitted. This leads to additional energy consumption by sensor nodes and ultimately becomes the primary reason for shortening the life span of the overall network [6, 7, 8, 9].

In this paper, we propose a new routing protocol that provides QoS related to delay, reliability, and energy efficiency. This protocol has an advantage in that it minimizes the routing control messages and therefore can safely operate from an energy-efficient perspective, as the algorithm utilizes the broadcast messages transmitted regularly by the sink node.

## 2. Analysis of the WMSN Traffic Characteristics

Periodically paused switched Ethernet (PPSE) was previously proposed to enhance energy efficiency in small-sized Ethernet switch[7]. The original wireless sensor networks (WSNs) collect environmental data of the scalar form measuring temperature, humidity, and location, and provide a simple monitoring service. Recently, increasing the demands for multimedia sensing data make the following conceptual and functional changes necessary in WMSNs.

- Request for integrated provision of various application services through a WSN.
- Request for video sensor networks for wireless surveillance systems [3]
- Due to expansion in WSN service areas, a need for WMSNs that can sense and transmit various multimedia information factors, such as a small amount of scalar information and high-definition images, sound capture information, low-resolution video data, or high-resolution large-size video information.
- Apart from simple surveillance functions of the sensor environment, a need for wireless sensors and actor networks, which include an actuator that can intellectually control the objects inside the sensor field.

The future is expected to include multimedia data-sensing functions such as sound, video, and multimodality characteristics. The traffic characteristics of WMSNs are as follows. First, the data captured from WMSNs consists of low-speed small-size scalar data, large-size scalar data, images, sound capture information, and video information at various resolution levels. As shown in Table 1, WMSNs data will be in various patterns such as periodic data reporting, continuous information monitoring, event-driven data, query-based data, and critical command for sensor control. QoS characteristics such as delay, error rate, and throughput requested by these data patterns are different [2, 5].

**Table 1. Classification of traffic characteristics of WMSNs application services**

| Application service perspective          | Data flow perspective                             |
|--|---|
| - Periodic reporting data                | - Real time, loss-tolerant multimedia stream      |
| - Continuous information monitoring data | - Delay-tolerant, loss-tolerant multimedia stream |
| - Event-driven data                      | - Real time, loss-tolerant data                   |
| - Query-based data                       | - Real time, loss-intolerant data                 |
| - Control command data                   | - Delay-tolerant, loss-intolerant data            |

Second, the traffic from sensor nodes to the sink node is many-to-one communication. Third, the data delivered from the sink node to the sensor nodes have a quarry purpose, program patch, or control information transmission purpose in a broadcast, multicast, or

geocast form, and the data transmission cycle and interval changes depending on the application service. Accordingly, the routing table in the sensor node does not need to have information on the overall node.

### 3. An Energy and QoS-aware Routing Algorithm for WMSN

In WMSNs, there are huge numbers of concentrated nodes and the network status changes frequently. Thus, a routing protocol that can respond appropriately to these dynamic changes is needed. Furthermore, restricted resources of sensor nodes and energy consumption are considered for increasing network lifetime.

**Table 2. The structure of broadcasting message**

| Specific Field       | Significance  |
|----------------------|---|
| ID                   | Broadcasting message identifier   |
| Flag                 | Identifier which distinguishes message types.<br>- Initial routing structuring message<br>- Message requesting for updating routing table |
| Node Identifier      | Transmission node identifier  |
| Location Information | Transmission node location information  |
| Hop to Sink          | Count from transmission node to sink node   |
| Node Delay           | Average time period of transmission node delay  |
| Total Delay          | Accumulated delay time period from transmission node to sink node.  |
| Residuary Energy     | Residuary energy levels of transmission node(5 levels)  |

The wireless sensor network system consists of various sensor nodes and has a structure that transmits data formed from the sensor node to the sink node. The routing information uses the sink node's broadcast information to transmit based on a fixed time. The routing information uses the sink node's broadcast information to transmit based on a fixed time. Table 2 reflects the specific fields and significance of the broadcast message to delivery of routing information. All nodes maintain their node identifier information, location information, and residuary energy level value. The node delay (sample\_delay) is measured each time the data is transmitted to the sink node, and the following formula is used to update the average delay time (avg\_delay).

$$\text{avg\_delay} = (1-w) \times \text{avg\_delay} + w \times \text{sample\_delay} \quad (\text{equation 1})$$

Figure 1 presents the routing table construction algorithm proposed in this paper. All sensor nodes maintain four types of internal status variables to establish the routing table. The variable brdcst\_count reflects the number of messages received in the relative session. The variable brdcst\_ID saves the identifier of the broadcast message received and, using this, determines whether or not the broadcast message was received in duplicate. The variable 'max' shows the maximum value of the broadcast message receivable in one session. When the value of brdcst\_count reaches max, the routing table updating process is terminated. If the value of the end\_flag is true, this suggests that the routing updating procedure has been terminated.

First, if the message reaches from the sink node to the routing renewable cycle, it creates a routing table revision request message and broadcasts this to the adjacent node. The sensor node that receives the broadcast message analyzes the message's ID field value and confirms whether or not it was the first message received. For the first message, the ID field value is

saved as the variable `brdcst_ID`, which increases the value of `brdcst_count`. Furthermore, it starts the routing renewal timer. This timer reflects the routing's maximum renewal time period. The process from the sensor node to the routing renewal process terminates when the `brdcst_count` value reaches `max` or when the routing renewal timer has been completed.

```
Initialize:
brdcst_count = 0;
tmp_brdcst_packetID = null;
max = k;
end_flag = 0;
On_Receiving_Broadcast_Message:
if(brdcst_packet.id != brdcst_ID){
brdcst_ID = brdcst_packet.id;
brdcst_count++;
register_nodee(source_nodee);
build_brdcs(nodee);
end_flag = false;
timer_start();
broadcast_msg();
} else {
if(end_flag == false){
brdcst_count++;
register_nodee(source_nodee);
build_brdcs(nodee);
broadcast_msg();
if(brdcst_count == max){
end_flag = true;
abort_timer();
update_route_table();
}
}
}
On_Timer_Expired:
end_flag = true;
update_route_table();
```

**Figure 1. Routing table construction algorithm**

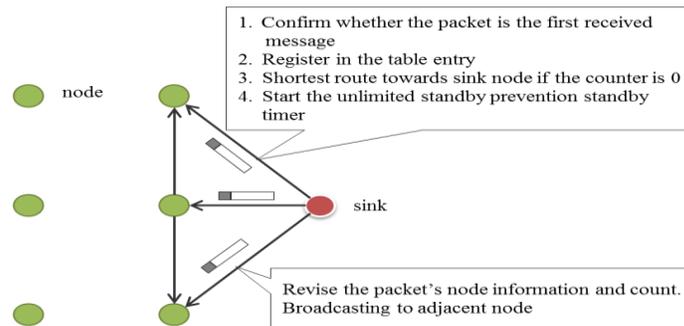
All of the information of the original routing table is deleted, registered in the sender node table, and count, location information, node delay, overall delay and residuary energy level information is saved (`register_nodee()`). Based on the message received, a new broadcast message is created(`build_brdcs()`). The ID and Flag value should be copied as is, the hop count should be increased by 1, the relative node information, such as node delay and residuary energy level, should be added, and the message should be broadcast to nearby nodes. In the case of an already-received message, first, if the `end_flag` value is true, the relative message should be dismissed. If the `end_flag` value is false, the sender node should be registered in the table, followed by saving the count, location information, node delay, total delay, and residuary energy level information (`register_nodee()`). Based on the received message, a new broadcast message is created (`build_brdcs()`). The ID and Flag value should be copied as is, and the hop count, node delay, total delay, and residuary energy level value should be used to choose the optimal value in the table to add to the message, followed by broadcasting the message to a nearby node. If the increased `brdcst_count` value is equivalent

to max, depending on the shortest delay and energy level, each routing table should be revised to enable a selection of the optimum route. Furthermore, the routing renewal timer should be stopped, the end\_flag set up as true, and the routing information renewal procedure should be terminated. If the routing renewal timer expires, depending on the shortest delay and energy level, each routing table should be revised to enable selection of the optimum route. Once the end\_flag is set up as true, the routing renewal procedure should be terminated. Table 3 presents the specific fields of the routing table proposed in this paper.

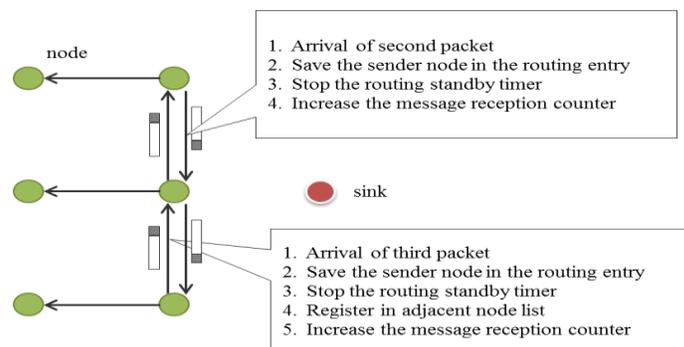
**Table 3. The structure of Routing table**

| Rank  | Next | Count | node | total | Remaining | Location |
|-------|------|-------|------|-------|-----------|----------|
| 1     |      |       |      |       |           |          |
| 2     |      |       |      |       |           |          |
| ..... |      |       |      |       |           |          |
| n     |      |       |      |       |           |          |

Figure 2 and 3 show the specific process of the routing table construction mechanism. The broadcast messages from the sink are transmitted to nodes 1, 2, and 3. Because it is the first message received from each node, the information related to the least node should be added. Node 2 should receive broadcast information from nodes 1 and 3, but because the message has already been registered, the relative node should be registered only in the adjacent node.



**Figure 2. Broadcast packet reception process 1**



**Figure 3. Broadcast packet reception process 2**

### 4. Verification and Result Analysis

The verification of the mechanism proposed in this paper was conducted through simulation. Figure 4 shows the node composition of the simulation. The simulation script was developed in Visual Studio 2010 operating in a Windows 7 environment with 8GB RAM. The 25 nodes that are used in the simulation form a 5x5 grid. The broadcast should revise and use Blind Broadcast in line with the simulation. Each node should transmit the packet in all directions to an adjacent node. The broadcast message used to renew the routing table should be transmitted to the sink. The simulation nodes should only be broadcast in received packets. In order to review the suitability of the protocol operation, the standard for deciding the node's routing table rank was determined by three factors: count, delay, and residuary energy level. When the broadcasting starts in the sink and the total node's routing table renewal is completed, each node's routing table should be checked to see whether the mechanism was moving appropriately. The node's routing table rank in the simulation should be determined by taking the count into consideration. Therefore, the information to be checked with the result is the connection node, count, and congestion level.

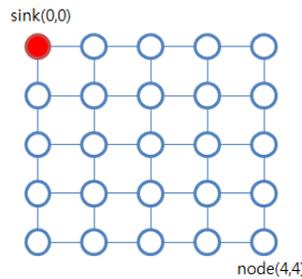


Figure 4. Network configuration for verification

| Node ID: [0][4] |                     |                           |
|-----------------|---------------------|---------------------------|
| Prior           | Congestion Level: 4 | Energy: 10                |
| 1st             | Node ID: [0][3]     | Distance: 4<br>Energy: 10 |
| 2nd             | Node ID: [1][4]     | Distance: 6<br>Energy: 10 |
| 3rd             | -                   |                           |

| Node ID: [4][4] |                     |                           |
|-----------------|---------------------|---------------------------|
| Prior           | Congestion Level: 3 | Energy: 10                |
| 1st             | Node ID: [3][4]     | Distance: 8<br>Energy: 10 |
| 2nd             | Node ID: [4][3]     | Distance: 8<br>Energy: 10 |
| 3rd             | -                   |                           |

| Node ID: [4][0] |                     |                           |
|-----------------|---------------------|---------------------------|
| Prior           | Congestion Level: 2 | Energy: 10                |
| 1st             | Node ID: [3][0]     | Distance: 4<br>Energy: 10 |
| 2nd             | Node ID: [4][1]     | Distance: 6<br>Energy: 10 |
| 3rd             | -                   |                           |

Figure 5. Routing table of Edge node

| Node ID: [3][4] |                     |                           |
|-----------------|---------------------|---------------------------|
| Prior           | Congestion Level: 6 | Energy: 9                 |
| 1st             | Node ID: [2][4]     | Distance: 7<br>Energy: 10 |
| 2nd             | Node ID: [3][3]     | Distance: 7<br>Energy: 9  |
| 3rd             | Node ID: [4][4]     | Distance: 9<br>Energy: 9  |

| Node ID: [4][3] |                     |                          |
|-----------------|---------------------|--------------------------|
| Prior           | Congestion Level: 7 | Energy: 9                |
| 1st             | Node ID: [3][3]     | Distance: 7<br>Energy: 9 |
| 2nd             | Node ID: [4][2]     | Distance: 7<br>Energy: 8 |
| 3rd             | Node ID: [4][4]     | Distance: 9<br>Energy: 9 |

Figure 6. Equivalent count node information

Figure 5 presents the edge area of the node's routing table such as nodes  $n(0,4)$ ,  $n(4,0)$ , and  $n(4,4)$  as a result of the simulation. As the edge node has two adjacent nodes, once the node's reception standby timer is completed, the table should be renewed. We can see that each node has two adjacent nodes. If you check the details of node  $n(4,4)$  of the results, a node with an equivalent count exists. Figure 6 reflects the equivalent count node information of node  $n(4,4)$ . Both nodes have the same count, but node  $n(3,4)$  has a lower congestion level compared to node  $n(4,3)$ . We are therefore able to see that the sensor node establishes a routing table based on the shortest route towards a sink, the energy efficiency of the foothold, and the least amount of congestion. Therefore it provides an appropriate routing service suited to current network circumstances.

## 5. Conclusion

The WMSN sensor node should be able to collect various forms of sensing information, prioritize each type of data based on the request conditions of the application service, and provide differentiated data transmission. In order for each sensor node to provide QoS, it should maintain routing information based on delay, reliability, and energy efficiency. We propose a routing protocol that can provide QoS that appropriately reflects changes in network status regarding reliability and delay, even in circumstances with a deficiency in sensor node resources. Our algorithm has the advantage of minimizing the routing control messages and therefore can safely operate from an energy-efficient perspective, as the algorithm utilizes broadcast messages regularly transmitted by the sink node. The verification of the proposed algorithm was conducted through simulation method. We were able to observe that the sensor node establishes a routing table based on the shortest route towards a sink, the energy efficiency of the foothold, and the least amount of congestion. This means that it provides an appropriate routing service suited to network circumstances.

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