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Multimedia Congestion Control in Wireless Sensor Networks

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Abstract. In this paper, we propose a new congestion control scheme to minimize data loss and maintain data quality in wireless multimedia sensor networks. The proposed scheme extracts and transfers dynamic regions by considering monitoring characteristics over multimedia sensor network environments to reduce the transferred data. Furthermore, it can reduce the packet size by deleting and transferring low-priority bit data by considering multimedia data characteristics during congestion situations to minimize packet loss. To show the superiority of the proposed scheme, we compare it with the existing congestion control schemes through simulation.

Keywords: wireless sensor, multimedia data, congestion control, dynamic region.

1. Introduction

As computing and wireless communication technologies have advanced exponentially over the last 10 years, a variety of applications that utilize wireless sensor networks have become available. A wireless sensor network is a network that consists of independent wireless devices on which unattended sensor modules are mounted to enable the detection of the surrounding environmental situation [1, 2, 3, 31, 32]. Such wireless sensor networks are actively utilized in circumstances such as military monitoring systems, environment monitoring systems, and U-City. Furthermore, as hardware technologies and monitoring techniques have advanced in recent years, multimedia data collection–based applications such as image, sound and video have expanded by utilizing multimedia sensor modules. Generally, wireless multimedia sensor networks are developed by adding multimedia sensor nodes to existing general sensor nodes [4, 5, 6]. However, although the infrastructure environments are similar to one another, the types and characteristics of collected data are fundamentally different, which makes the platform technologies developed for general numerical data applications difficult to apply to wireless multimedia sensor networks. Thus, it is important to construct design requirements for efficient energy utilization and data collection over wireless multimedia sensor networks [7, 8, 9, 10, 23, 33, 34, 35].

Since a large amount of multimedia data can be transferred over wireless multimedia sensor networks, congestion situations occur frequently due to bandwidth limitations. Congestion situations could result in packet loss and data quality degradation, therefore eventually causing the failure of environment monitoring [11, 12, 13, 28, 29, 36, 37, 38]. In addition, continuous packet retransmissions are attempted over congestion situations, which reduce the overall network lifetime. Therefore, it is essential to study and apply congestion control schemes that consider multimedia sensor networks. Congestion control schemes proposed for existing general wireless sensor networks are optimized for general numerical data transmission. Therefore, they are unsuitable for environments in which high capacity multimedia data transmission is required [14, 15, 18, 19, 29]. Accordingly, congestion control schemes that consider high capacity multimedia data collection environments have been actively proposed. M. Maimour utilize multiple paths over multimedia sensor network environments to control congestion and alleviates congestion by adjusting traffic dynamically when congestion occurs [16]. However, doing so generates additional congestion in a situation where all the paths held by a source node are being utilized. That is, if part of the traffic in a congested path is transferred to other paths, existing congested paths may alleviate a congestion situation, but other paths to which part of traffic is transferred may experience additional congestion situations, resulting in packet loss. To solve this problem, [17] was proposed to reduce packet sizes by averaging pixels and minimizing packet loss by distributing transmission scheduling at the time of the congestion occurrence. However, this also created the additional problem of data quality degradation due to the overhead involved with arranging congestion control.

To solve this problem, this paper proposes an energy-efficient congestion control scheme that minimizes packet loss through congestion control and provides high quality data over wireless multimedia sensor networks. The proposed scheme controls congestion situations by reducing packet size through low-bit plane data deletion, which has no significant impact on image quality by taking advantage of the transmission characteristics of multimedia data once a congestion situation has been detected. The proposed scheme can minimize energy consumption and maintain a high image quality by adding a bit deletion operation during the congestion control process.

This paper is organized as follows. In Section 2, the drawbacks of previously proposed congestion control schemes are analyzed. In Section 3, the proposed energy-efficient congestion control scheme over wireless multimedia sensor networks is described. In Section 4, a performance evaluation of the proposed scheme is presented to demonstrate the better performance by comparing it with existing schemes. Finally, in Section 5 presents the conclusion of this paper.

2. Related Work

S. A. Munir proposed a congestion estimation model based on fuzzy logic to enhance QoS in wireless sensor networks [20]. The QoS model consists of two modules: QoS management and control module, which is implemented both at node level and at sink. The Fuzzy logic with fuzzy set variables is used to estimate congestion. A fuzzy table is maintained which takes the values of buffer state and incoming to outgoing packets ratios as to whether a decision needs to be taken or not.

M. Maimour proposed load repartition strategies for congestion control with multipath routing to provide the necessary bandwidth and to reduce the congestion problem of video streaming [16]. Video streaming data is split on multipath instead of decreasing the transmission rate to guarantee the video quality. SLiM is used to provide multipath routing from a set of sources to a given sink with a path lifetime criterion [30].

C. Wang proposed a hop-by-hop upstream congestion control called PCCP(Priority based Congestion Control Protocol) under both single-path routing and multi-path routing in wireless sensor networks [18]. PCCP measures congestion degree as the ratio of packet inter-arrival time along over packet service time and uses node priority index to reflect the importance of each sensor node. The node with higher priority index gets more bandwidth and proportional to the priority index and a node with sufficient traffic gets more bandwidth than one that generates less traffic. PCCP reduce packet loss and accomplish high link utilization and low packet delay.

The PCCP increases the scheduling rate and source rate of all traffic sources in the case of low congestion and decrease the sending rate of all traffic sources based on their priority index in the case of high congestion. M. H. Yaghmaee proposed a congestion control called QCCP-PS (Queue based Congestion Control Protocol with Priority Support) to enhance the performance of PCCP using a proper adjustment of the rate [19]. QCCP-PS has a separate queue to store input packets from each child node in each sensor node and considers queue length as an indication of congestion degree in wireless multimedia sensor networks [19]. QCCP-PS adjusts the sending rate of each traffic source according to congestion condition and priority index of node. The rate adjustment unit calculates the new rate of each child traffic sources as well as its local traffic source according to the current congestion index and the source traffic priority. The congestion notification receives unit the new rate and executes an implicit congestion notification to decrease energy consumption.

Since the amount of multimedia data is very large, data loss occurs due to the congestion on particular nodes, E. Ryu proposed a novel congestion control scheme for minimizing data-loss in wireless multimedia sensor networks [17]. If congestion occurs in a node, fundamentally the size of the packets is reduced through data compression and data loss with data conflict is reduced through data transmission scheduling. The data compress is not performed in initial source node every time but is performed whenever congestion occurs. As a result, it is possible to guarantee the high data quality and low latency. When the congestion occurs in certain node, a congestion occurrence message is distributed to child nodes. The child nodes receiving this message perform data compression and then retransmit the compressed packets with transmission priority. The congestion occurrence message contains transmission scheduling information to minimize data loss and transmission latency. The transmission priority of the compressed packet is given as follows.

M. O. Farooq categorized the traffic of wireless multimedia sensor networks into six different classes and proposed differentiated services based congestion control scheme [21]. The congested node calculates the reduced share of the bandwidth for all one hop away upstream nodes for which it is acting as a relaying node. While estimating the data rate, the congested node takes into account the characteristic of the different traffic classes. Upstream nodes which generate less data and low priority data are more penalized compared to the nodes producing the bulk volume of data and high priority data.

To increase the frame delivery performance by decreasing the quality, C. Sonmez proposed a cross-layer progressive image transport scheme with Fuzzy Logic Based Congestion Control called SUIT (Sensor fUzzy-based Image Transmission) in Wireless Multimedia Sensor Networks [22]. SUIT provides a fuzzy logic based congestion estimation and a novel congestion mitigation technique. SUIT randomly drops some sub-frames of encoded JPEG without corrupting the image file to improve the continuity of the video streaming data

3. The Proposed Congestion Control Scheme

3.1 Overall procedure of the proposed scheme

A congestion control scheme that reduces the data transmission period can satisfy the real-time requirements of monitoring utilizing multimedia sensor networks, but it may reduce data quality. On the other hand, a congestion control scheme that maintains a data transmission period adds part of congested traffic to other paths, thereby creating the possibility of additional congestion in other paths, and additional energy consumption caused by the required reporting of the congestion situation to the source node. Along with this problem, existing schemes have the problem of data quality degradation when performing pixel averaging during periods of congestion. Therefore, it is necessary to study a congestion control scheme that considers applications over wireless multimedia sensor networks to minimize energy consumption and the packet loss rate while avoiding increasing the development costs of sensor networks and providing high quality monitoring information.

In this paper, a congestion control scheme is proposed that minimizes packet loss and maintains data quality once a congestion situation is detected in a specific node over a wireless multimedia sensor network environment while transferring high capacity multimedia data. In the proposed scheme, the packet loss during a congestion situation is minimized while data quality is maintained as high as possible by reducing packet sizes through low bit-plane data deletion and transmission by considering multimedia data characteristics. We use MPEG formats provided in the existing multimedia sensor nodes as a media to do congestion control. The proposed scheme also is not related to video codecs since it deletes bit plane information or transmits only the dynamic frame information. Fig. 1 shows the overall process of the proposed scheme. Once a source node detects an event, data is collected. Using the monitoring characteristics of the collected data, the previous and current data are compared to check the dynamic region data so that the data can be transferred separately. Here, energy-efficient transmission can be made by only transferring data in dynamic regions. Once the congestion situation is detected during data transmission, congestion control is conducted in a prior node of the current node where the congestion has occurred and then the data is transferred.

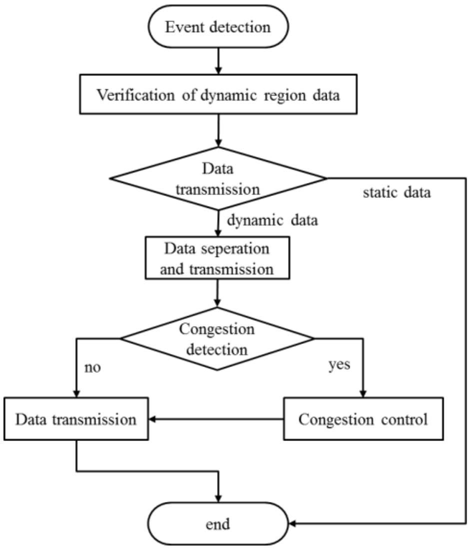


Fig. 1. Overall procedure of the proposed scheme

3.2 Path setup and congestion detection

It is possible to send data faster by maintaining multiple paths for all nodes to a destination node in a routing table before an event occurs. Such a routing table includes multiple paths that are created based on nodes that ensure the shortest path to a destination and the reliability of the node that is receiving the data. To ensure the reliability of data sending and receiving processes, every node stores the nodes whose remaining energy is above a threshold to a neighbor node table from neighbor nodes within a transmission range. It is essential for congestion control schemes to detect congestion as rapidly as possible. A significant amount of data loss can be prevented by detecting congestion quickly. To detect congestion situation as quickly as possible, the proposed scheme detects congestion situations by analyzing changes in the data reception/processing rates by putting reception/processing queues in every node. Once a congestion situation is detected, a node that have detected the congestion sends a congestion notice message to its child nodes that send/receive data to/from a node to have its child nodes perform congestion control.

In this paper, we propose a new congestion control scheme based on congestion occurrence characteristics. Since we are similar to the existing schemes over the same data transmission environment with a multiple path transmission scheme [23] in the existing multimedia sensor networks, the proposed scheme determines the proper threshold value based on the method that the existing scheme [23] determines the threshold value. First, it is necessary to collect foundational information to create a routing path to a destination node the same as in the existing schemes. To create a path, all sensor nodes within a sensing field broadcast an information collection message to their neighbor nodes. A message receiving node replies to a sending node with a message containing information as shown in fig. 2 to create a neighbor node table, where the neighbor node table maintains a list of nodes that have remaining energy above a threshold out of the nodes that replied. The neighbor node table is used as foundational information to create a path to the desired destination node.

Node identifier	*Remaining energy*	*X coordinate*	*Y coordinate*

Fig. 2. Reply message in the network initialization process

Once a neighbor node table has been created, all nodes create all possible paths to a destination node to make up the data transmission environment. Fig. 3 shows a data transmission environment of the proposed scheme. Every node searches and determines the next node to create a path that consists of optimum nodes whose remaining energy is high and the distance to the destination node is the shortest for its own neighbor table. All nodes iterate this process up to the destination node to create the final path. To prevent the created path overlapping, nodes that were not used in the previously created path in the neighbor node table are searched and the above-mentioned process is iterated. Once multiple path creation has been completed at every node, a multiple path routing table is created to maintain the path. A multiple path routing table maintains information such as the path identifier, next node in the path, and the transmission traffic.

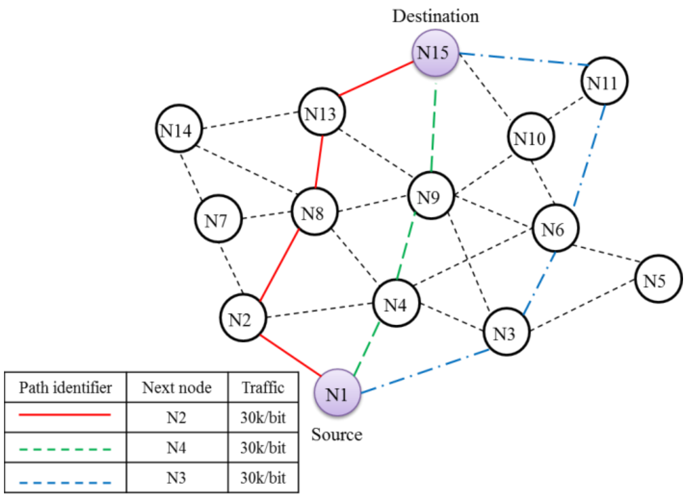


Fig. 3. Creation of a data transmission path

Fig. 4 shows an algorithm of the creation and maintenance process of the multiple paths for all nodes. Every node utilizes its own path routing table for data transmission, which prevents the operation required for data transmission path creation.

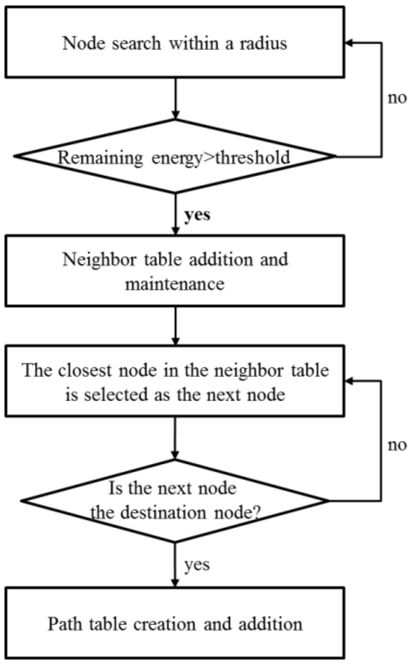


Fig. 4. Algorithm of multiple path creation and maintaining

It is essential for congestion control to detect and control the congestion situation that can be generated during the data transmission process as rapidly as possible. In the proposed scheme, any congestion situation is detected as quickly as possible on the basis of the changing rate of data loading in reception/processing queues, as shown in fig. 5.

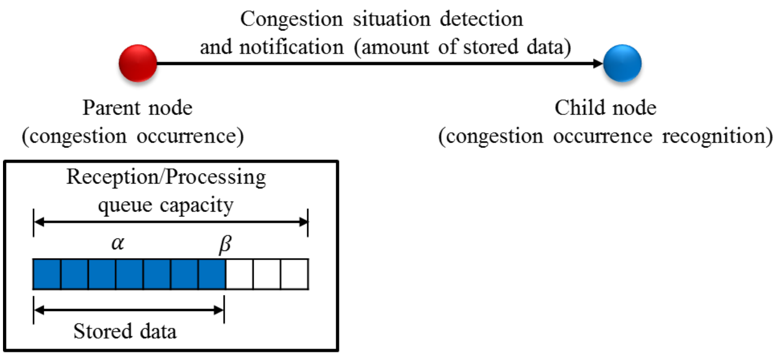


Fig. 5. Congestion situation detection and notification

For each node, a certain level of data is accumulated in its reception/processing queues. The congestion is detected if the amount of data to be processed is larger than that of the data received as equation (1). If this is detected, a congestion notice message is sent to child nodes. A child node that receives a congestion notice message performs a series of congestion control processes based on that message.

$$Congestion = \left(\frac{Sizeof\ StoredData}{Capacityof\ ReceiveQueue} > \beta\right) \wedge \left(\frac{Sizeof\ RecieveData_{sec}}{Sizeof\ SendData_{sec}} > 1\right) \quad (1)$$

3.3 Dynamic region data and separated transmission

Data transferred from a sensor node is divided into dynamic and non-dynamic regions over time. A non-dynamic region has the same data even after some time has elapsed. Thus, rather than sending all data, it is more energy efficient to send just the dynamic regions except for the first frame, due to the reduction of a data transmission size. Therefore, it is highly important to detect dynamic regions. The existing motion detection schemes increase the energy consumption of the whole sensor network since they compare the information of all pixels in the frame in order to detect dynamic regions. The proposed scheme performs pixel averaging for each block by creating a virtual comparison block of grid pattern in a frame. Then, a dynamic change region is detected if the differences of the pixel averaging figures of comparison blocks before and after a frame are above a specific threshold. We detect dynamic regions that the absolute values of pixels in a block changes over 5% because the proposed scheme uses the threshold values of the dynamic regions as the pixel average of the block unit to detect the dynamic region. The proposed scheme uses the confidence tolerance -5% ~ +5% since it compares the value difference between the previous block and the current block by using the average value of the block.

Dynamic region data is transferred using the monitoring characteristics of the collected data in multimedia sensor networks. Fig. 6 shows the monitoring characteristics in multimedia sensor networks. A sensor node detects a signal and takes a shot continuously, thereby producing dynamic and non-dynamic regions over time. Utilizing this characteristic, not all data is transferred, only the dynamic region data without the first frame is transferred to ensure energy-efficient transmission.

(a) Image frame at T1

(b) Image frame at T2

Fig. 6. Characteristic of collected images in a multimedia sensor network

It is important to detect dynamic change regions in collected data. To detect a dynamic change region, all pixels should be compared, which requires high operation costs. Thus, the pixel averaging of blocks is performed once comparison blocks of a grid pattern are created, as shown in fig. 7. If the difference of pixel averaging between comparison blocks before and after a frame is more than a specific threshold, it is detected as a dynamic change region, whose block is then sent to a destination node.

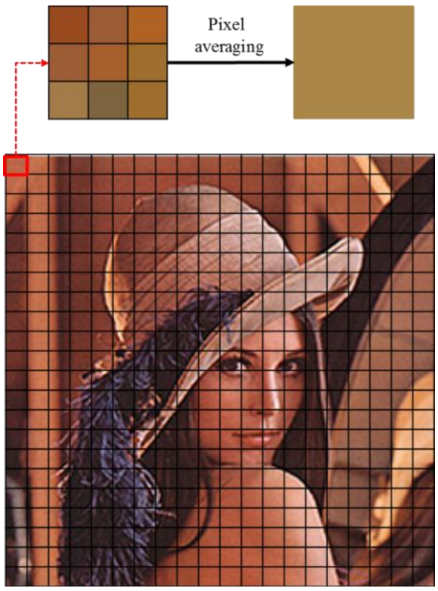


Fig. 7. Creation of virtual comparison blocks and pixel averaging

3.4 Structure and characteristics of multimedia data

The proposed congestion control scheme is a control mode that utilizes multimedia data characteristics. Thus, it is necessary to have a multimedia data structure. The multimedia image data that is collected at sensor networks has a pixel-unit data bit structure as shown in fig. 8, in which each pixel has 8-bit data information (0–255) per color channel (R, G, and B). The same bit data is bundled with one bit-plane, and an image consists of 24 bit-planes. The data size in each bit-plane is the same as one another, but the amount and importance of representable information differs. That is, an upper bit-plane represents a large color change, whereas a low bit-plane represents a small color change. In the proposed scheme, it performs congestion control by reducing the image data size based on this fact.

Fig. 8 shows a multimedia image data structure collected in wireless multimedia sensor networks. Generally, a sensor node is run based on limited energy and computing performance, so that it requires an additional compression module to perform data compression. Therefore, it is more general to transfer original data rather than performing a compression of collected data. Image data collected at wireless multimedia sensor networks is a pixel-unit data bit structure as shown in fig. 8, in which each pixel has 8-bit data information (0–255) per color channel (R, G, and B). The same bit data is bundled with one bit-plane, and an image consists of 24 bit-planes. That is, a single color image consists of 24 bit-planes. The data size in each bit-plane is the same as one another, but the amount and importance of representable information differs. For example, the most significant seventh bit-plane can represent 128, whereas the least significant 0th bit-plane can represent one. Therefore, an upper bit-plane represents a large color change, whereas a low bit-plane represents a small color change.

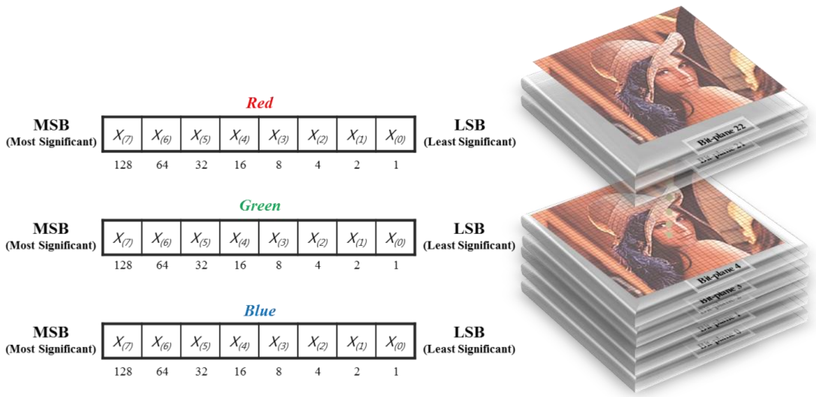


Fig. 8. Multimedia image data structure in sensor networks

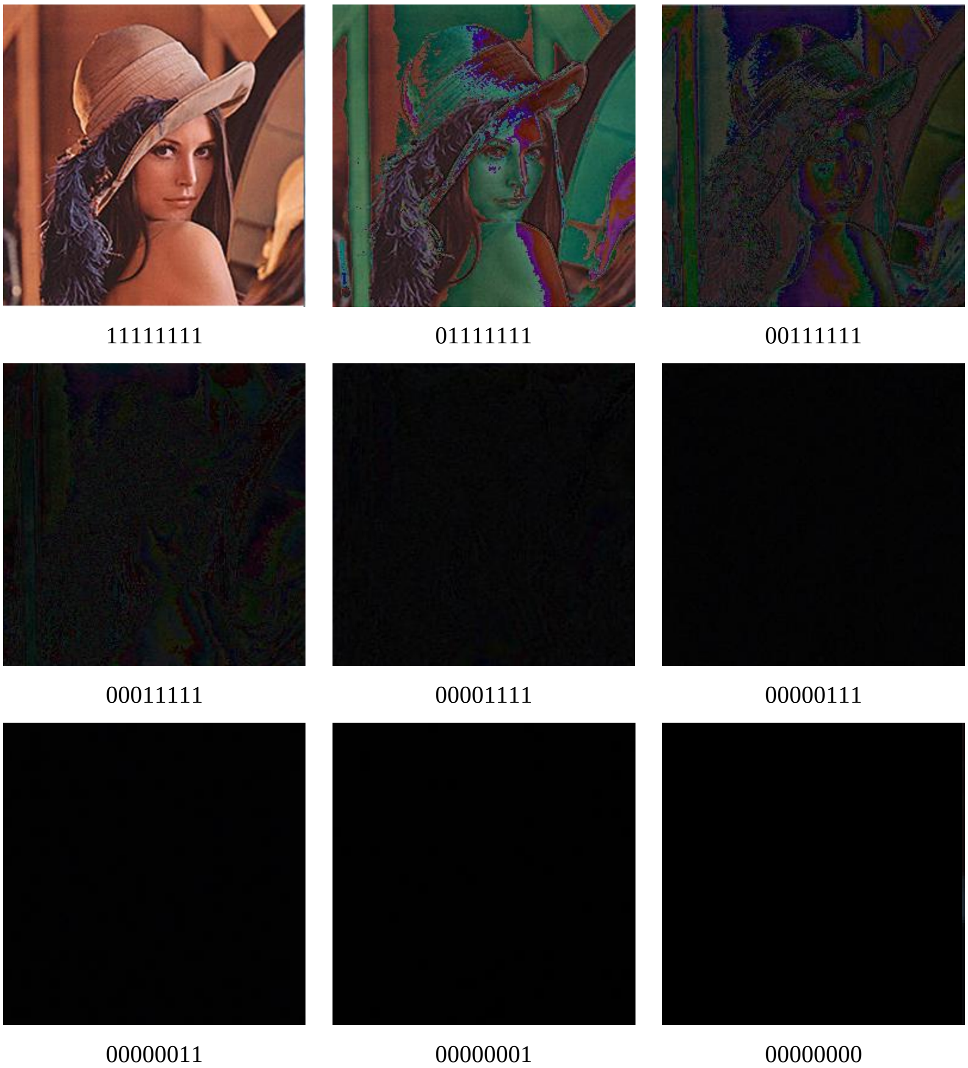
Based on the above analysis, fig. 9 shows experimental evaluation results of changes in image quality due to the deletion of bit-plane data. If the upper bit-plane data is deleted, much information is lost, resulting in a significant loss in the original data quality. On the other hand, if low bit-plane data is deleted, less information is lost in a relative sense, resulting in no significant impact to the original data quality. In other words, if not all sets of bit-plane data can be transferred, the least significant bit-plane data is deleted, which ensures as high quality as possible for the received image. In the proposed scheme, it performs congestion control by reducing an image's data size based on this fact.

11111111 11111110 11111100

11111000 11110000 11100000

11000000 10000000 00000000

(a) Lower bit-plane deletion



(b) Upper bit-plane deletion

Fig. 9. Bit-plane data deletion

3.5 Congestion control

The proposed scheme performs congestion control by utilizing a structural characteristic of multimedia data collected over a sensor network. If congestion occurs, it can be controlled by reducing the transmission data size through lower bit-plane data deletion, which contains small color change information. By performing this, the data size can be efficiently reduced without overly affecting data quality. Congestion control is performed in a child node that receives a notice message from a congestion node, and a child node performs optimal congestion control based on the state information of the congestion node noticed in the congestion notice message. It is not appropriate to delete as much bit-plane data as possible to maintain high quality data. The proposed scheme always detects and controls congestion based on the amount of data load of the queue in the parent node in real time. Therefore, even if some segments on the paths from the source node to the target node cause congestion, the congestion detected between parent nodes and child nodes is controlled independently each other. The proposed scheme first deletes the bit planes and then when there do not exist bits to be deleted any more, it transmits data by re-routing them into other available paths that the source node has.

In the proposed scheme, the optimum size of data to be transferred is calculated to ensure the data loading amount in the reception/processing queues in a node that experienced congestion within an appropriate threshold range, as shown in Equation (2). Furthermore, based on the above calculation, the number of bit-planes to be deleted is calculated as shown in Equation (3), and the least significant bit-plane data is deleted to reduce data size. A child node that receives a congestion message performs a series of congestion control processes, and then the result is re-transmitted to a congestion occurrence node.

$$\frac{StoredData - SendData_{sec} + ReceiveData_{sec}}{Capacity\,of\ ReceiveQueue} \tag{2}$$

$$ReceiveData = Sizeof\ Head + Sizeof\ Trail + \sum Sizeof\ BitPlance_i \tag{3}$$

During the data transmission, it may be that no data is deleted, due to the continuous occurrence of congestion and execution of congestion control. In that case, the data is re-distributed to other paths by considering the available data amount in all multiple paths held by a source node that performs congestion control. Fig. 10 shows the overall congestion control structure of the proposed scheme. Once congestion occurs, a congestion node transfers a congestion notice message to its child nodes. A child node that receives a congestion notice message sends data by deleting the lower bit data based on the message information to alleviate the congestion situation. In the proposed congestion control scheme, packet loss during congestion situations is minimized while the data quality is maintained as high as possible by reducing the packet size because of the low bit-plane data deletion and transmission that considers multimedia data characteristics.

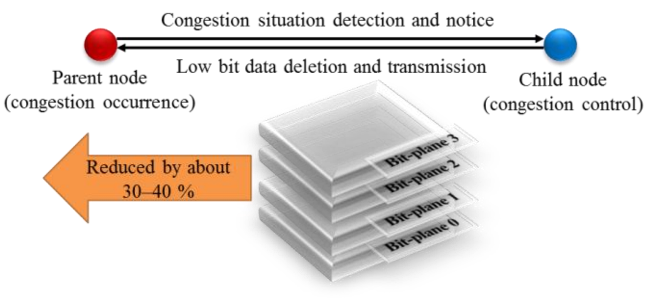


Fig. 10. Overall process of congestion control

4. Performance evaluation

To prove the superiority of the proposed scheme, a performance evaluation was conducted by comparison with existing congestion control schemes [16, 17] through simulation. This simulation was conducted over a performance evaluation environment, as shown in Table 1. Based on the simulation environments constructed in the previous sensor network–related studies [24, 25], a performance evaluation was conducted. We also conducted a performance evaluation based on the existing simulation environment [24, 25] by implementing a virtual sensor network. A sensor node in a sensor network was arranged at a uniform distance in an area of square shape with a size of 200m×200m. An energy model consumed in a message transmission between sensor nodes is (message size)·{(transmission cost)+(amplification cost)·(distance)}, in which the transmission cost and amplification cost are 50 nJ/b and 100 pJ/b/m2, respectively. An energy model consumed in message reception is (message size)×(reception cost), in which reception cost is set to 50 nJ/b. Collection data is gathered in a base station according to the period of time or queries. It was assumed that a source node is selected randomly while each sensor node has limited energy, which is consumed according to the performance evaluation environment during the data reception and transmission time [26, 27].

Table 1. Environment of the performance evaluation

Parameter	Value
Size of sensor network (m × m)	200 × 200
No. of sensor nodes (nodes)	100~300
Location of base station (X, Y)	(200,200)
Communication radius of sensor node (m)	25
Size of multimedia data (Kbytes)	12
No. of source nodes (nodes)	No. of sensor nodes /6
Congestion limit (%)	50–70

Fig. 11 shows a comparison result of the packet loss rate according to the number of distributed nodes. The traffic-dividing scheme (LRCC) [16] in existing congestion control schemes has the possibility of generating extra congestion occurrences when traffic at a node where congestion is occurring is transferred to other paths. Therefore, packet loss due to the above scheme can occur continuously. A pixel-averaging scheme (CCMD) [17] performs congestion control as it reduces data sizes through pixel averaging before data transmission. Thus, packet loss can be reduced, even if quality degradation occurs due to pixel averaging. The proposed scheme 1 reduces packet size by deleting lower bit-plane data before transferring data while considering multimedia data characteristics to enable congestion control. In addition, it performs bit-plane deletion that considers data quality to enable high quality data collection without the transmission of congestion situation to other paths. The proposed scheme 2 combines dynamic change region transmission and bit-plane deletion while considering the characteristics of the collected data over sensor networks to prevent congestion, resulting in effective congestion control. The performance evaluation results show that the proposed scheme reduces packet loss by an average of up to 83%, compared to existing schemes.

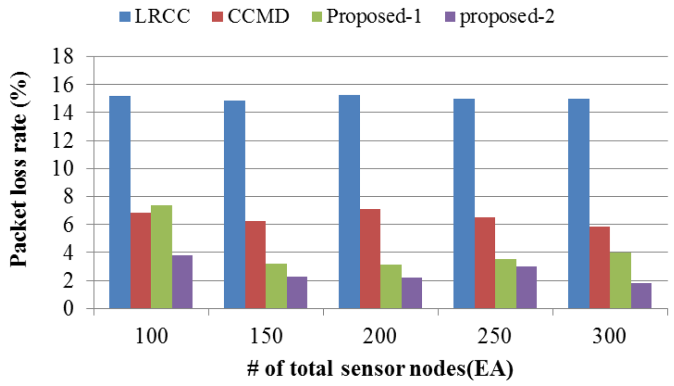


Fig. 11. Packet loss rate according to the number of nodes

Fig. 12 shows the comparison result of network lifetime according to the number of distributed nodes. According to previous studies, if more than 80% of nodes survive, it is determined to be a reliable network. In this performance evaluation, an execution round where more than 80% of the total nodes survived was evaluated, while energy consumption including transmission data and congestion messages were evaluated. Among the existing congestion control schemes, LRCC reduced the overall network lifetime, because it consumed energy as it sent unnecessary congestion messages to source nodes whenever congestion situations occurred. CCMD also reduced the network lifetime, since it consumed energy by transferring congestion messages to source nodes until all available paths were fully utilized. The proposed scheme 1 sent data separately to all paths from the initial transmission time and only sent congestion messages to the previous node when congestion occurred, thereby minimizing unnecessary message transmission and sending data separately to all available paths, resulting in the distribution of energy consumption and increasing the network lifetime. In the proposed scheme 2, only dynamic change regions were transferred, which reduced the transmission data size. As a result, it can prevent a congestion situation arising as much as possible, while also maximizing the network lifetime. When the number of sensor nodes on the same space is 100, the proposed scheme looks like the best performance since the number of source nodes is the least. In our experiments, the number of source nodes increases when the number of sensor nodes increases. As the number of sensor nodes increases from 100 to 300, the proposed scheme has high energy consumption since it causes a lot of congestion when the number of source nodes increases. Therefore, in the performance evaluation, the proposed scheme shows the best performance when the number of sensor nodes is 100. The performance evaluation results show that the proposed scheme increased the average network lifetime by up to approximately 91% compared to existing schemes.

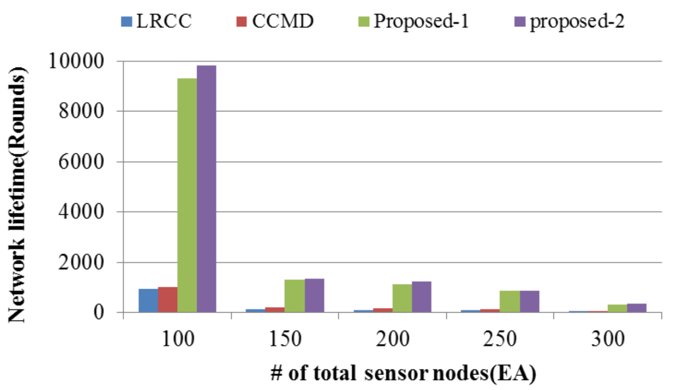


Fig. 12. Network lifetime according to the number of distributed nodes

Fig. 13 shows the comparison results of energy consumption according to the number of distributed nodes. A traffic dividing scheme (LRCC) among existing congestion control schemes increased energy consumption, since it increased unnecessary message transmission by sending congestion control messages to source nodes whenever congestion occurred. A pixel averaging scheme (CCMD) also showed large energy consumption, since it sent congestion control messages to source nodes until all the available paths were fully utilized. The proposed scheme 1 minimized unnecessary message transmission by sending data separately to all available paths from the first transmission time and only sending congestion messages to the previous node when congestion occurred. The proposed scheme 2 minimized energy consumption by reducing the probability of congestion occurrence. The performance evaluation result showed that the proposed scheme reduced average energy consumption by up to 91% compared to existing schemes.

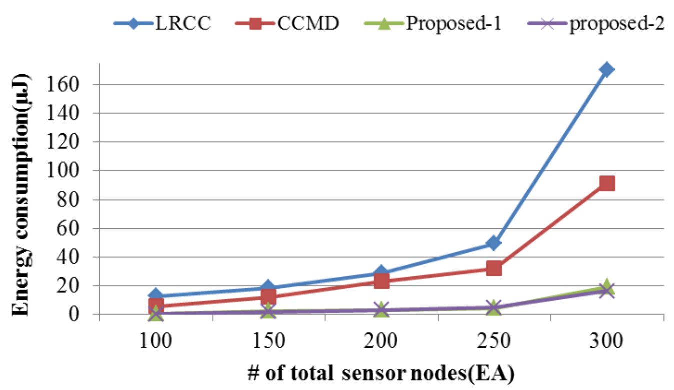


Fig. 13. Energy consumption according to the number of distributed nodes

Fig. 14 shows comparison results of changes in data quality due to congestion control. A pixel-averaging scheme (CCMD) could reduce data size by 3/4 through pixel averaging when congestion occurred. However, it also experienced noticeable data quality degradation as congestion control was conducted. The proposed scheme also reduced data size by 5/8, by deleting lower bit-planes in consideration of multimedia data characteristics while maintaining the high quality of data. It was also verified that the proposed scheme maintained high data quality even if the data size was reduced by 3/4.

(a) Original image

(b) Pixel averaging image

(c) Low bit deletion (4–8 bit-plane)

(c) Low bit deletion (3–8 bit-plane)

Fig. 14. Data quality change according to congestion control

5. Conclusion

In this paper, we proposed a new congestion control scheme to minimize multimedia data loss in wireless sensor networks. The proposed scheme utilized low bit-plane data deletion and transmission in consideration of multimedia data characteristics to reduce packet size, thereby controlling congestion situations, minimizing both packet loss, and maintaining high data quality. The performance evaluation result showed that the proposed scheme reduced average packet loss by up to 83%, while reducing the average energy consumption by up to 91% compared to existing schemes. In addition, it increased the average network lifetime by up to 91%. The node density does not influence the performance of the proposed scheme. Actually the number of source nodes influences the performance. In the performance evaluation, the performance of the proposed scheme seems to be degraded when the number of nodes increases from 100 to 300 in the same region. Since the optimal node is the next node when establishing paths, the overlaps of nodes included in the paths that the source nodes choose occurs. Therefore, the performance degradation occurs since the number of source nodes increases. As these results, the proposed scheme showed high utilization, since it maintained high data quality despite the large reduction in the packet loss rate and energy consumption during congestion situations.

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