

A Multimedia Data Compression Scheme for Disaster Prevention in Wireless Multimedia Sensor Networks

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ABSTRACT

Recent years have seen a significant increase in demand for multimedia data over wireless sensor networks for monitoring applications that utilize sensor nodes to collect multimedia data, including sound and video. However, the multimedia streams generate a very large amount of data. When data transmission schemes for traditional wireless sensor networks are applied in wireless multimedia sensor networks, the network lifetime significantly decreases due to the excessive energy consumption of specific nodes. In this paper, we propose a data compression scheme that implements the Chinese remainder theorem to a wireless multimedia sensor network. The proposed scheme uses the Chinese Remainder Theorem (CRT) to compress and split multimedia data, and it then transmits the bit-pattern packets of the remainder to the base station. As a result, the amount of multimedia data that is transmitted is reduced. The superiority of our proposed scheme is demonstrated by comparing its performance to that of an existing scheme. The results of our experiment indicate that our proposed scheme significantly increased the compression ratio and reduced the compression operation in comparison to those of existing compression schemes.

Key words: Wireless Multimedia Sensor Networks, Compression, Chinese Remainder Theorem, Energy-efficient.

1. INTRODUCTION

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In recent, with the development of hardware technologies and monitoring schemes, the applications for gathering multimedia data such as sound and image using multimedia

sensors have been increased [1]. As the multimedia data are very large over simple data in traditional sensor networks, the network lifetime of the sensor network is significantly reduced due to excessive energy consumption in particular nodes for transmitting the data. In addition, the multimedia data increase the data transmission time and decline the data reception ratio. Consequently, the existing schemes based on the traditional sensor networks are not suitable for the environments to collect the multimedia data [1]-[3].

For the purpose of performance improvement in the wireless multimedia sensor networks, the multimedia data compression schemes have been actively in progress as a representative study. It is necessary to use compression schemes to improve the wireless multimedia sensor networks. However, most of the existing compression schemes for sensor data are based on signal compression such as wavelet and variable quantization and code compression [4]-[12]. These studies are not suitable for the environments based on wireless sensor networks. The compression schemes for wireless multimedia sensor networks are also in their infancy. Therefore, it is necessary to study an energy-efficient multimedia data compression scheme considering the characteristics of the wireless multimedia sensor networks.

In this paper, we propose a novel data compression scheme for wireless multimedia sensor networks. The proposed scheme splits and compresses the sensing multimedia data based on the Chinese Remainder Theorem (CRT) [13] algorithm considering their characteristics. Moreover, the proposed scheme decides the number of segments to be sent via each node based on the remaining energy of the nodes of the upper level in the path of the sending data. By doing so, it is possible to consume the balanced energy among the sensor nodes.

2. THE PROPOSED DATA COMPRESSION SCHEME

In this paper, we propose an energy-efficient data compression and transmission scheme to extend the network lifetime by reducing the energy consumption and load on particular nodes. The proposed scheme consumes the energy of the entire network in balance by transmitting the split packets via the multi-paths considering remaining energy of the upper level nodes. At first, the source node recognizes the number of nodes on the path to transmit the sensor readings and splits massive multimedia data into the segments based on the Chinese Remainder Theorem (CRT) algorithm. Then, it transmits the packets by the remaining energy of the upper nodes.

In order to carry out the proposed scheme, it is necessary to identify the transfer nodes during data transmission from the source node to the base station. Thus, all nodes identify information of the transfer nodes to send the multimedia data through the network initialization stage. Fig. 1 shows a network initialization stage. The proposed scheme identifies routing levels on the basis of the number of hops for the nodes participating in data transmission. It also finds the level that the maximum number of nodes exist, called Maximum Transfer

Level (MTL), during routing process. The source nodes utilize MTL for data partition.

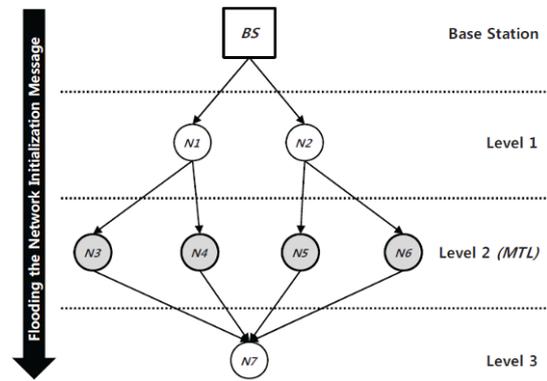


Fig. 1. Network initialization stage

The base station prepares a Network Initialization Message in a format shown in Fig. 2-(a) and transfers it to the entire network with a flooding method. During network initialization, when each node receives the network initialization message from the neighboring nodes, it generates routing tables shown in Fig. 2-(b) on the basis of the information of the initialization message. Each node is able to identify information on the depth of the upper parent level, transfer_node IDs when transmitting the data by themselves and MTL using the routing tables. This process is repeated until all of the sensor nodes generate the routing table.

Level	Transfer_Node			
	lv_1	lv_2	...	lv_n
Nodes	N1	N3 / N4 / N5	...	N10

(a) Configuration on network initialization message

Level	Transfer_Node IDs	Is_MaxTransferLevel(MTL)
lv_1	N1	False
lv_2	N3, N4, N5	True
...	...	False
lv_n	N10	False

(b) Routing table

Fig. 2. Network initialization message and routing table

The data partition algorithm such as the proposed scheme splits the data to be transmitted via the entire network. Therefore, it has an advantage of the balanced energy consumption. However, as the packets contain basic elements such as header and footer, excessive number of split segments is rather inefficient. Thus, it is essential to split the data into an appropriate number for high efficiency. Accordingly, in this stage, it is required to carry out data partition on the basis of the remaining energy of the transfer nodes at the MTL on the transmission paths.

Fig. 3 shows the data partitioning of the proposed scheme. At the first, the source nodes collect the remaining energy of the transfer nodes at level_N corresponding to MTL that belongs to the path from the source node to the base station. To do this, after the source node detects an event and then generates the multimedia data, it requests the remaining energy of the each node in MTL before transmitting the first data. Each node in MTL replies the ack message containing its remaining energy to the source node and the source node decides the number of split segments based on it. The number of split segments can be gotten by calculating the greatest common measure (GCM) after carrying out the simplification of the collected remaining energy information. It defines the number that is obtained by dividing the remaining energy by the least common measure (LCM) as the final number of split segments and carries out the data partitioning based on it.

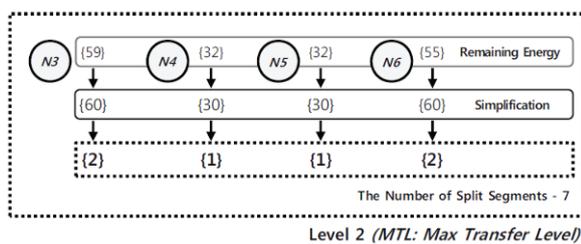


Fig. 3. Establishment of the number of split segments

The partitioning and compression process are carried out by using the Chinese Remainder Theorem (CRT) algorithm on the basis of the number of the split segments. Figure 4 shows the entire data partition and compression processes. It carries out data separation and compression by using the Chinese Remainder Theorem (CRT) algorithm and the following assumptions:

- [Assumption 1] The base station should know the size of the original multimedia data, 2ω .
- [Assumption 2] A set of minimum prime numbers are chosen so that they are the smallest prime numbers that satisfy the condition $P_1 \times P_2 \times \dots \times P_n > 2\omega$. The base station should know the minimum prime numbers set in order to restore the original multimedia data.
- [Assumption 3] The prime numbers in the minimum prime numbers set are consecutive.

When N and ω denote the number of split segments used to split the data and the number of bits for original data, respectively, we select a set of N minimum prime numbers to compress the original data and carry out data partition and compression on the each prime number. Fig. 4 shows how the multimedia data using the Chinese Remainder Theorem (CRT) algorithm are partitioned. If the size of the original data is 40 bits and the number of split segments N is 7, the set of minimum prime numbers becomes $\{43, 47, 53, 59, 61, 67, 71\}$. For data of each packet, the bit-pattern of remainder by splitting the original data by the minimum prime number is sent. As the remainder is always smaller than the divisor from the

characteristics of modular operation, it is possible to get larger energy gain than transmitting the original data.

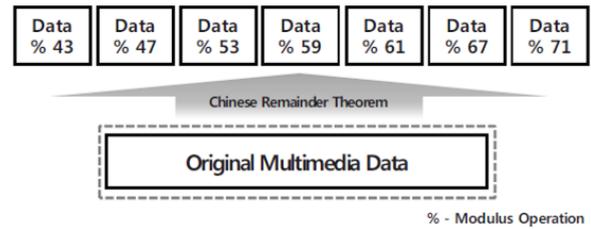


Fig. 4. Splitting Multimedia data

As the proposed scheme allows the entire data to be split into several segments and to be transmitted via multiple paths, it is very important for the base station to recognize the index of the split packets on the original data for recovering the data after receiving the entire split packets. To do this, the proposed scheme sends the compressed split segments (payload) and bit-identifier using the XML label scheme to the base station when transmitting the packet. The bit-identifier allocates as many bits as the number of split segments and sets the bit corresponding to the index of the transmitted data to '1'. Therefore, each bit indicates the index of the corresponding packet. Figure 5 shows a transmission packet structure and how to transmit packets from a source node to the base station. As the data has been split into 7 segments as shown in Figure 4, 7 bits have been allocated and the positions corresponding to the index of the split segments are set to '1'. Accordingly, Node N2 that receives data from node N7 may check the bit-identifier to confirm that the 1st and 2nd payloads have been sent, while Node N5 may check the bit-identifier to confirm that the 5th payload has been sent. The base station carries out data recovery using the Chinese remainder theorem (CRT) algorithm and the bit-identifier when the entire split packets are received.

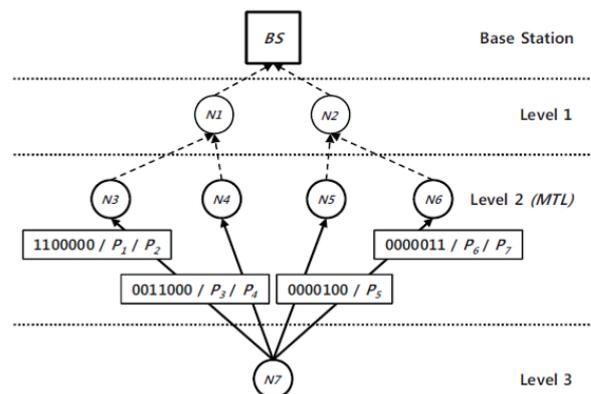


Fig. 5. Transmission of the split packets

3. PERFORMANCE EVALUATION

We have developed a simulator based on JAVA to evaluate our proposed scheme and the existing compression schemes [14]-[18]. This simulation was carried out by

constructing the performance evaluation environment shown in Table 1.

Table 1. Simulation Parameters

Parameters	Values
Multimedia data	Uncompressed MPEG-4 standard images provided by Xiph.org [19]
Length of multimedia data (Frames)	50
Format of multimedia data (px x px)	CIF(352 x 288) QCIF(176 x 144)

Fig. 6 shows the compression ratio per frame of the proposed scheme and the existing schemes. Although the occurrence of the deviation depending on the spatial complexity, JPEG-LS, L-JPEG, JPEG2000 and SPIHT reduced the original text data drastically regardless of image resolution. L-JPEG produces the highest compression ratio because it carries out loss compression. The proposed scheme is possible to reduce the size more drastically in comparison with the existing schemes because the proposed scheme can compress the multimedia sensor data into a very tiny remainder numerical value data within the scope of 1~16 byte by utilizing Chinese remainder theorem. As a result, the proposed scheme shows more excellent performance than the existing scheme-L-JPEG which had shown the highest compression ratio, and the proposed scheme improved data compression ratio by about 152.5% over the existing scheme.

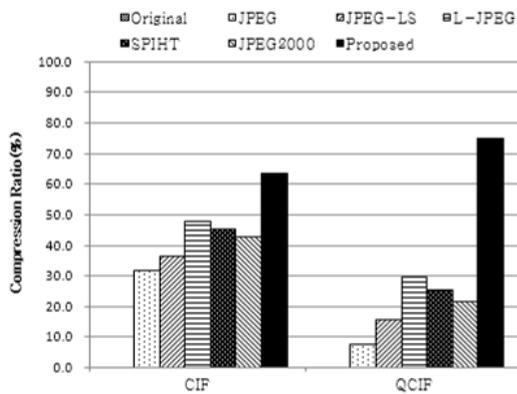


Fig. 6. Compression ratio per frame

Fig. 7 shows the compression operation quantity of the proposed scheme and the existing schemes. JPEG and JPEG 2000 which use DCT and DWT as pre-processing algorithms, and use arithmetic coding as a post-processing algorithm respectively, and in the same way SPIHT, which uses DWT as a pre-processing algorithm and uses arithmetic coding as a post-processing algorithm, require a large scale of arithmetic operation. The proposed scheme using Chinese remainder theorem based on the remainder operation which falls under the four fundamental arithmetic operations instead of complicated arithmetic operation shows a relatively low “operation quantity compared to the popularly used JPEG and JPEG2000. However, the proposed scheme shows a bigger arithmetic operation

quantity than JPEG-LS, which does not use DCT or arithmetic coding for reducing the complexity.

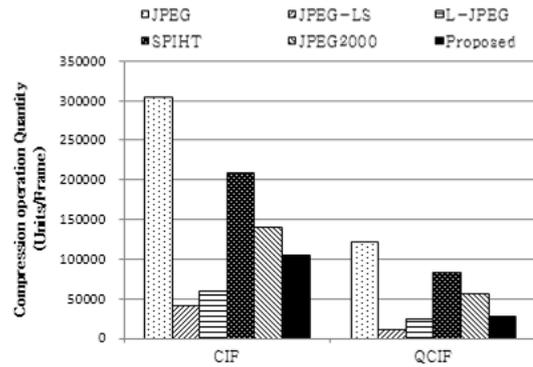


Fig. 7. Compression operation quantity

4. CONCLUSION

In this paper, we have proposed a novel data compression scheme for wireless multimedia sensor networks. Our proposed scheme splits and compresses the multimedia data using the Chinese Remainder Theorem(CRT) on the basis of the number of nodes in maximum transfer level and the remaining energy. And then it transmits the bit-pattern of the remainder to the base station. In addition, the entire energy could be balanced by differentiating the number of transmitted packets considering the remaining energy of the transfer nodes belonging to the upper level. Therefore, the proposed scheme can reduce the amount of data transmission. To show the superiority of our schemes, we simulated our schemes with many conventional schemes. As a result, it was shown through performance evaluation that the proposed scheme significantly increased compression ratio while reducing compression operation comparing to the existing compression schemes. In the future work, we plan to extend our work to prolong the lifetime of a sensor network by making a detour route in consideration of the remaining energy of entire nodes.

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