A High-efficiency Data Compression Scheme in Wireless Multimedia Sensor Networks

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1. Introduction

According to the recent development of hardware technologies and monitoring techniques, applications have been expanded that they are based on multimedia data collection such as audio, image, and video through multimedia sensor modules. As the size of multimedia data is much bigger different from a simple numerical data of the existing sensor network, it causes the excessive energy consumption in a specific node at the time of data transmission. As a result, it causes the problem of reduction in the network lifetime [1].

For the purpose of performance improvement in the wireless multimedia sensor network, the multimedia data compression schemes have been actively in progress as a representative study. The existing compression schemes are largely classified into a compression technique based on DCT(Discrete Cosine Transform), a signal compression technique such as EZW (Embedded Zero-tree Wavelet), and a code compression technique such as Pyramidal Vector Quantization [2]. As these existing compression schemes require many arithmetic operations for the data compression and a mass memory to store temporary data, they are not suitable to the wireless sensor network with the limited energy and computing performance. Moreover, as they need additional hardware modules for the compression performance, they require a lot of installation costs. Considering this, a novel compression scheme based on the Chinese remainder theorem for the multimedia data was proposed in [3]. The effective multimedia data compression scheme considered the characteristics and limitation of wireless sensor networks. However, the existing compression scheme suffers from energy consumption in the wireless multimedia sensor network with the limited energy.

In this paper, we propose a high-efficiency data compression scheme in wireless multimedia sensor networks. The proposed scheme considers the characteristics of sensed multimedia data to perform the first compression by deleting the low priority bits that do not affect the image quality. The second stage compression is also performed based on the Chinese remainder theorem for the undeleted high priority bits. By performing this two-stage compression, it is possible to reduce the multimedia data size in large. Through this, to the proposed scheme minimizes the energy consumption and increases the lifetime of entire network.

2. The proposed data compression scheme

As mentioned above, the sensor node is driven based on the limited energy and computing performance so that it needs an additional compression module to perform the data compression. However, it require a lot of installation costs. Considering this, transmitting the original data was common in the existing scheme. The image data sensed from the wireless multimedia sensor network has a data bit structure of the pixel unit, and each pixel has eight bits (0~255) per color channel (R, G, B). The same bits are bound together to compose a bit plane. As a result, the color image is composed of 24 bit planes in total. While the data sizes of the bit plane are equivalent, the amount of their expressible information and the importance are different. For example, each bit of the most significant 7-bit plane can express 128, but each bit of the lowest significant 0-bit plane can express only 1. In other words, the most significant bit plane shows a big color change and the lowest bit plane shows the small color change.

Based on this analysis, Figure 1 shows the image quality change according to the deletion of bit planes. When the most significant bit plane is deleted, serious damages to the quality of the original data occur. However, when the low significant bit plane data is deleted, it does not largely affect the quality of the original data. From the result, when all bit plane data cannot be transmitted, the high quality image can be maintained by deleting data near the lowest bit plane. In the proposed scheme, the first compression is performed for the image data based on this fact.

Figure. 1. Image quality change according to the deletion of bit plane data

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According to the result from the first compression performance, few bit plane data is selected as a transmission data. In this proposed scheme, the second compression based on the Chinese remainder theorem is performed for the transmission data. If the divisor and the remainder are known through the Chinese remainder theorem, it is possible to find the minimum dividend which satisfies this. Using this characteristics, it is possible to restore the original data in a particular node of the sensor network that has the limited energy and communication bandwidth by transmitting the remaining data instead of transmitting the whole data. As a result, it is possible to reduce the energy consumption due to the data compression. The proposed scheme carries out data separation and compression by using the Chinese remainder theorem and the following assumptions:

[Assumption 1] The base station should know the size of the original multimedia data, 2^{ω}.
[Assumption 2] A set of minimum prime numbers are chosen so that they are the smallest prime numbers that satisfy the condition $P_1 \times P_2 \times \ldots \times P_n > 2^{\omega}$. The base station should know the minimum prime numbers set in order to restore the original multimedia data.
[Assumption3] The prime numbers in the minimum prime numbers set are consecutive.

The proposed scheme minimizes the energy consumption and increases the lifetime of a whole network by utilizing this kind of multi compression scheme.

3. Performance evaluation

We have developed a simulator based on JAVA to evaluate the data transmission scheme without the compression scheme[3], the data transmission scheme without the compression scheme[4] and our proposed scheme.

Figure 2 shows the amount of transmission data according to the execution time. The amount of transmission data in the network is proportional to the size of transmission data in the initial source node. Therefore, since the data transmission scheme without the compression scheme transmits the sensed original images from the source node to the sink node, the amount of transmission data is largely increased. Since the data transmission scheme with the existing compression scheme also compresses and transmits all bit plane data of a sensed original image, the reduction of data size is limited. However, as the proposed scheme performs the compression for some bit plane of the original image, the size of data decreases largely. It was shown through performance evaluation that the proposed scheme reduces the amount of transmission data by about 55.6% compared to the existing compression schemes on average.

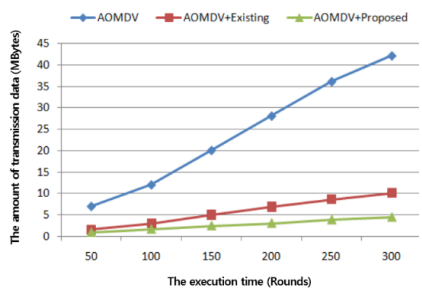

Figure. 2. The amount of transmission data according to the execution time

4. Conclusion

In this paper, we have proposed a new compression scheme in order to minimize the size of transmission data in multimedia sensor networks. To do this, we analyzed the problems of mass data under the environment of multimedia sensor networks. The proposed scheme performs two compression stages. In the first stage, it performs compression based on the deletion of low priority bit data. In the second stage, it performs compression based on the Chinese remainder theorem considering the characteristics of multimedia data. By doing so, the proposed scheme reduces the data size and also offers the high quality data. It was shown through performance evaluation that the proposed scheme decreased the amount of transmission data by about 56% compared to the existing compression scheme on average.

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