Optimization of Power Allocation in Multimedia Wireless Sensor Networks

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ABSTRACT

Wireless Sensor Networks (WSN) have been widely applied in monitoring and surveillance fields in recent years and have dramatically changed the methodologies and technologies in monitoring and surveillance. However, the sensor nodes in WSN have very limited computing resources and power supply, and thus the maximization of network life is a very critical issue. In the newly-emerging Wireless Multimedia Sensor Network (WMSN), the high volume of sensed video data needs to be compressed before transmission. Different video coding schemes have been developed and applied to wireless multimedia sensor networks, and there exists a tradeoff between the power consumption of data compression and that of data transmission. Video compression will reduce the amount of data that needs to be transmitted and thus the amount of power consumed for data transmission; however, too much video compression will consume excessive power which outweighs the power savings on data transmission. Thus, how to reach an optimized balance between compression and transmission and maximize network life becomes a challenging research issue. In this paper, the authors propose mathematical models which describe power consumptions of data compression and transmission of sensor nodes in hexagon-shaped clusters. Under the proposed model, they have achieved the optimized data compression ratio which can minimize the overall power consumption of the whole cluster.

Keywords: Cluster, Compression, Multimedia, Power, Sensor, Transmission, Wireless

1. INTRODUCTION

The availability of low-cost hardware has resulted in fast growth of WMSN with their applications in remote environment monitoring, video surveillance, image-based tracking, etc. (Akyildiz, Melodia, & Chowdhury, 2007; Bender, 2008; Puri, Majumdar, Ishwar, & Ramchandran, 2006; Molina, Mora-Merchan, Barbancho, & Leon, 2010; Akyildiz, Melodia, & Chowdhury, 2007). The amount of multimedia data sensed by the nodes is huge, and the data needs to be compressed before transmission.
The power constraints of sensor nodes require low-complexity and high compression efficiency in order to prolong the network lifetime. Both processing and communication power consumptions need to be carefully balanced and reduced to acceptable levels to make the multimedia transport over WMSN feasible.

In WMSN, power allocation between compression and transmission is a critical issue. In one extreme, if no compression is performed at all on the sensed data, then the transmission data rate is the same as the sensed data rate, and the battery power of the sensor nodes is consumed exclusively on data transmission. On the other hand, if we compress the multimedia data as much as possible and minimize the output data rate of the video encoder to minimize data transmission power, then the compression power consumption is maximized. In this case, the overall power consumption may be much more than transmitting the raw uncompressed data without any compression (Tahir & Farrell, 2009). Thus, the battery power of the sensor nodes need to be carefully allocated between compression and transmission in order to minimize the overall power consumption and maximize the network life.

How much compression should be performed on the raw sensed data before its transmission, leading to network lifetime maximization, is the question that we try to answer in this paper. We adopt a hexagon clustering model which utilizes 2-dimensional Poisson distribution to model the sensor network (Wang, Lin, & Xu, 2011). Under this clustering model, we analyze the tradeoff and balance between power consumptions in data compression and transmission and try to achieve an optimum compression ratio for the sensor nodes in the network.

The rest of the paper is organized as follows. In Section 2, different video compression techniques are reviewed; in Section 3, we outline the node and network models as well as the set of assumptions underlying these models; the power consumption models for data compression and transmission are discussed in Section 4; the optimum compression rate that minimizes the overall power consumption will be discussed in Section 5; in Section 6, we will discuss the performance analysis of the power consumption mode; the paper will be concluded in Section 7; future work will also be discussed in Section 7.

2. VIDEO CODING SCHEMES FOR WIRELESS MULTIMEDIA SENSOR NETWORKS

2.1. Predictive Video Coding

In WMSN, usage of video encoders such as predictive encoders such as H.26x, MPEG-x, necessitates higher processing and memory capacities. The key idea of predictive coding is to utilize motion estimation and motion compression to reduce temporal redundancy, use Discrete Cosine Transformation (DCT) to remove spatial redundancy, and then use Huffman/Arithmetic Coding to reduce coding redundancy. The state-of-the-art predictive video encoders have very good rate distortion characteristics by following the classical complex encoder and simple decoder balance. The computational complexity of the encoder is much higher than that of the decoder.

Predictive coding can reach high compression ratios and dramatically reduce the bit rate of the source video. However, predictive coding schemes has the following disadvantages when being applied to WMSN: (1) high memory requirements due to the need to store reference frames (used for motion estimation); (2) processing delay caused by motion search; (3) high power consumption due to the complexity of motion estimation/compensation algorithms; (4) sensitivity to packet loss and errors in wireless transmission (Figure 1).

2.2. Intra-Frame Video Coding

Unlike predictive coding, intra-frame video coders exploit only spatial correlation within each
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