Computers and Electrical Engineering 48 (2015) 389–404

Contents lists available at ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

An energy saving audio compression scheme for wireless multimedia sensor networks using spatio-temporal partial discrete wavelet transform ☆

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ARTICLE INFO

Article history:
Received 19 December 2013
Received in revised form 6 September 2015
Accepted 9 September 2015
Available online 14 November 2015

Keywords:
Wireless multimedia sensor network
Compression
Partial discrete wavelet transform (PDWT)
Spatio-temporal Partial discrete wavelet transform (STPDWT)
Spatio-temporal Partial discrete wavelet transform with Encoding (STPDWTE)
Tree based routing

ABSTRACT

Due to strict inherent limitations in terms of processing power, storage and bandwidth, data processing is a challenge in the wireless multimedia sensor networks. In this paper, we provide an energy-saving audio data compression technique for such a network using lifting based partial discrete wavelet transform (PDWT). Unlike existing implementation of such a lifting based PDWT, we exploit both spatial and temporal correlation of data together, with an objective to save energy while achieving acceptable signal-to-noise ratio (SNR). We subsequently design a tree based routing scheme and an encoding scheme to be used with the proposed compression scheme with a target to reduce energy further. Finally, the design feasibility along with simulation results, including statistical analysis is presented to evaluate efficacy of the scheme in terms of two conflicting parameters viz. energy consumption and SNR. The comparative results confirm our scheme's supremacy over a few competing schemes.

1. Introduction

The availability of low-cost hardware and advancement in short range radio communication has enabled the development of wireless multimedia sensor networks (WMSNs). The WMSNs can process multimedia data such as video and audio streams, still images collected from the application area [1,3]. Energy is one of the scarcest resources [4] in such networks. In-network processing is one of the techniques to save energy and data compression is one of the implementing techniques of in-network processing.

Generally, the sensor nodes are densely spaced and therefore, the sensory data are bound to be spatially correlated. On the other hand, in the majority of real time signal processing (e.g. audio signal) applications, high temporal correlation exists [2] in addition to spatial correlation. Typically in the continuous monitoring application, e.g. road-traffic pollution control, sensory data comprises of both spatially and temporally correlated data. We consider such a continuous monitoring application domain. The various transform techniques (e.g. DWT, DCT) usually exploit spatial correlation of data. However, in order to save energy further while maintaining quality retrieval of compressed data, in presence of both types of correlation, the obvious choice is to have compression technique, which exploits spatial and temporal correlation of data together.

☆ Reviews processed and recommended for publication to the Editor-in-Chief by Associate Editor Dr. S. Thampi.

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http://dx.doi.org/10.1016/j.compeleceng.2015.09.009
0045-7906/

1.1. Motivation

In WMSN due to strict inherent limitations in terms of processing power, storage and bandwidth data processing is a challenge. Most of the state-of-the-art techniques used in compression applicable to WMSN exploit spatial correlation to save transmission energy. However, in order to save energy further while maintaining quality reconstruction in terms of good SNR usage of temporal correlation is also desirable. This motivates us to exploit spatial and temporal correlation together in order to achieve energy-saving while keeping reconstruction quality (SNR) to an acceptable limit.

1.2. Contribution and organization

Precisely our contributions are as follows:

- We propose an energy-saving data compression scheme for WMSNs where nodes are randomly deployed.
- Unlike conventional compression techniques, energy is primarily saved by exploiting spatial and temporal correlation together.
- Energy is further saved by proposing a tree based routing, which ensures a unidirectional data flow toward the sink.
- A lossless encoding scheme is proposed to save energy further.
- We establish the supremacy of our technique by experimental verification and comparison with other state-of-the-art techniques by taking real time multimedia data.

The rest of the paper is organized as follows. Literature review is placed in Section 2. Brief on preliminary version of this work is provided in Section 3. System model is described in Section 4. The proposed data compression scheme along with routing and encoding is elaborated in Section 5. Performance evaluation of the scheme is described in Section 6. Finally, the work is concluded in Section 7.

2. Literature review

Many works have so far been reported where energy-saving data processing technique in WSN/WMSN is addressed. In one such work [5], a distributed wavelet compression algorithm has been proposed for data compression in WMSN. The algorithm implements distributed wavelet compression using lifting method. This method helps to decorrelate data by exchanging information among neighboring sensor nodes. The advantage of this is in-place computation reduces the transmission cost. However, measurements at the sensor node may contain vectorial data, which means each sensor node would acquire data over time.

Another wavelet lifting based scheme is proposed in [6] where the compression algorithm has been made adaptive. The scheme is made adaptive by selecting an appropriate number of decomposition level based on the network structure, power constraint in sensor nodes and data correlation among sensors. In choosing the best level of decomposition the same step size of the quantizer is considered to make the quantizer error negligible. This helps to reduce energy consumption with good reconstruction. However, both the schemes [5,6] do not consider temporal correlation and assume one-dimensional linear placement of the nodes which is not a very realistic assumption.

In the work [7] the authors have designed a lifting-based 2D transform exploiting spatial correlation for WSNs with flat/arbitrary architecture. This transform enables unidirectional computation found in existing path-wise transforms, thereby eliminating costly backward transmissions while achieving greater data decorrelation than those path-wise transforms. The transform is also optimized by exploiting the trade-off between higher local overhead for complex coding and lower transmission overhead. This scheme also has not exploited temporal correlation.

The authors of [8] have also proposed a lifting-based wavelet scheme by appropriate designing of even/odd splitting of nodes in a network with flat/arbitrary architecture. The split is done in such a way that minimizes the number of even nodes to reduce correlated sensory data while ensuring at least one even node in the vicinity of the odd nodes. Since an even node is generally a raw data node, it transmits data first, followed by computation at the odd nodes. The odd nodes upon receiving all the data from the even node compute predicted data values and after that transmit its own data to the next node. The communication between the nodes is actually achieved through a transmission schedule based routing, which states that if a communication path is established by two nodes, then that path cannot be utilized for other transmission. Here energy consumption due to raw data transmission by even nodes is reduced, however, network delay increases. Similar to many other techniques, this work also exploited spatial correlation only.

The authors of [9] have presented an energy efficient compressed data steam protocol (CDP) where they exploit temporal correlation of sensory data. To start with a General predictive coding (GPC) is employed where the difference between the current and previous data samples is estimated based on which either the data is encoded, or it is transmitted as a raw sample. In order to minimize the packet overhead and memory use in CDP, a data stream is defined as an aggregate flow of multiple individual sensor data flows from a single mote employing the same compression algorithm. The design of compressed data-stream protocol (CDP) is generic in the sense that other lossless or lossy compression algorithms can be easily ‘plugged’