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A Discrete Wavelet Transform Compression Technique Used in Underwater Sensor Network (UWSN) for Energy Efficiency

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Abstract: **The underwater sensors are used in various activity monitoring, data sensing or other similar applications. The underwater sensors works in the dense medium than the air, which increases the possibility of higher data drop rates etc. The higher data drop rate decreases the efficiency of the Underwater Wireless Sensor Networks (UWSN), because high volumes of data drop causes higher number of missing values, which directly affects the statistical calculations. In this paper, the model has been proposed for the data compression of the sensor data in the underwater applications. The proposed model is offered with the discrete wavelet transform (DWT) method of compression. The DWT method decomposes the data into multiple coefficients. One coefficient is known as the approximation coefficient, which is the approximation of the original data, and the original data can be produced by using the reverse DWT process. The proposed model has been evaluated on the basis of network load, data loss, and power consumption etc. The experimental results have shown the effectiveness of the proposed model.**

Key words- **Data compression, Electromagnetic signal compression, Signal decomposition, Wavelet compression, Underwater sensor applications**

I. INTRODUCTION

Wireless Sensor Network (WSN) is composed of multiple small electrically charged devices named as sensor nodes. WSN deployed either in underground, aboveground or in underwater. Batteries are the working base for these sensor nodes, but the lifespan of their batteries is very less due to energy consumption by nodes in sensing, processing and transmitting the data from one node to another. Sensing and processing consumes less energy but most of the energy is utilized while transmission. Underwater Wireless Sensor Network (UWSN) faces more problems than in terrestrial WSN due to ionized nature of water as most of the energy is smashed due to several factors. For propagating in ionized sea water electromagnetic waves or optical waves are used as Radio waves are absorbed by the water. USWN used in various applications like disaster prevention, military activities, scientific research etc.

Without being able to replace the battery of sensor nodes, power consumption is a major challenge in UWSN. The main aim of this paper is to overcome the problem of power consumption, so that battery life of nodes will increase which in turns increases the end user work. To overcome the problem or power consumption, various techniques are applied like various routing algorithms are applied like SH-FEER and MH-FEER [1] routing algorithm, Autonomous underwater vehicle (AUV) is used which is responsible for collecting data from various nodes and the send it to the base or sink node and various other compressed sensing algorithms are used which is used to compressed the data before transmitting. One of the main technique which can overcome the problem battery issue is Data compression.

Data Compression is a technique which is used to compress the data by reducing the number of redundant bits and then transmitting the compressed data to the receiver. Compressed data utilize less energy than original data, thus enhancing the battery life. Data compressions are both loss and lossless techniques. Discrete Fourier Transform (DFT) and Discrete Wavelet Transform (DWT) both are lossless data compression techniques.

DFT works in frequency domain, so there is a need to convert signal from time domain to frequency domain which also utilize energy. But DWT works in both time as well as in frequency domain, so this technique is more easy to use.

II. SURVEY REPORT

Sihem Souiki et.al[2015] proposed two clustering algorithms depend on Fuzzy C-Means technique. One is Single-hop Fuzzy Based Energy Efficient Routing Algorithm (SH-FEER) and the other is Multi-hop Fuzzy Based Energy Efficient Routing Algorithm (MH-FEER). SH-FEER process involves three steps: first is cluster formation i.e. clusters are formed randomly with different number of nodes, second is cluster head enrollment i.e. initially one node from the cluster becomes a cluster head based on the nearness of a node from centre and after that the node with highest energy will take the charge of cluster head, and the third is data transmission through single-hop. Cluster head is the one who is responsible for aggregating data from non-head nodes and then transmit aggregated data to the sink node through single-hop routing. MH-FEER scheme also consists of three consecutive steps, in which first two are same as that of SH-FEER i.e. cluster formation and head selection but in this process data is transmitted through multiple cluster heads depends on the shortest path to the sink node. These two algorithms are further applied on both static and dynamic deployment of sensor nodes in underwater. This algorithms result in addition of battery life.

Zigeng Wang et.al[2015] targeted on power consumed by each sensing component used in underwater sensing system for communication. This sensing system composed of number of components like underwater sensor nodes, micro-control unit (MCU) and acoustic communication device. Power consumed by each sensing system will be calculated and analyzed at various states like in sleeping state, in idle state, in sampling state etc. and at different time intervals. Average power consumption is calculated with deployment designs. To save power consumption, MCU follows OMAP design which permits the Linux kernel, a power manager to put unimportant data in sleep mode. Power management feature can switch the system into different modes of operation to save energy depending on the application being run on the system. The central control and processing module targeted the process of calculating the power consumption before and after the improvement which results in less power consumption. This paper surveyed various methods to improve the battery life and to decrease the power consumption by sensing components.

Chun-Hao Yang et.al [2015] analyzed the occurrence of collision between two transmissions in three-dimensional underwater sensor networks. In USN, the acoustic waves are responsible for propagating data which is comparatively slower in speed than electromagnetic waves in terrestrial networks, which can theoretically, proves that the collision occurrence in underwater is less than in ground. But to prove practically, a distributed delay aware and energy efficient routing protocol (DEEP) method is introduced. DEEP considers distance-bandwidth dependency and also tells the link connectivity issue. DEEP successfully fulfilled the demand of packet delivery to the receiver without any delay. To avoid packet delay and to send the time critical data to the receiver on time, DEEP does not send acknowledgment to the sender which in turns avoid collision occurrence, and consumes less power for data transmission than other routing protocols. DEEP model works with real parameters. Even in unfavorable network environment DEEP gives high packet delivery ratio and high data rate. This shows that the DEEP performs better than the existing schemes.

Stefano Basagni et.al [2014] focused on monitoring of wireless sensor nodes buried underwater. Purpose of this paper is to find best data collecting route to the sink node located on the surface of water using autonomous underwater vehicle (AUV) in order to get maximum value of information (VOI) of data to be delivered. Underwater sensor nodes sensed the data and record the same in its memory, which is then carried away to the sink node by AUV. AUV are equipped with optical communicating devices whereas nodes are blessed with acoustic modems for the purpose of exchanging information with each other. The performance of two techniques is compared in order to get best results for VOI. First technique is Integer Linear Programming (ILP), it works with AUV for deciding the best suitable route for collecting data from nodes and sending it to sink node that boost the VOI of data. ILP considers AUV speed, data generation and sensing rate. Second technique is Greedy and Adaptive AUV Path (GAAP) to collects the data packets first with high VOI i.e. path is selected taking into account of maximum VOI. Thus, results shown by GAAP are far better than ILP model. GAAP delivers 80% of maximum VOI.

Ayman Alharbi et al[2014] advocated a new system architecture named Underwater Sensing and Processing Network (USPN) to alleviate the major issue of energy consumption in underwater sensor networks. USPN applies various energy efficient algorithms to reduce the data size of node and thus, in turns utilize less energy for transmission which reverts in extra battery life of node. Two designs are discussed in this paper: In first design, a single composite node communicates with the sink node or gateway. Composite node is a one that is able to perform complicated algorithms as this node is blessed with high-feature processing unit; this node is responsible for reducing the size of data packets by applying any technique either by compressing data, or by data mining. In second design, communication with the sink node is done via relay node which is comparatively less expensive than composite node. In this the composite node is chased by number of relay nodes, the compressed data is sending to gateway through relay nodes in packets. The performance is analyzed on the basis of various parameters like signal-noise ratio, performance ratio, depth, distance. Thus, the results come after reducing packet size will enhance the battery life of senor node.

Wafa Mohamed Elmannai et.al[2015] focused on data compression technique used in underwater sensor network. The main aim of this paper is to face the major issue of battery life of sensor nodes, as these nodes are not able to recharge, so to alleviate the major problem of power consumption, a data compression technique Discrete Fourier Transform (DFT) is used. In this paper, two algorithms are used: one is DFT and other is Morse code. DFT works in frequency domain, so it first converts the sound signal from time domain to frequency domain as it is easier to work in frequency domain. Second is Morse code which is used to compress the text to speech or light. Morse code requires skilled listener and a decoding device. As in underwater, propagating distance is less due to ionized nature of water, but with DFT propagating distance increases without the increase in power consumption. Thus, these compression algorithms give better results which enhance the battery life of sensor nodes.

III. EXPERIMENTAL DESIGN

The discrete wavelet transform (DWT) technique has been used in the proposed model for the signal decomposition and compression using the multi-level decomposition level based system offered using the DWT. The study has been conducted over the various compression schemes including the existing compression model of discrete Fourier transform (DFT). Primarily the study has been conducted over the popular wavelet compression methods of Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT) and Discrete Fourier Transform (DFT) models along with other bit or entropy encoding methods such as run length, Huffman encoding and LZW.

The selection of DWT is entirely based upon its efficiency for the data compression applications, specifically in the case of network components. The effectiveness, quickness and robustness of the discrete wavelet transform (DWT) have influenced us to use it for the underwater sensor data compression

Algorithm 1: Compression Algorithm

1. The sensing signal is acquired by the DWT based compression module.
2. The signal is sampled and divided in the blocks of 8 bytes.
3. Working in the LR (left to right) fashion the DWT is applied over each block divided from the signal.
4. Each signal data block is compressed through the DWT quantization method.
5. The DWT algorithm supports separate signal quantization step-sizes for each decomposition coefficient or sub band for each block. The quantization is performed in the step sizes known as Δ_j for every sub band *j*. *It* is calculated based on the dynamic range of the sub band values. The formula of uniform scalar quantization with a dead-zone is

$$q_j(m,n) = \mathrm{sign}(y_j(m,n))\left\lfloor \frac{|W_j(m,n)|}{\Delta_j} \right\rfloor$$

Where $W_j(m,n)$ is a DWT coefficient in sub band *j* and Δ_j is the quantization step size for the sub band *j*. All the resulting quantized DWT coefficients $q_i(m,n)$ are signed integers.

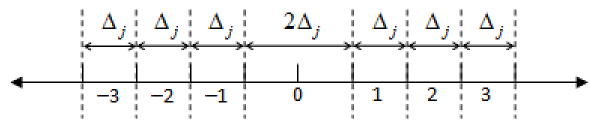

Figure Dead-zone quantization about the origin.

6. The array of compressed blocks that constitute the image is stored in a drastically reduced amount of space.
7. When desired, the image is reconstructed through decompression, a process that uses the inverse discrete wavelet transform (iDWT).

IV. RESULT ANALYSIS

The results have been obtained in the form of various performance parameters such as load, data loss, delay, frequency and energy consumption levels. The proposed model evaluation has been performed in the detailed manner on the basis of the listed performance parameters. The performance parameters indicate the various aspects of the proposed model evaluation for various data compression levels. The performance parameter of data loss indicates the data loss during the communications. The data loss should be always under the check for an idle communication model. The data losses usually occur due to the over-burdened traffic volumes. The data loss can be prevented using the wavelet based compression model for the underwater sensor networks.

The performance parameters of delay and throughput indicate the performance of the network in the case of delivery of data packets from one point to another. The data compression model must be capable of decreasing the network delay while keeping the higher level of throughput for the underwater sensor network.

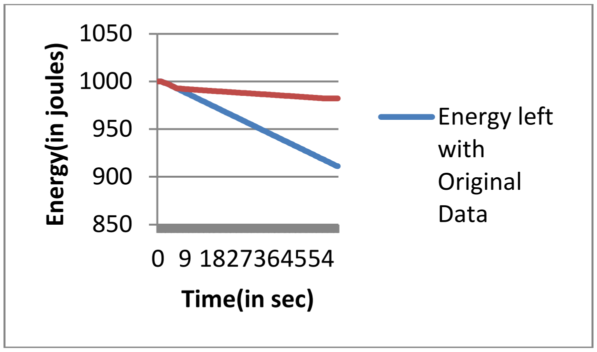

Figure 1: Residual Energy based Comparison

Residual Energy means energy left with nodes while transmitting the data between the nodes. In the above graph the comparison is shown between the existing model i.e. the original model where no compression is done and the proposed model where DWT technique is applied which shows that compressed data consumes less energy and therefore leads to power consumption.

Packet Loss means the number of packets lost per second. In Figure 2 graph, the packet lost in existing data is more than in compressed data which shows that DWT technique enhance the network environment by reducing the packet loss.

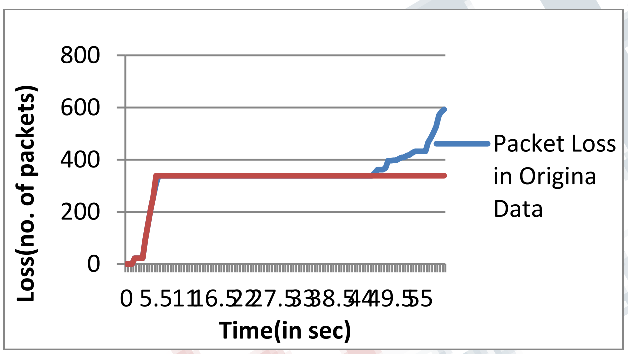

Figure 2: The Packet loss rate based comparison

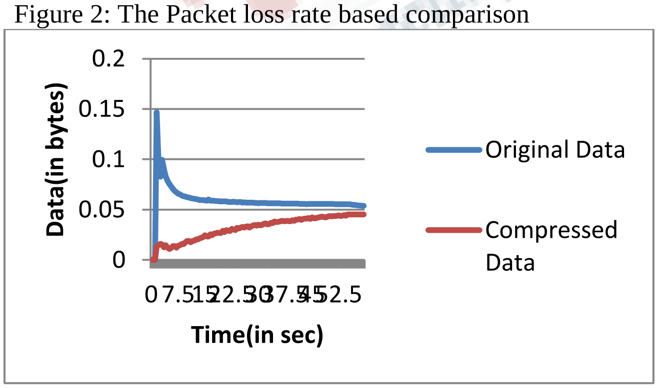

Figure 3: The data delivery depicts the delay in the proposed model

Delay and load are connected to each other as more load on the network leads to more delay in receiving the packets. Figure 3 represents the delay in bytes per second between the original and the proposed technique which shows that the compressed data give less load on the network which in turns results in less delay n receiving the packets. Figure 4 represents the amount of load in bits per microsecond, as wavelet compression will erase the redundant bits and number of data wavelets are formed which gives less load on network.

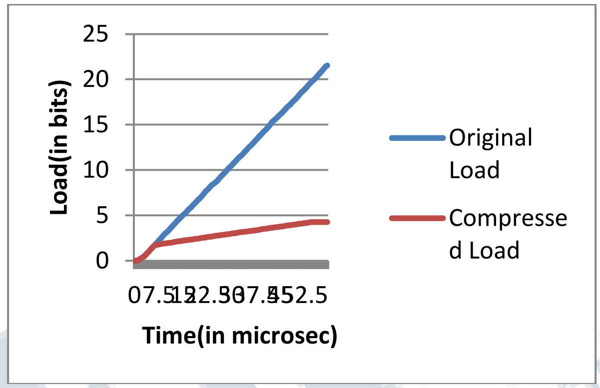

Figure 4: The above graph depicts the load based comparison.

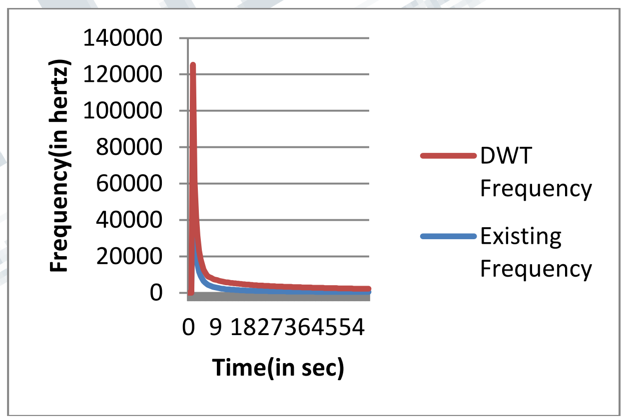

Figure 5: Frequency based comparison between existing and proposed.

Frequency means the number of bits transferred from one sensor node to another per second. The average frequency obtained in the original data where no compression is done is 2300 joules but after using wavelet technique number of bits transferred per second is 3000 joules which shows the effectiveness of the technique than the existing one. Figure 5 shows the frequency comparison and thus the figure 6 shows the throughput rate, as more the number of bits transferred from the network per second more is the throughput obtained.

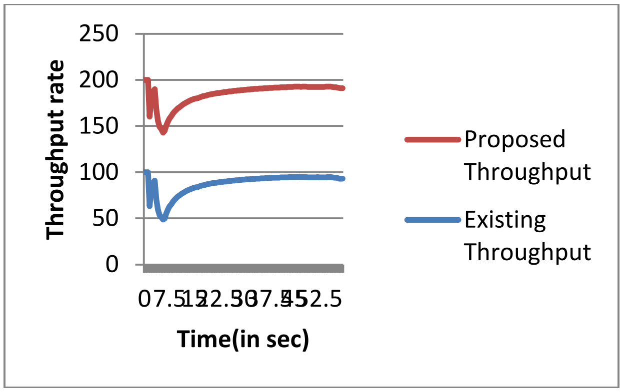

Figure6: Throughput rate comparison between the existing and the proposed one.

The proposed model results have shown the effectiveness of the proposed model. The proposed model has been recorded with the performance parameters throughput, packet loss rate and residual energy. The proposed model has performed well in comparison with the normal situations or the existing models.

CONCLUSION & FUTURE SCOPE

The proposed model has been based upon the data compression for the underwater sensors using the discrete wavelet transform (DWT). The proposed model has been evaluated using the first level of DWT compression in which numbers of wavelets are formed which are encoded and then decoded. By using this technique, energy left is more than the existing one. The above results shows the effectiveness of the technique in terms of less delay, less packet loss, more throughput and more residual energy and therefore successful in saving the energy or power battery. In future, this compression technique is to be used with some other technique like with Morse code or with LMW to get the better results and thus saving more energy.

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