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An Efficient Energy Savings Schemes using Adjacent Lossless Entropy Compression for WSN

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Abstract—*The proposed work aims at designing routing method and data compression algorithm for WSN's. An ad-hoc network (WANET) is considered and based on certain criteria the data is forwarded dynamically. Various parameters such as Compression Ratio, Packet Delivery Rate, Energy consumption are considered to determine the efficiency of the network. One of the primary parameters to be considered in the configuration of Wireless Sensor Networks (WSN) is the energy consumption of the nodes and the data throughput. Since the nodes are controlled by batteries with lower energy limit, it is required to minimize the energy utilization. Henceforth a proficient routing technique in light of LEACH protocol is proposed alongside the utilization of A-LEC data compression strategy.The simulations are carried out through Network Simulator 2 (NS2). The compression code is written in GNU-C*

Keywords— Multi-hop routing, LEACH, LEC compression, Energy consumption., network lifetime,

I. INTRODUCTION

Due to the inception of nano technology and MEMS [1] (Micro electro Mechanical systems), WSN's have been realized to create network with actuators and sensors. Similarly, technological emergence in communication hardware, low power VLSI design and embedded computing are combinely helpful towards making the innovation show up as a reality, the combination of computing and communications has the capability to create revolution everywhere. It incorporates financial aspects, ecological checking, mining, meteorology seismic observing, acoustic discovery, medicinal services applications, process observing, foundation assurance, setting mindful figuring, undersea route, brilliant spaces, stock following and strategic military reconnaissance.

The adequacy of the WSNs lie in their detecting quality, adaptability, vitality utilization, versatility, system lifetime, versatility, scope, and so on they can offer. WSNs normally turn into the principal decision with regards to organization in remote and dangerous environment.

A definitive objective of such WSNs sent in the above scenarios is to send the detected information from sensors to sink followed by further examination at the sink. The performance of such WSN's depends on the way data is collected, the sensor topology, amount of data travelling in the network and so on. To achieve good performance, many network topologies and their routing protocols have been proposed for information gathering. Administration of topology plays an important role in diminishing various limitations like failure of node and communication, crisis of computational resource, less energy, traffic, delay and so on.

The type of routing path – unicast or broadcast, the size of data packets, overhead are determined by the topology. The performance, lifetime, network coverage and the Quality of Service of the network depend directly on the topology. Hence it is important to choose the right topology to enhance the network parameters. Energy consumption is one of the significant parameters which has a significant role in performance of WSN. The energy consumption depends upon the distance between the sensor nodes. The power consumption is proportional to the distance to be transmitted between the nodes

II. LITERATURE SURVEY

Few of the existing methodologies are overviewed in this section. The focus is more on lossless data compression algorithms: C M Salder and M. Martonosi [1] have proposed a low complex data compression algorithm for WSN's that lack resources. It is a modified form of the Lempel-Ziv-Welch algorithm. In this paper, the Sensor LZW is modified and the better energy saving is obtained by using different amounts of compression. The data sets from several real world data are used and 0reduction in energy consumption upto 4.5 x is obtained.

F. Marcelonni and M. Vechio [2] have proposed a lossless compression algorithm comprising of predictive coding in which encoder and predictor are used. The aim is to reduce the computational and storage resources. Huffmann coding is used to code the residues obtained from the predictor. The compression algorithm is implemented and simulated on Avrora and environmental dataset is used as input. A compression ratio of 27.25% is obtained for Temperature data and a ratio of 42.57% is obtained for relative humidity. Though compression is performed here the energy consumption is not analyzed. The comparison of compression ratio is performed w.r.t gzip and bzip2 and is found to outperform both the methods. It is also noted that the algorithm is not effective when the correlation of data changes since it does not adapt to changing data.

J Tehola [3] developed an algorithm for lossless compression based on Golumb Coding. The basic form of Golumb Code consists of prefix code and rail code separated by a separator bit which is usually a zero bit. This is applicable for coding run-length sequences which mainly consists of clusters of either 0's or 1's. For example if the original binary code consists of clusters of zero's, the prefix code is the group of 1's representing the clusters in kth powers of 2 of zeros (Sub-Clusters). The construction of Golumb Code is modified by representing the sub clusters of zero's by grouping them in exponentially increasing order of kth powers of 2. By doing so the size of prefix code decreases. Large compression ratios of upto 64.99% were obtained by choosing an optimal k.

H. Nakayama and N. Ansari [4] proposed a movable sensor node around the area of sensing which essentially collects data from the nodes , and the energy is balanced effectively. Due to the advancement in MEMS, complicated sensors are available and as a result mobile nodes and sinks are conceivable. The proposed method here uses several mobile sinks to gather data. The data gathering method is faster and hence the data would be collected in a real time manner. By using mobile nodes along with hierarchical routing the paper demonstrates conserving energy as efficiently as possible. The disadvantage is the non-possibility of deploying mobile nodes and sinks in various areas.

J Al-Karaki and Ahmed E. Kamal [5] have made a survey on routing techniques in WSN. The routing methods surveyed are categorized into flat, hierarchical and location-based based on the structure. The protocols are classified as : multipath based, query-based, negotiation-based and QoS based. All the above structures have the same purpose of increasing the network lifetime without affecting the delivery of data.

C K Toh [6,7] wrote a paper on Maximum Battery life routing for Wireless Ad hoc networks. During simulation here, five different routes selection methods are analyzed : Minimum transmission power, Minimum battery cost, Min-Max battery cost, Conditional Max-Min battery cost and Stability of Association. Among these, the Conditional Max-Min Battery Cost was found to be most effective assuming the transmission power of each node is equal in all the cases. The proposed algorithm here is conditional max-min battery capacity routing which selects a shorter path if the nodes in all routes possess enough battery capacity. A threshold γ is set. If the node energy falls below it, every route going through the node is avoided.

W. Heinzelman and A. Chandrakasan [8,9] have analyzed Low energy adaptive clustering hierarchy, a protocol for Wireless Micro Sensor Networks. Here, a protocol architecture consisting of efficient energy cluster method routing along with data aggregation is used. The results of using LEACH shows that the network lifespan can be increased by an order of magnitude in comparison with general multi-hop techniques. In addition the method here shows a reduction in energy dissipation and latency[10,11,12].

III. PROPOSED PROTOCOL METHODOLOGY

We proposed a method to minimize the energy utilization of the nodes including effective routing with data compression. Filter calculation is utilized to course the data and A-LEC technique is utilized to pack the data got by the nodes.

Lossless Entropy compression encodes the residue/difference sequence using modified Golumb code. The residues ri = (i = 1,2,3,…….,N, where N is the size of data block) of LEC are assumed to be uncorrelated to each other. Therefore they are coded independently. LEC performs well if the differential predictor captures the temporal correlation roughly, based on residue independence. Otherwise it would perform badly in cases where the residue sequence is dependent and correlated. By considering that the residue sequence is correlated, it is possible to devise a modified form of LEC known as A-LEC(Adjacent LEC) which can exploit the correlation better and yield a higher compression ratio.

3.1 LEC Overview:

The residue sequence of integers produced by the differential predictor is packed into groups which increase exponentially in size. Codeword of LEC mainly consists of two parts :

1) Entropy Code indicating the group
2) Index in the group indicating the position of the residue in the group

Subsequent groups in the table differ by 1 bit in the entropy code. The size of each group increases exponentially with n. Hence the group size is equal to 2n. Therefore by having a common code entropy code for a large number of group entries, the code word reduces substantially, since it is seen that that the residues normally won't exceed the 8th group.

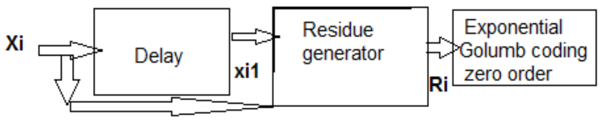

Fig.1: Block diagram for LEC Compression:

Above Figure explains the working principle of LEC Compression. Based on the modified method of exponential Golumb Coding, the integer residues xi's obtained from the residue generator is divided into two groups whose size increase exponentially. Referring to table 1, for residue Ri not equal to zero, Ri coded as hi|ai, where hi represents the code for the group to which the residue belongs to and ai represents the index or the position of the residue in the group to which it belongs to. The table consists of sixteen groups. For if the obtained residue is say +9, the group it belongs to is (±8, · · · ± 15) where hi = 101 and its position in the group (+8,*-8*,+9,*-9* · · · ± 15) is 3 whose binary representation is 011. Therefore ai = 011. The representation of +9 would be a concatenation of hi and ai which is 011101. Similarly other residues are coded. If residue is 0, ai is omitted.

Table.1: LEC Coding

n	h(n)	d(n)
0	00	0
1	010	-1,+1
2	011	-2,+2,-3,+3
3	100	±4, · · · ± 7
4	101	±8, · · · ± 15
5	110	±16, · · · ± 31
6	1110	±32, · · · ± 63
7	11110	±64, · · · ± 127
8	111110	±128, · · · ± 255
9	1111110	±256, · · · ± 511
10	11111110	±512, · · · ± 1023
11	111111110	±1024, · · · ± 2047
12	1111111110	±2048, · · · ± 4095
13	11111111110	±4096, · · · ± 8191
14	111111111110	±8192, · · · ± 16383
15	1111111111110	±16384, · · · ± 32767

3.2 A-LEC Method :

Adjacent LEC is a modified form of LEC devised for robustness. The context information among the residues is exploited by the algorithm. A-LEC uses an extra codeword si into the main codeword. Si acts as a set of status bits which specify one among the four conditions as shown in table 2. The concept here is that while coding the present residue the contextual information of the previous residue is considered.

Table.2: A LEC coding table

S_i	Context Data	Codeword for $h(n_i)$	Group
00	$n_i = n_{i-1}$	No codeword for h	Same
01	$n_i = (n_{i-1}) - 1$	No codeword for h	Neighbor above
10	$n_i = (n_{i-1}) + 1$	No codeword for h	Neighbor Below
11	Otherwise	$h(n_i)$	Otherwise

- For Si = 00, the present residue is same as the previous residue and the code word for h in the present residue is omitted.
- For Si = 01, the present residue belongs to the group just above the group of previous residue. Here again, the code word for hi is omitted.
- For Si = 10, the present residue belongs to the group just below the group of previous residue .Again, the code word for hi is omitted.
- For Si = 11, the present residue belongs to a non-neighbor different group. Here the code word for hi should exist in the main code word.

The number of nodes in the area comprising the hotspots is less when compared to other area in the network. Therefore the volume of data generated by the hotspot area is small in comparison with the amount of data flowing into the hotspot area. This suggests that majority of the power consumption in the hotpot area is by forwarding the data coming from outside the hotspot. To decrease the energy consumed in the hotspot, the volume of data sent to the hotspot must be decreased. The energy required to transmit the data is proportional to the amount of data to be transferred. Data compression can reduce the amount of data. Since in general the environmental data collected by the sensors (temperature, humidity, and atmospheric pressure) is correlated, it can be compressed. The extent of compression or the compression ratio depends on the amount of correlation in the data. The proposed scheme here utilizes hierarchical routing outside the hotspot and flat multi-hop routing inside the hotspot area. Hierarchical routing makes sure data is The performance of the network is studied under 4 scenarios and comparisons are made.

1) CC-BTS transmission without compression
2) CC-BTS transmission with compression
3) CC-CC transmission without compression
4) CC-CC transmission with compression

The simulations are conducted in NS2 and the following graphs for the residual energy was obtained. Compressed before sending it to the hotspot and flat multi-hop routing optimizes the distance metric in the hotspot area.

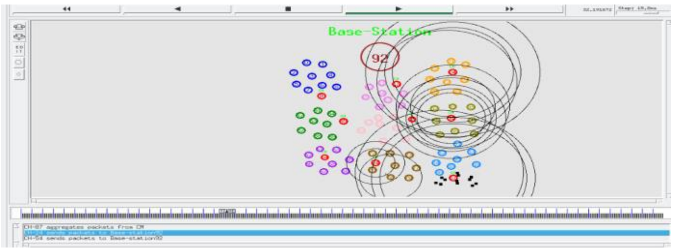

Fig.2: CC 24 and CC 54 sends data packets to the sink

As shown in fig 2. above, CC 24 and CC 54 send data packets to the sink. The data is compressed using A-LEC method (Adjacent Lossless Energy Compression). In LEC, the data collected by the nodes is given to a difference computation block whose output is a sequence of residues ri (i=1,2, . . M). The residue sequence is encoded by the entropy encoder and are considered to have no correlation amongst each other and hence are coded independently. The central idea here is to formulate a coding method that would exploit the temporal correlation in the residue sequence and thereby resulting in higher compression ratio.

IV. RESULTS AND PERFORMANCE EVALUATION

The environmental monitoring real world data sets from Sensor-Scope [7] are used. The comparison of LEC and S-LZW is made for temperature and relative humidity measurements. Le-Genepi and stbernanrd from Sensor Scope deployments are tested. The size of the data sets range from 31253 to 71536 samples. The temperature and humidity readings are connected to an ADC. The outputs of ADC for the raw relative humidity and raw temperature are represented with resolutions of 14and 12 bits. These raw outputs are then converted [8] to physical measures expressed as t and h as shown by the code below. The t and h values are then used as inputs for A-LEC Compression.

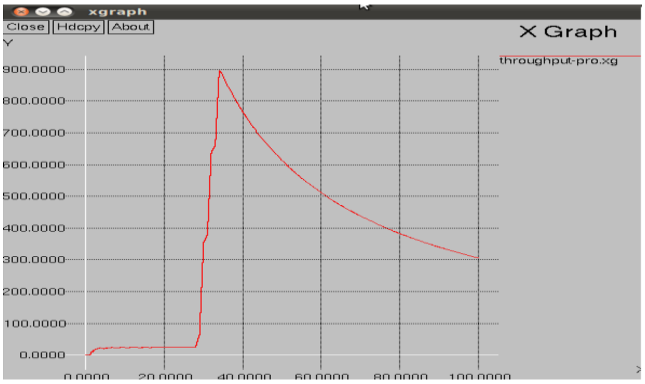

Fig.3: Throughput of CC-BTS Topology without compression

Fig 3 is a plot of data throughput versus the round number..

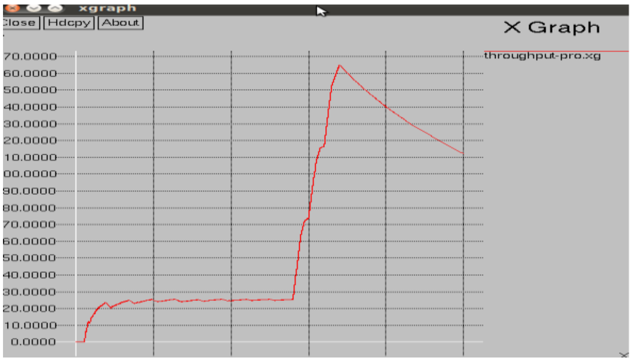

Fig.4: Throughput of CC-BTS with Compression

The data throughput as shown in Fig 4. has increased since throughput depends on the packet loss and the packet loss substantially reduces when lossless compression is used.

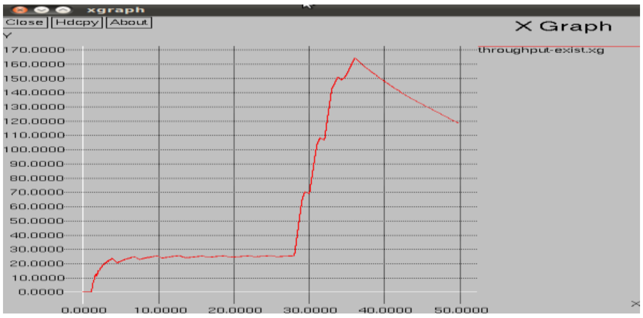

Fig.5: Throughput of CC-CC without compression

Fig 5 is a plot of node number against the residual energy in the respective node at the end of 100 rounds. The data packets move from the cluster head of one to another and finally to the sink in a multi-hop fashion. Since the transmission distance of each cluster head is less, the energy consumed for transmission is also less, thereby the residual energy is more as seen from the graph and the network lifespan is also more. The throughput is seen to be higher in this case.

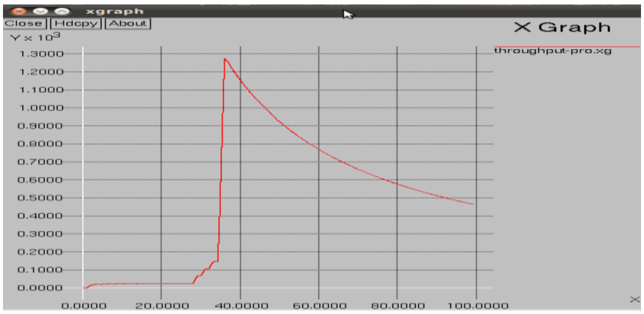

Fig.6: Throughput for CC-CC with Compression

Fig 6 is plot of node number versus the residual energy the corresponding node the end of 100 rounds. Initially the energy of the nodes was 100 Joules. After several rounds of operation the final energy possessed was found to be more in CC-CC transmission with the use of A-LEC data compression. The number of negative peaks is lesser, indicating that the energy is distributed equally among the nodes. The compression performance was evaluated by compression ratio as follows: R = 1-(z/z) where z and z denote the original raw data size and compressed data size in bits respectively. The throughput obtained is also seen to be the maximum.

V. CONCLUSION

The routing of data in the networks is performed using hierarchical multi-hop method. Simulations are conducted in NS2 in different scenarios and the one with Hierarchical Multi-hop routing is found to be most efficient. A-LEC compression method is adopted and is compared with S-LZW and LEC compression methods. The A-LEC shows a higher degree of ruggedness and hence it is adaptive to changes in the data pattern. Four Scenarios related to routing are compared and the energy utilization is also compared. It shows that CC-CC with data compression is most effective since it consumes least amount of energy. The data sets are collected from sensor scope and compression ratio is computed for the prescribed algorithm for different types of data. Since different types of data have different temporal correlations, the prescribed algorithm effectively utilizes the temporal correlations and adapts better to different kinds of data

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