Variable Length Syndrome Coding using AYAA Algorithm for WSNs

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***Abstract*—Wireless Sensor Network (WSN) has become one of the most interesting research areas for researchers. The WSN nodes are generally established in hostile environment where recharging or replacing of the batteries is very difficult. Hence to save the transmission energy of the system many techniques have been proposed. Distributed Source Coding (DSC) is one amongst them. One such popular DSC algorithm is Distributed Source Coding Using Syndrome (DISCUS). This algorithm provides an efficient compression of the data using syndrome bits. However the algorithm can be still improved by considering non prefix coding of the syndrome bits. In this paper we propose a novel technique, AYAA (Adish Yashkirti Abhishek Amit) algorithm to compress the syndrome bits resulting in ComSyn bits. The simulation results show the performance of AYAA algorithm over DISCUS algorithm.**

Keywords: Distributed Source Coding Using Syndromes (DISCUS), Compressed Syndrome (ComSyn) bits, Linear Block Codes

I. INTRODUCTION

Wireless Sensor Networks (WSN) have become a ubiquitous part of the modern communication system, It finds applications in vast areas like habitat monitoring, military, environmental monitoring etc [1].

WSN is a network of small devices called sensors. Sensors are autonomous devices powered by batteries and perform data sensing operation from the area it is encircled, process the sensed data and communicate the information to the central entity called the Base Station (BS).

As WSNs are generally deployed in hostile environments, recharging or replacing of batteries are generally infeasible. Thus energy efficient data communication is one of the important design issues for a WSN. A typical WSN is as shown in figure 1.

As nodes are densely deployed in a WSN, data sensed by nearby nodes are highly correlated. This correlation can be explored to perform data fusion by one of the nodes and the aggregated data can be sent to the BS. The process is called as data aggregation [2, 3]. As the compression of the data is also involved in the transmission of the data, it is also termed as source coding.

Also as BS is generally not resource constrained the source coding algorithm can be distributed. Thus many Distributed Source Coding (DSC) algorithms have been developed in the literature.

In DSC, the entire sensing area is divided into smaller areas called clusters. One of the nodes in the cluster is called a Cluster head (CH) [4, 5]. CHs are sometime called as data gathering nodes. CH is also a normal sensor node which performs sensing operation All nodes in a cluster send the sensed information to the CH. The CH does the data aggregation and the fused data is sent to the BS.

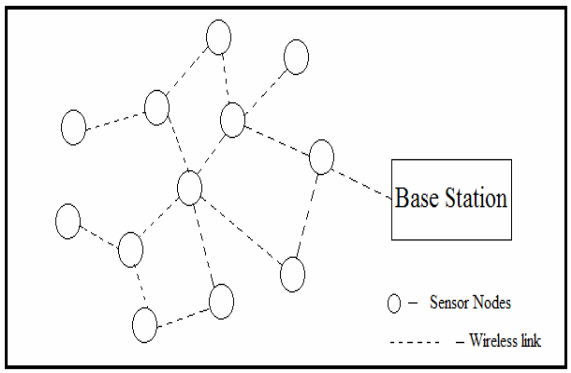

Fig 1: Basic Wireless Network

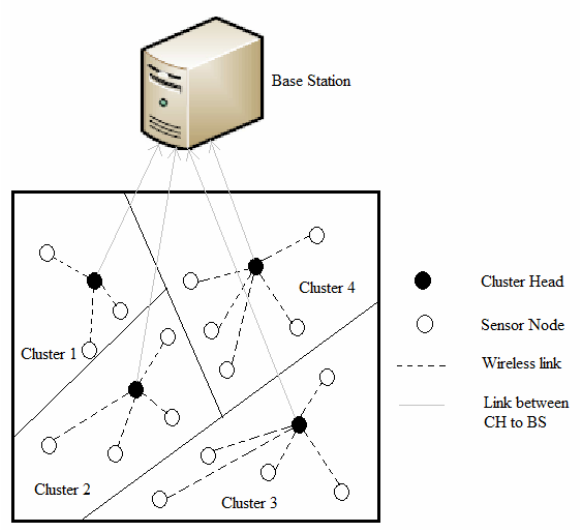

Fig 2: Basic CH Communication in DSC

A typical data communication in a WSN using clustering approach is detailed in figure 2. Here we consider four clusters, each is assigned with a CH [6, 7, 8]. There are different methods to select CH which uses different protocols. Generally nodes with higher energy in the network are selected as CHs. A CH performs data fusion from all other nodes, performs data compression operation based on correlation between nodes and sends the compressed data to the BS. Mostly the communication between nodes and CH uses CSMA technique for avoiding collision. And the communication between CH and BS uses TDMA method.

The rest of the paper is organized as follows: section II gives the detailed description of the DISCUS algorithm. Section III describes the proposed AYAA algorithm. Section IV shows the results and analysis and finally Section V gives the concluding remarks.

II. DISCUS ALGORITHM

DISCUS stands for Distributed Source Coding Using Syndrome. As the name indicates the Syndrome bits are used to transfer the data instead of data itself. These syndrome bits can be generated using a traditional (n,k) Linear Block Code (LBC). LBC is one of the efficient ways of channel coding. Thus, in DISCUS, a channel coding mechanism has been used to achieve source coding. A traditional LBC can be represented as (n, k, d_{min}) where n is the code length, k is the message length and d_{min} is the minimum Hamming distance of the data.

DISCUS algorithm is detailed as follows: for any value of m>1, we can define n as 2^m-1and k is (n-m). Using n and k values, a parity check matrix, H can be generated which is in the form of $[P^T : I_{n-k}]$. Then the corresponding generator matrix, G can be obtained using matrix H. Matrix G takes the form $[I_k : P]$. Then the standard array for the designed (n,k) LBC is constructed. The standard array has 2^k n-tuples in each row and 2^{n-k} such rows. The first column of the Standard Array is known as coset leader. The syndrome vector is calculated by multiplying coset leader with the H^T matrix.

In the algorithm, two correlated sources are considered with the corresponding data separated by atmost one bit position [9, 10]. One of the two data is transmitted as it is whereas the syndrome of the other will be transmitted. It is detailed as shown in below example.

Let us consider the value of m=3. The corresponding values of n and k are 7 and 4 respectively. By using n and k values, the H matrix of the form $[P^T : I_{n-k}]$ can be constructed as { 1101100, 1011010, 1110001}. The generator matrix is then obtained as {1000111, 0100101, 0010011, 0001110}. The data matrix is the binary data from 0 to 2^k-1. These data vectors get multiplied with G matrix to form code vectors. Code vectors for the given example are {0000000, 0001110, 0010011, 0011101, 0100101, 0101011, 0110110, 0111000, 1000111, 1001001, 1010100, 1011010, 1100010, 1101100, 1110001, 1111111}. These code vectors form the first row of the standard array and the complete standard array can be constructed.

The first column of this standard array is considered as the coset leader. The coset leaders corresponding to the given example are {0000000, 0000001, 0000010, 0010000, 0000100, 0100000, 0001000, 1000000}. The coset leaders will get multiplied with H^T matrix to form the syndrome vectors given by {000, 001, 010, 011, 100, 101, 110, 111}.

Let us consider two correlated data generated by the sources as {1100101} and {1110101}. One of these data and along with the syndrome of other data will be transmitted to the decoder side. Say {1100101}, {0100} is transmitted. At the decoder side the syndrome is matched with corresponding row of the standard array. Each element of the selected row is compared with the transmitted data, the element which is having the least Hamming distance with the data will be taken as decoded data.

DISCUS algorithm was proposed only for two distributed sources. However it can be implemented for more than two sources also. In [ ] authors have considered more than two correlated sources and the DISCUS algorithm has been implemented for the same.

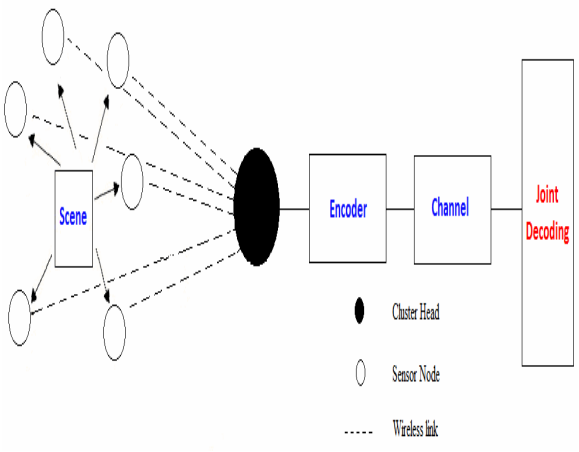

Fig 3: Basic Architecture of DISCUS Algorithm

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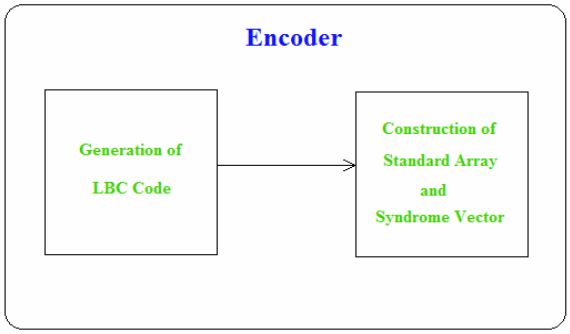

Fig 4: Encoder Part of the DISCUS Algorithm

Fig 3 shows the basic architecture of the DISCUS algorithm. In the figure all sensor nodes sense the data and transmit to the CH. The CH performs the basic encoding operation. It has been showed that the data from the correlated sources will be aggregated in one of the nodes called the CH [11, 12]. The CH does all necessary computations for data fusion and the aggregated data is sent to the BS. In the encoder the standard array is being constructed, of which the first column elements are known as coset leaders. These coset leaders will give the syndrome vectors by multiplying with the H^T matrix as shown in the fig 4.

At the receiver side the joint decoding will perform to decode the data properly. Code will be identified using syndrome bits and perform decoding based on the distance property i.e. the Hamming distance between the data will be less than or equal to 1.

III. AYAA ALGORITHM

The proposed DISCUS algorithm was based on syndrome bits i.e. the n bit data will get compressed to n-k bits giving better performance and an efficient compression over the data. However DISCUS can be further improvised to achieve a better compression. In this section we propose one such method to compress the data over the network.

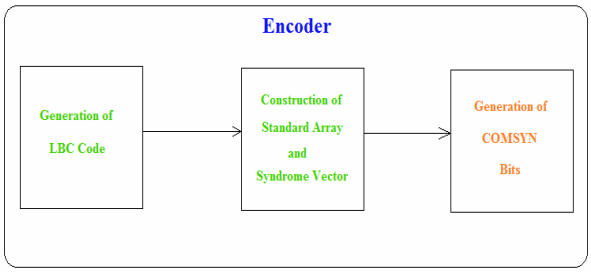

Fig 5: Encoder Part of the AYAA Algorithm

After constructing the Standard Array of the LBC code, the encoding of the data is done. The sources generate correlated data having Hamming distance of atmost 1. One of these data is kept as it is and for other data syndrome bits are generated. These syndrome bits are then converted to Compressed Syndrome (ComSyn) bits by removing the prefix zeros from it. The process is detailed in fig 5. These bits can be transmitted over a channel using Time Division Multiple Access (TDMA) technique.

Let us take an example of n=7 bits which will gives syndromes of 3 bits as {000, 001, 010, 011, 100, 101, 110, 111}. Instead of transmitting 3 bit length for syndrome bits, we can use variable length for syndrome bits. For 000 syndrome 0 can be transmit, for 001 syndrome 1 can be transmit, for 011 syndrome 11 can be transmit, etc. as {0, 1, 10, 11, 100, 101, 110, 111}. The modified syndrome bits are called ComSyn bits. Hence we can achieve a better compression by reducing the syndrome bits which in turn reduces the overall energy consumed in the network to transmit the data to the receiver side.

This algorithm can be more improvised by considering some other technique than TDMA technique as TDMA is not so efficient technique to transmit the data from nodes to the BS.

IV. RESULTS AND ANALYSIS

A comparison of the achievable compression with DISCUS with the proposed AYAA algorithm has been made. Fig 6 shows the comparison of compression achieved from our algorithm and DISCUS algorithm for m=3 for less number of nodes in a network.

It has been clearly seen that the compression achieved by AYAA algorithm is more than the compression achieved by DISCUS algorithm. This is because of the reduction in the syndrome bits during transmission.

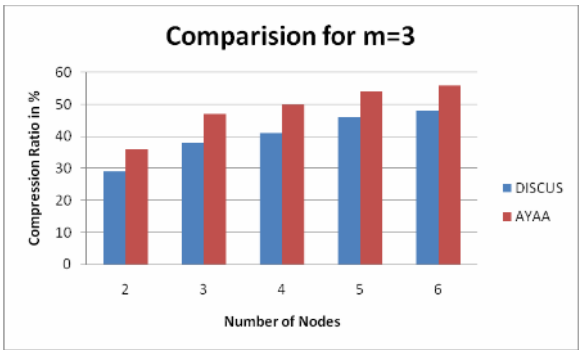

Fig 6: Comparison of Compression Achieved for m=3

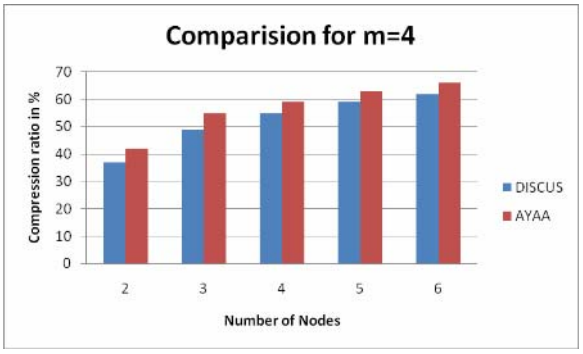

Fig 7: Comparison of Compression achieved for m=4

Fig 7 shows the comparison of compression achieved by AYAA algorithm and DISCUS algorithm for m=4 with less number of nodes in a network. It has been clearly seen that even for m=4 the compression achieved is more for AYAA algorithm than DISCUS algorithm.

The comparison of compression achieved by AYAA algorithm and DISCUS algorithm for m=3 and m=4 with large number of nodes in a network are shown in figures 8 and 9 respectively. The graphs detail the results. It is evident from the plots that AYAA outperforms DISCUS.

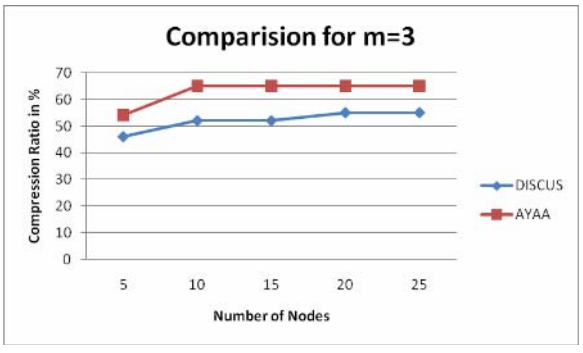

Fig 8: Comparison of Compression achieved for m=3 for Large Networks

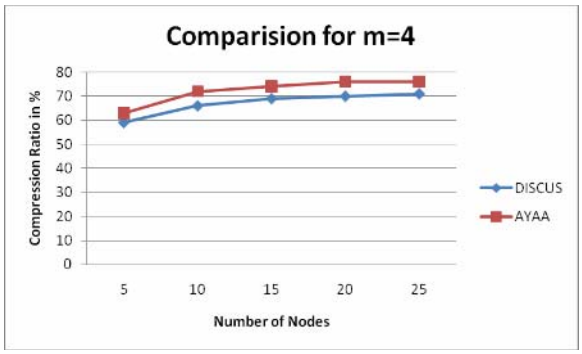

Fig 9: Comparison of Compression achieved fir m=4 for Large Networks

Thus it can be concluded that AYAA algorithm performs better than DISCUS in all cases.

V. Conclusion

DISCUS is one of the Distributed Source technique used to compress the correlated data generated from two Distributed Sources. In this paper a modified algorithm is implemented (AYAA algorithm) which achieves a better compression than the DISCUS algorithm. The results are validated from simulations. From the simulations, we can conclude that the proposed algorithm is performing very well in all aspects. Either for less number of nodes or more number of nodes in a network, proposed algorithm will always compress the data more than the compression done by DISCUS algorithm.

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