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Energy Aware Cluster based Data Aggregation Scheme for Wireless Sensor Networks

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Abstract

Data transmission plays a significant role in communication, due to the rapid development of electronic devices and information technology. Wireless sensor network is one such communication paradigm. Data aggregation is one of the thrust research areas in the field of wireless sensor networks. Compressive sampling methods are widely used for data aggregation in wireless sensor networks. This research work proposes energy aware cluster based data aggregation (EAC-DA) scheme for wireless sensor networks. Chunk oblique matrix is applied for compressive sampling and the conventional Dijsktra's algorithm is employed for obtaining the shortest path from source sensor node to destination sink node. Performance metrics such as throughput, overhead, average energy consumption of nodes, network lifetime and aggregation latency are chosen. The proposed EAC-DA is compared with the existing data aggregation mechanisms. Simulation results are proved that the proposed EAC-DA outperforms in terms of preferred performance metrics.

Key Words: Wireless sensor networks, data aggregation, energy, routing, compressive sampling, throughput, packet delivery ratio, overhead, packets drop, energy consumption.

1. Introduction

Wireless sensor network consists of number of sensor nodes which are self-organized and connected through air i.e. by wireless medium. The sensor node encompasses with the sensing devices, micro-processor, memory, transmitter and batteries. Such sensor nodes in the WSN will accumulate information from the local milieu and propel to the destination(s) i.e., sink(s) sensor nodes. In WSN, each sensor node carries out firm operations such as computing, sensing and self-organizing for transmitting explicit data to the destination sink node via more than one path. In such situation, the deployed sensor nodes are normally powered by some degree of lifetime batteries that are difficult to be replaced or recharged. In such situation resource constraints such as short communication range, low bandwidth, limited processing/storage and in particular, the energy consumption will certainly occur. A sample wireless sensor network with routing nodes is shown in Figure 1.

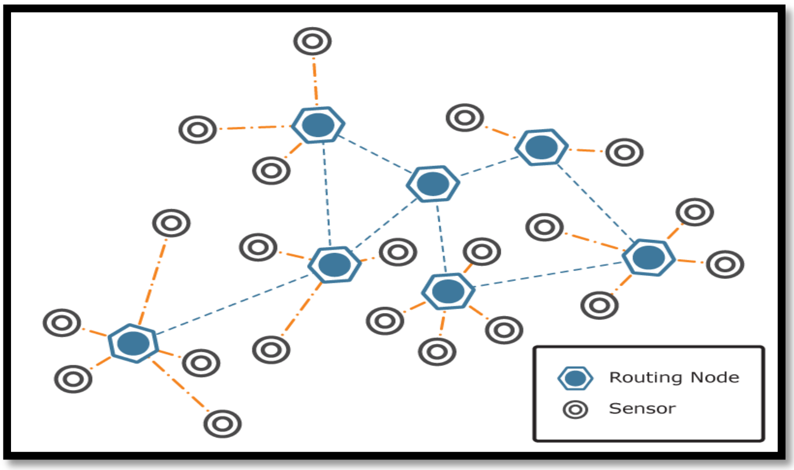

Figure 1: Wireless sensor network with routing nodes

Data gathering is nothing but a data aggregation which propels their measurements (possibly over multiple hops) to a meticulous node called a destination (or) sink sensor node. Converge cast usually a logical tree known as converge cast tree the Radio Frequency (RF) operations consume far more energy as compared to the CPU instructions, there exists a necessitate to reduce the communication overhead. It is noteworthy that the reduction of communication overhead increases the lifetime of sensor networks. While mechanisms, such as radio scheduling, control packet elimination, and topology control, help in reducing energy consumption, which is one of the widely acknowledged approaches to reduce the energy consumption is in-network data aggregation [7–10]. Hence, this paper aims to propose EAC-DA. Section-2 reviews the literature. Section – 3 presents EAC-DA. Section – 4 portrays the simulation settings and performance metrics chosen in this research. Section – 5 depicts the results and discussions. Section - 6 conclusion.

2. Related Works

An extensive literature review is presented in [12]. Recently there happened a paradigm shift in utilizing one of the data aggregation methods called CS based. This is due to augment that the wireless sensor network's lifetime by dropping down the amount of data transmissions and pondering the network traffic load all the way through the whole WSN (e.g. [13–17]).

In [14] the work has been extended by making use of a competent Compressive Data Aggregation (CDA) method in order to perk up the network's lifetime and transmission cost in large-scale WSNs. The authors of [14] also investigated the network's capacity using the CDA method the total data transmissions were lessened during the number of required measuring samples were small enough. On the other hand the authors presented numerically with an increased number of measured samples which shows the way to an increased in transmissions when compared to the other method. In [15] the authors proposed a CS based adaptive data aggregation method which is local spatial correlation among data of neighboring sensor nodes. In [16], the authors developed a CS-based data aggregation method to re-enact data at the destination sink node. The authors claim that their results show that the proposed data aggregation. However, the scheme in [16] cannot automatically match the features of complex spatio-temporal correlation data. The authors in [17] claim that since the measurement matrix is not sparse enough, to apply a plain-CS which may not yield a significant improvement in the throughput, while, it can result in a high throughput in the hybrid-CS method. These techniques utilize both routing and CS-based data aggregation methods to reduce the data traffic. In, the authors present a CS-based scheme which considers both routing and compression methods to minimize the energy consumption required for data collection in a WSN. The authors in [17] claim that each CS measurement only needs a combination of some sensed data instead of using all of them. In addition, it is shown in [17] that using the sparse random measurement considerably reduces the energy consumption of WSNs.

3. Energy Aware Cluster based Data Aggregation (EAC-DA) Scheme

Preliminaries

In this phase a multi-hop WSN is considered that has n stationary and location-aware sensor nodes, denoted by $\{s_1, s_2, ,..., s_n\}$, randomly distributed throughout an $A \times A$ area. WSN has the destination sensor node denoted by s_0 in a pre-location that gathers data from rest of the nodes in the network. The system is modeled by a weighted bidirectional graph $G(V, E)$ in which vertices set V represents the destination sink node and all the sensor nodes, and edge set E

represents bidirectional wireless links between nodes. For every link $i, j \in V$, when a link is there, nodes that are in the communication range of each other, a direct communication between them is potential to connect. $w(i, j)$ is denoted as the transmission cost defined by the Euclidean distance between two nodes i, j. For each single-hop link $i, j \in V$ with the Euclide an distance d_{ij}, the sensor node s_i transmits one data packet x_i of size L bits toward node s_j, where L is a fixed parameter for all the nodes. Assuming that all s_i , $i = 1,..., n$, have data packets for transmission at the beginning of each round, the main task of a data aggregation method is to aggregate adequate information for recovering the n-dimensional signal vector.

Compressive Sampling Vs EAC – DA

There are certain compressive sampling (CS) methods are directly depended on the construction of routing trees and maintenance of such routing trees. At the same time such methods consume more energy which is not fit for real – time sensor networks. The deployed sensor nodes are selected in random fashion, but certain sensor nodes may be far from each other in terms of distance. In such scenario, obtaining each compressive sampling measurement $y_i, i = 1,.....m$, an assortment tree with lots of links are produced that results in tree's cost. The above mentioned challenges inspired and stimulated this research work for proposing an energy efficient method in order to build a momentous reduction in the energy consumption in the WSN model. The key idea of the proposed EAC-DA scheme is for lessening the number of involved sensor nodes during each compressive sampling measurement. In the proposed EAC – DA scheme, the deployed member sensor nodes related to each member node are selected among the nodes inside one cluster. This acquiesces in the formation of collection trees with a smaller structure when compared to conventional WCDA algorithm [17].

In EAC-DA scheme the WSN is divided into n_C local non-overlaid clusters, and represented as $Cl = \{cl_1,....cl_{n_C}\}$. This formation is done by making use of K-means algorithm [11], in which the destination sensor node discretely gathers the data of all clusters. As the clustering procedure is carried out in random fashion, the number of sensor nodes that are present in every cluster is estimated by n / n_C. The ceiling communication range of each sensor node in cluster cl_k, which is denoted by CR_{c_k}, is attained when the graph is unremittingin every cluster. There are certain preliminary discussions needed to be portrayed for ChunkOblique Matrix (COM) [20 – 30].

Chunk Oblique Matrix (COM)

The chunk oblique matrix with a total of n_C sub-matrices $\Phi_k, k=1,....n_C$, each Φ_k has the individual size $m_k \times n_k$, while other non-oblique entries of the COM are all zero. To understand the signal $x \in R^n$ I has been divided into n_C vectors $xk \in R^{n_k}$ and for each $k \in \{1,.....n_C\}$, sub-matrix $\Phi_k : R^{n_k} \rightarrow R^{m_k}$ gathers the compressive sampling measurements $Y_k = \Phi_k x_k$. The gross compressive sampling measurement vector $Y = \left[Y_1^T,......Y_{n_C}^T\right]^T \in R^m$ is given by

$$Y = \Phi x \Leftrightarrow \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_{n_C} \end{bmatrix} = \begin{bmatrix} \Phi_1 & 0 & \cdots & 0 \\ 0 & \Phi_2 & \ddots & \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \Phi_{n_C} \end{bmatrix} \begin{bmatrix} x1 \\ x2 \\ \vdots \\ x_{n_C} \end{bmatrix} \ldots (1)$$

It is presumed that Φ_k is a sparse random measurement matrix by which COM Φ gratifies the Restricted Isometry Property (RIP)state [25 - 30]. It is observed to be an effectualdimension matrix. The count of compressive sampling dimensions m is based on the compression basis ψ in which the signal is meager. When the dimension matrix contains a low rationality with the compression basis increasing n_{Cl} results in a more meager dimension matrix, while n_{Cl} does not increase with m.

Working of EAC - DA

In the proposed EAC-DA algorithm,the compressive sampling based data aggregation method generates a COM that has several sampling sub-matrices $\Phi_k, k=1,....n_C$,each Φ_k belongs to the k th cluster. It is represented n_k and m_k as the number of nodes and the CS measurements for k th cluster, respectively. Since, m_k is a linear function of the number of nodes n_k in cluster c_k, it brings to a close that $m_k = (n_k / n) \times m, k=1,...,n_C$. In the proposed EAC – DA scheme, the destination sensor node aggregates $m = \sum_{k=1}^{n_C} m_k$ CS measurements $Y_i, i=1,...,n$ conversely; the traffic load in each cluster c_k is reduced to m_k CS measurements. The algorithm is portrayed below:

Algorithm - 1 The proposed EAC - DA algorithm.

Inputs : $G(V,E), n_C, E_p$, Outputs **:** $T_{i,k}, i=1,....,m_k, T_k, k=1,...,n_C, B_T$

1: Divide nodes into n_C clusters using K -means algorithm.

2: Find R_{c_k} for a continuous graph of each cluster

3: Create Distance_C and Adjacent_c relative to Range_C

4: Find the shortest path using Dijskra's algorithm from r_i to corresponding cluster head

end for

end for

for each cluster head $c_k, k = 1,...,n_C$ **do**

5: Find shortest path to s_0 s0

end for

forall nodes **do**

calculate consumed E_i

end for: **end while**

4. Simulation Settings and Performance Metrics

The NS-2 Simulator is used in this simulation. The WSN nodes are placedrandomly with varying density of between 500 and 1000. The packets are used to transfer bit at constant rate Through GPS all sensor nodes have ability to communicate with their neighbor nodes and their location. The performance metrics chosen are throughput, key length, key generation time and aggregation latency. The simulation settings are depicted in Table 1. A sample simulation scenario using NS2 is shown in Figure 2.

Table 1: Simulation settings

Parameter Name	Value
Number of nodes	500 nodes to 1000 nodes
Terrain Size	1500 meters X 1500 meters
Initial energy / node	50 joules
Simulation time	1500 seconds
Baseline node power	6mW
Simulation runs	10
Packet size	300 bytes
Radio Propagation	Free Space
MAC Protocol	802.11
Radio Range	200 meters

The performance metrics chosen include throughput, overhead, average energy consumption, network lifetime and latency.

5. Results and Discussions

The simulations are conducted with varying number of nodes that ranges from 500 to 1000. Fig.2 portrays the throughput performance of the proposed EAC-DA and the other existing protocols. From the results it is evident that the proposed EAC-DA attains better throughput than existing protocols. The simulation result values of throughput are given in Table 2.The overhead performance of the proposed EAC-DA is projected in Figure 3. From the results it is obvious that the proposed EAC-DA obtains lesser overhead packets than existing protocols. The simulation result values of overhead are given in Table 3.

Table 2: Number of nodes Vs throughput (packets)

Number of Nodes	PDA [1]	MAI [2]	FASM [3]	EAC-DA
500	18094	19046	21332	25947
600	17485	18461	19004	23846
700	16835	17946	18563	21001
800	15364	16483	17452	20736
900	14273	15038	16493	19037
1000	13563	14343	15008	17473

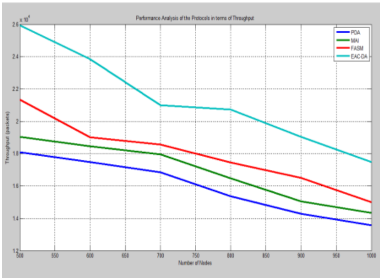

Figure 2: Number of nodes Vs throughput (packets)

Table 3: Number of nodes Vs overhead (packets)

Number of Nodes	PDA [1]	MAI [2]	FASM [3]	EAC-DA
500	658	549	492	399
600	735	631	572	478
700	836	749	601	528
800	903	842	725	627
900	991	901	807	702
1000	1091	992	889	782

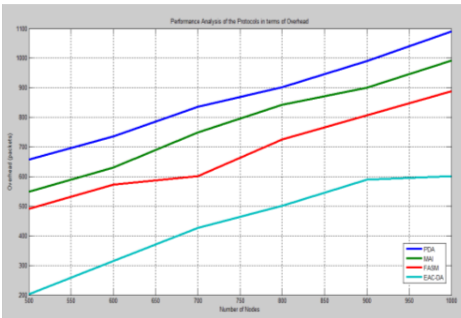

Figure 3: Number of nodes Vs overhead (packets)

Table 4: Number of nodes Vs average energy consumption of nodes (joules)

Number of Nodes	PDA [1]	MAI [2]	FASM [3]	EAC-DA
500	35.04	31.64	28.02	17.83
600	36.13	32.13	29.73	18.03
700	37.92	33.29	30.14	19.05
800	38.69	34.01	31.18	20.14
900	39.92	35.16	32.01	21.24
1000	41.01	35.92	32.96	21.91

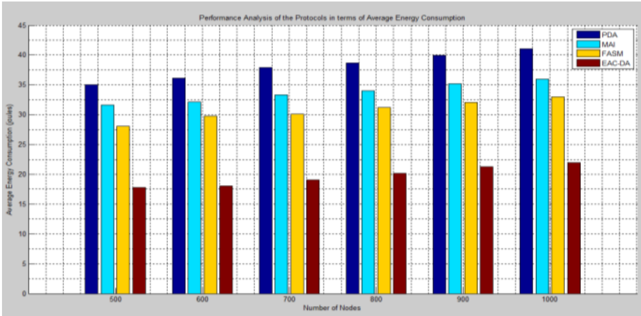

Figure 4: Number of nodes Vs average energy consumption of nodes (joules)

Fig.4 presents the average energy consumption of nodes performance of the proposed EAC-DA and the other existing protocols. From the results it is clear that EAC-DA consumes lesser energy than existing protocols. The simulation result values of average energy consumption are given in Table 4.

Table 5: Number of nodes Vs network lifetime (seconds)

Number of Nodes	PDA [1]	MAI [2]	FASM [3]	EAC-DA
500	1028.59	1284.74	1382.82	1788.39
600	1292.63	1472.93	1573.01	1984.82
700	1483.22	1634.21	1784.84	2189.64
800	1648.95	1873.94	1966.71	2304.79
900	1893.78	2088.93	2103.82	2583.62
1000	2101.62	2294.16	2399.59	2762.01

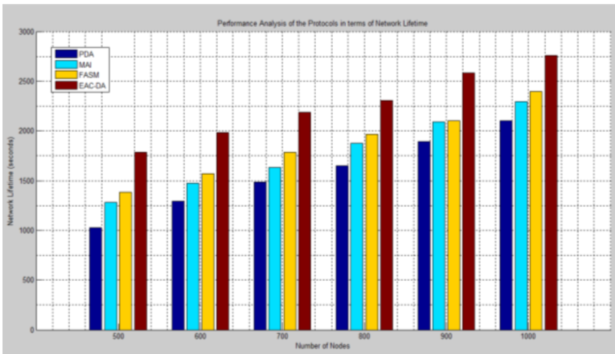

Figure 5: Number of nodes Vs network lifetime (Seconds)

Fig.5 demonstrates network lifetime performance of the proposed EAC-DA and the other existing protocols. From the results it is clear that the proposed EAC-DA extends network lifetime than that of existing protocols. The simulation result of network lifetime is given in Table 5.

6. Conclusion

This research work aims to propose Energy Aware Custer Based Data Aggregation (EAC-DA) scheme for wireless sensor networks. The objective of this research work is to attain better throughput, reduced overhead packets, extended lifetime, reduced energy consumption and less latency for data aggregation. The simulations are done with varying number of nodes ranges between 500 to 1000. Compressive sampling disadvantages are ruled out by employing chunk oblique matrix (COM) method. Shortest routes from the source sensor node and the destination sink node are constructed based on the Dijsktra's algorithm. The results show that the EAC-DA perform better than existing protocols.

References

[1] Wang P., He Y., Huang L., Near optimal scheduling of data aggregation in wireless sensor networks, Ad Hoc Networks 11(4) (2013), 1287-1296.

[2] Li H., Li K., Qu W., Stojmenovic I., Secure and energy-efficient data aggregation with malicious aggregator identification in wireless sensor networks, Future Generation Computer Systems 37(5) (2014), 108-116.

[3] Yousefi H., Malekimajd M., Ashouri M., Movaghar A., Fast Aggregation Scheduling in Wireless Sensor Networks, IEEE Transactions on Wireless Communications 14(6) (2015), 3402-3414.

[4] Rabbat M., Haupt J., Singh A., Nowak R., Decentralized compression and predistribution via randomized gossiping, Proceedings of IEEE International Conference on Information Processing in Sensor Networks (2006), 51–59.

[5] Luo C., Wu F., Sun J., Chen C.W., Compressive data gathering for large-scale wireless sensor networks, Proceedings of the 15th Annual International Conference on Mobile Computing and Networking (2009), 145–156.

[6] Wang J., Tang S., Yin B., Li X.Y., Data gathering in wireless sensor networks through intelligent compressive sensing, in: Proceedings of IEEE International Conference on Computer Communications (2012), 603–611.

[7] Luo C., Wu F., Sun J., Chen C.W., Efficient measurement generation and pervasivesparsity for compressive data gathering, IEEE Trans. Wirel.Commun. 9 (12) (2010), 3728–3738.

[8] Luo J., Xiang L., Rosenberg C., Does compressed sensing improve the throughput of wireless sensor networks?, IEEE International Conference on Communications (2010), 1–6.

[9] Hill J., Szewczyk R., Woo A., Hollar S., Culler D., Pister K., System architecture directions for networked sensors, ACM SIGPLAN Notic. 35 (11) (2000), 93–104.

[10] Krishnamachari B., Estrin D., Wicker S.B., The impact of data aggregation inwireless sensor networks, Proceedings of the 22nd International Conference on Distributed Computing Systems, ICDCSW (2002), 575–578.

[11] Boulis A., Ganeriwal S., Srivastava M.B., Aggregation in sensor networks: Anenergy-accuracy trade-off, Ad Hoc Netw. 1 (2-3) (2003), 317–331.

[12] Rajagopalan R., Varshney P., Data-aggregation techniques in sensor networks: A survey, IEEE Commun. Surveys Tutorials 8 (4) (2006), 48–63.

[13] Fasolo E., Rossi M., Widmer J., Zorzi M., In-network aggregation techniques forwireless sensor networks: A survey, Wireless Commun 14 (2) (2007), 70–87.

[14] Sasikumar P., Khara S., K-Means Clustering in Wireless Sensor Networks, Proceedings of the Fourth International Conference on Computational Intelligence and Communication Networks (2012), 140-144.

[15] Parmar K., Jinwala D.C., Concealed data aggregation in wireless sensor networks: A comprehensive survey, Computer Networks 103 (2016), 207-227.

[16] Rabbat M., Haupt J., Singh A., Nowak R., Decentralized compression and predistribution via randomized gossiping, Proceedings of IEEE International Conference on Information Processing in Sensor Networks (2006), 51–59.

[17] Luo C., Wu F., Sun J., Chen C.W., Compressive data gathering for large-scale wireless sensor networks, Proceedings of the 15th Annual International Conference on Mobile Computing and Networking (2009), 145–156.

[18] Quer G., Masiero R., Munaretto D., Rossi M., Widmer J., Zorzi M., On the interplay between routing and signal representation for compressive sensing in wireless sensor networks, Proceedings of Information Theory and Applications Workshop (2009), 206-215.

[19] Imon S.K.A., Khan A., Das S.K., EFFECT: an energy efficient framework for data compression in tree-based wireless sensor networks, IEEE International Symposium on A World of Wireless, Mobile and Multimedia Networks (2014), 1–9.

[20] Prema R., Rangarajan R., Secure Power Aware Routing Protocol (SPARP) for Wireless Sensor Networks, International Journal of Computer Application (2012), 13-18.