Distributed Intra and Inter Cluster Chaining Framework for Energy-Efficient, Delay Bounded and Scalable Data Gathering Applications in Large Scale Sensor Network

Biswanath Dey, Navajyoti Nath, Sivaji Bandyopadhyay, Sukumar Nandi

Abstract*: This paper proposes a scalable, energy-efficient and scalable, energy efficient, delay bounded intra and inter cluster routing framework viz. GIICCF (Generalized Intra and Inter cluster chaining framework) for efficient data gathering in large scale wireless sensor networks. This approach extricates the benefits of both pure chain-based as well as pure cluster-based data gathering schemes in large scale Wireless Sensor Network (WSNs) without undermining with the drawbacks. GIICCF defines a localized energy-efficient chaining scheme among the member nodes within the cluster with bounded data delivery delay to the respective cluster-heads (CH) as well as enables the CH to deliver data to the Base station (BS) following an energy-efficient multi-hop fashion. Detailed experimental analysis and simulation results reveal GIICCF increases the performance of any pure cluster-based and chain-based protocols by a huge margin.

Keywords: Wireless Sensor Network, Cluster based routing, Chain based routing, in network processing, data aggregation, intra and inter cluster chaining, data forwarding, energy*delay metric, network lifetime.

I. INTRODUCTION

In wireless sensor networks, as the sensing nodes are in an acute shortage of energy and replacement of energy source is not possible once deployed. Thus, the primary focus should be on the effective usage of the limited energy of the sensor nodes. The framework proposed in this paper considers these facts and with the help of well-known hierarchical protocols, e.g., LEACH [1,2], PEGASIS [3], etc., to improve the lifespan of sensing nodes and eventually to improve the network lifespan. This framework introduces intra-cluster as well as inter-cluster, chaining mechanism with bounded data delivery delay and also helps the cluster-heads (CHs) to propagate the received cluster information to the base station via a multi-hop scheme, which is considered as the most energy-efficient.

The key idea behind the inclusion of hierarchical routing protocols is that these protocols impart high energy efficiency, higher scalability, and have effective data aggregation mechanism. In the proposed approach, chaining is done within the cluster as well as between CHs of different clusters within the system. In the intra-cluster chain is formed between the cluster nodes and CH, whereas in inter-cluster chaining is performed within the CHs. This helps in improving the efficiency of the protocols and converts into a more energy-efficient protocols with higher network longevity. The remainder of the article is constructed in the following way: Section 2 discusses the Recent Works, Section 3 proposes the Generalized Intra and Inter-Cluster Chaining Framework (GIICCF), Section 4 shows the experimental studies about the proposed model and finally, in Section 5 the conclusion is provided.

II. RECENT WORKS

- **Low-Energy Adaptive Cluster Hierarchy(LEACH)**

LEACH protocol as presented by Heinzelman et al in 2002 [1, 2], the network consisting of several nodes is cleaved into small clusters depending on the cluster heads in the system. This whole process is cleaved into two parts; Start-Up & Steady-State Phase. The Start-Up phase is where the cluster-heads are elected among the nodes in the network in a distributed way based on the formulation devised in (1) but in every round (except first round) only few of the nodes participate in this process. Participating nodes in every round self-elect itself as cluster-head and generates a random value ranging from 0 to 1. For the running round, the value generated by a node if is smaller than the threshold, then that node is chosen as the head for the cluster for that very round, although a node, elected as head for any round, can't participate in the election process till the next $1/p_c^{th}$ rounds are over.

Revised Manuscript Received on December 30, 2019.
* Correspondence Author
Biswanath Dey*, Department of CSE, NIT, Silchar, India. Email: bdey33@yahoo.com
Navajyoti Nath, Department of CSE, NIT, Silchar, India. Email: navajyoti.cse@gmail.com
Sivaji Bandyopadhyay, Department of CSE, NIT, Silchar, India.
Sukumar Nandi, Department of CSE, IIT, Guwahati, India.

$$T(i) = \begin{cases} \frac{p_c}{1-p_c*(round,\frac{1}{p_c})}, & if\ i \in G_c \\ 0 \quad , & otherwise \end{cases} \quad (1)$$

Where p_c = pre-decided percentage of cluster-heads, round = present round and G_c = collection of nodes that were not CHs for the past $1/p_c^{th}$ rounds, c represents CH and i = i^{th} node.

Once the cluster heads are elected, every node broadcasts an *Advertisement* message throughout the network. During this period all the other nodes are required to keep their receivers on. As the advertisement is sent, the member-nodes after selecting the cluster-head to attach to for that round transmits a *Join* message to the head of the cluster and eventually forms a cluster. The decision of choosing a cluster-head to join, relies on the *RSSI* [4] value which is obtained from the *Advertisement* message passed by the heads. As the clusters are now formed, each head multi-casts a TDMA schedule to its members-nodes, to make them aware of the allotted slots. In steady-state phase the actual data transmission takes place between the member-nodes and heads and afterward between heads and base-station. In this phase, the non-head-node relay its data to the respective heads as per the allotted slots. Once the heads of each cluster receive all the information passed by the member-nodes, it carry out the aggregation operations on the received data to make it into a single data signal and finally transmits that data to the command station.

This protocol is efficient as the nodes are only required to be awake during their allotted slots, which aggressively reduces the power requirement of the nodes.

- **Power-Efficient GAthering in Sensor Information Systems (PEGASIS)**

In [3], the authors have proposed PEGASIS, that forms a chain to transmit data between close neighbors and finally to BS presuming that every node has the information regarding the network. Here, the chain is formed based on a greedy algorithm in the beginning just ahead of the first round of transmission, and the formation begins at the farthest sensor node from the BS. Moments after the chaining process is over the data transmission starts. Farthest node begins this process by transmitting the data to the nearest neighbor along the chain, where the next node fuses its data with the received data and forwards the data further to the neighbor node in the chain. In each round, a node is selected among the member nodes to relay the data to the sink and is referred as *leader* and the formulation for a node j to become a leader among N numbers of nodes is in (4).

$$Mod(j,N) \quad (2)$$

The role of a leader before transmission of data is also to inform other nodes in the chain, which is done using short control messages. In PEGASIS, a node in the chain is debarred from becoming a leader, if the distance to its neighbor along the chain is not within the threshold limits. The chain in the network holds until the death of any node occurs or any topological imbalance occurs, in that event the chaining is done again but with a new threshold value.

- **Energy influenced Probability based LEACH Protocol (EiP-LEACH)**

The authors in [5] proposed a protocol that is predominantly depended on LEACH protocol [1]. In this, the election procedure of CH is unlike the protocol in [1]. In the LEACH protocol, choosing a cluster-head is purely dependent on equation (1), whereas in this algorithm another set of selection criterion which is depended upon two factors; remaining energy and initial energy of the nodes in the network and as given in (5).

$$T(i) = \begin{cases} \frac{p_c}{1-p_c*(round,\frac{1}{p_c})} * \frac{E_i}{E_{initavg}}, & if\ i \in G_c \\ 0 \quad , & otherwise \end{cases} \quad (3)$$

Where i is the engaged node for the election process, E_i is present remaining energy, $E_{initavg}$ is the mean of initial energy. Remaining functionalities are similar to that of the original [1] protocol. The formations of clusters are initiated by transmitting a "*join-request*" message to head and then head relays time-slots to the member-nodes in the cluster. Thereafter, member-nodes of the cluster initiate the next process by transmitting their data to the respective heads and afterward to the sink.

- **D-PEGASIS**

Nearly all the algorithms based on chaining, the formation of chain is either done at the sink or is done by the nodes in the network with the structural information of the network. But in [6], authors have proposed another algorithm where the chaining is done among the nodes (self-activating) without even having the information of the SN. In this, initially the network is separated to form different zones or areas depending upon the positions of the nodes and distance to the BS. Afterward, depending on the identified areas, a formation of PEGASIS chain is initiated from the node at the farthest area and also at a certain position from the outer region (boundary) of the network. The PEGASIS chain formation is done area-wise, that is, the chain formation initiates from the node which is located in the farthest area and then the chain forwards and moves closer to the BS area by area.

- **EE-LEACH**

In this approach [7] an energy-efficient version of the LEACH protocol is proposed. In this protocol, the node deployment is based on the Gaussian Distribution model. Here, the location of sensor nodes and sink are known from the beginning. The predominant reason to propose this protocol is to enhance the data gathering process in the LEACH protocol. This is achieved by selecting optimal routes for data transfer with the help of effective data ensemble and also by forming efficient clusters. In this approach, the efficient cluster formation relies upon the remaining energy of nodes and the neighbor information retrieval. Moment the clusters are formed, the optimal heads are chosen based on the highest remaining energy and on the spatial information as the CHs have to carry out data fusion and also data transfer to the BS.

The data aggregation in this is based on data ensemble and conditional probability and finally, the fused data is sent to the BS.

- **LEACH-M**

This protocol in [8] focuses mainly on reducing the energy dissipation that occurs during the selection procedure of heads in LEACH protocol, and hence proposes a novel approach for the cluster-head selection. LEACH-M protocol, considers the remaining energy as well as the network address of the nodes to optimize CHs threshold equation, which in turn establishes a stable and energy efficient clusters. The objective of the protocol is similar to the LEACH protocol and moreover also follows the principle of ZigBee cluster-tree [9] [10] [11], where the network is separated in three different categories, namely, coordinator, router, and end-node. To evaluate the network addresses of route nodes *(A_{router})* and end nodes *(A_{end})* based on the address of parent *(A_{parent})*, the following equations are used [9].

$$A_{end} = A_{parent} + 1 + C_{skip}(nd) * (end - 1), \quad 1 \le end \le R_k \tag{4}$$

$$A_{router} = A_{parent} + C_{skip}(nd) * R_k + router, \quad 1 \le router \le C_k - R_k \tag{5}$$

Where n_d is the network depth of the node, $C_{skip}(nd)$ is the address space of the node, R_k is the highest no. of router-nodes, L_k is the deepest depth of the system, and C_k indicates the highest no. of child nodes. Once the addresses are calculated, this algorithm evaluates the average energy of the network and finally based on these two factors chooses a competitive CH.

- **Cluster-Chain Mobile Agent Routing (CCMAR)**

In [12], the authors have proposed a model where it uses the fundamental principle of both LEACH and PEGASIS. Here based on [13], which basically uses the remaining energy of the node and besides the transmission range of the nodes to select cluster heads. Once CHs are selected the cluster formation process is initiated. After the cluster formation is over the role of CHs takes the role of cluster chains and forms a chain within the clusters, starting from the farthest node from to the CHs. These chains and clusters remain active until a node is dead. After data aggregation is performed by the chain heads the data is send to the base station using a mobile agent (MA) [14][15]instead of direct transmission from the cluster/chain heads. Thus, reducing the energy dissipation in the process of data transmission.

III. GENERALIZED INTRA AND INTER CLUSTER CHAINING FRAMEWORK (GIICCF)

In this framework, after the CH selection and cluster formation, the chaining process within the cluster (intra-cluster) as well as chaining among the CHs (inter-cluster) is performed. In case of intra-clustering, the farthest node from the CH and the closest node to the CH in the clusters are selected for the chain formation. Even in the inter-cluster communication, the CH farthest from the the BS and the CH closest to the BS are elected to begin the chain formation. But in both the cases, the number of hops are restricted to a certain level. During the chain formation not all nodes within the cluster as well as not all CHs in the network are assigned to a single chain. Here in GIICCF, the idea is to form more than one chains using minimal spanning tree and to discover the optimal path for the message forwarding. The detailed proposal is discussed in the following sections.

A. Network Model & Assumption

Here in this paper, the wireless sensor network that is implemented is of size M X M, and the nodes (N) are randomly deployed. The sensor nodes are homogeneous, that is the operational capacity, processing capacity and initial energy for the nodes, with that they are also location aware. The base station is placed far away from the sensor field and is on unlimited power supply. Every node is capable to relay data to the BS.

B. Energy Model

In this work, the first-order radio model [16] is used to represent the energy dissipation for communication and is being implemented in various other recent models [17] [18] [19]. Two propagation channel models are used in this work (free-space channel and multi-path space model). The choice is based on the distance between the sender and the receiver, if the range is smaller (smaller than the threshold distance, D_0) free space propagation model is adopted and if the distance between transmitter and receiver is greater (greater than the threshold distance, D_0) multi-path space propagation model is opted. The energy consumption expression for transmitting a k-bit data over a distance *d* is as follows:

$$E_{tx}(k,d) = \begin{cases} k\left(E_{elec} + \varepsilon_{fs} d^2\right), d \le D_0 \\ k\left(E_{elec} + \varepsilon_{mp} d^4\right), d > D_0 \end{cases} \tag{6}$$

Where $E_{tx\text{-}amp}$ *(k, d)* = energy dissipation done at the transmitter unit for relaying *k-bit* data across a distance of *d*. E_{elec} = energy dissipation at the relaying unit and the ε_{mp} = constant co-efficient for multi-path propagation ε_{fs}= constant co-efficient for free-space propagation. The values of ε_{fs} and ε_{mp} are as per the values used in [1] [2].

Moreover, the energy expense on collecting a *k-bit* message, the expression is as follows:

$$E_{rx}(k) = k * E_{elec} \tag{7}$$

Therefore, the energy required to forward a *k-bit* message in a hop to hop multi path fashion is:

$$E_{tx}(n, n+1) = \sum_{n=1}^{N} 2k * E_{elec} + k * \varepsilon_{mp} d^4 \tag{8}$$

where *n* being the current node which wants to send information to the next node *n+1*.

Moreover, the proposed model also uses optimal number of hops that are required in data transmission either from sensor nodes to CHs or CHs to the BS.

Therefore, to find out the optimal number of hops H^{opt} for a given d is [20]:

$$H^{opt} = \sqrt[4]{d\frac{3\varepsilon_{mp}}{2E_{elec}}} \quad (9)$$

C. GIICCF-Bounded Diameter Minimum Spanning Tree

As mentioned earlier, the suggested framework is segregated into two major components; Intra cluster chaining and Inter-cluster chaining framework (explained in later sections). Here, unlike PEGASIS or any other chaining protocols, not all nodes are included in one chain, that is, more than one chain may exist. This can be accomplished through implementation of a graph [21], *G (V, E).* $V = \{CH, v_1, v_2, \ldots, v_n\}$ and *E = weighted links between member nodes and CH*. In intra-cluster, the center is first taken from the vertices set (*V*), as with clustering, CHs are regarded as the main unit, therefore CH is selected as a center node. Once the center node is discovered, another nodes from the vertices set is considered based on the energy remaining and distance to the CH. With the assistance of these two nodes the minimum spanning tree (*T*) is constructed and is illustrated in the following algorithm (1).

The same procedure is followed for the construction of minimum spanning tree T_{CH} for inter-cluster part also. Here the set of vertices V_{CH} are all CHs in the system and the base stations, and E is the links connecting the CHs and to the base station. In this case, the center is chosen based on the distance and energy. A cluster head having the distance closer to the average distance to BS and with highest remainder energy is selected as the center. Afterwards the next-hop is selected again based on the criteria of distance to the center, and remainder of the algorithm is followed (Algorithm 1).

Algorithm 1: GIICCF-Bounded Diameter Minimum Spanning Tree

Initialization

```
T ⟵ φ
U ⟵ V
CH ⟵ center(V)                         ▷ Cluster Head chosen as Center
U ⟵ U − {CH}
C ⟵ {CH}
depth[CH] ⟵ 0
{v1} ⟵ next − hop(U)
U ⟵ U − {v1}
C ⟵ C ∪ {v1}
depth[v1] = depth[CH] + 1
T ⟵ T ∪ {(CH, v1)}
```

Child node selection for the MST

```
for (every node w ϵ U) do
    if H^Opt is not reached
    {
    if dist(CH, w) ≤ dist(v1, w)
    {
    w becomes child of CH
    depth[w] ⟵ depth[CH] + 1
    T ⟵ T ∪ {(CH, w)}
    }
    else
    {
    w becomes child of v1
    depth[w] ⟵ depth[v1] + 1
    T ⟵ T ∪ {(v1, w)}
    }
    endif }
    endif
end for
```

D. Intra-Cluster Chaining Framework

To be able to minimize the power usage of sensor nodes, the chaining framework is implemented using the Greedy algorithm along with the help of bounded hop MSTs. Thus, once the cluster formation is completed, the *i*[th] CH in the system, having the information of positions of all the member nodes in that cluster, creates a weighted graph $G(V, E)$,where $V = \{CH_i, node_1, node_2, node_3, \ldots, node_j\}$ and *E* is the weighted edges linking the nodes and CH in the cluster [22][23]. Now from the graph *G*, CH constructs a MST, *T* that assists in constructing the best possible path for the data flow from the member-nodes to the CH, as illustrated in fig. (1). selects the farthest node in the cluster and informs it to start the chaining process with the information of the distances of remaining nodes. After receiving the information, the j[th] node starts the chain formation process and relying on the information received from the CH, selects the neighbour nodes and along with forwards the distance information of remaining nodes. This chaining process runs till the optimal hops (k-neighbours) using equation (4), the bounded hop MST is met.

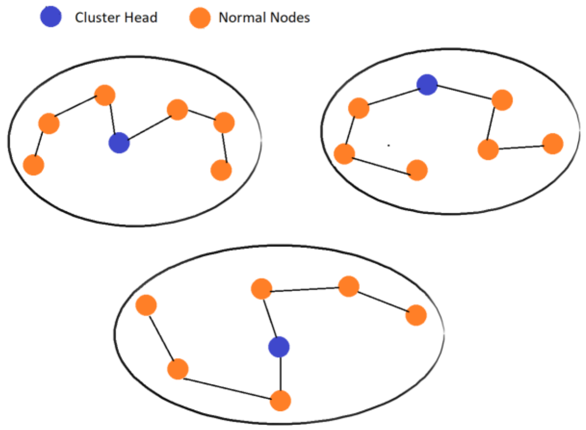

Figure 1: Intra-cluster Chaining Framework Architecture

Algorithm 2: Intra-Cluster Chaining Framework

```
Network Initialization (Nodes(N_i), BaseStation(BS), Location(x_i, y_i), Energy_i)
for i=1:100 do
    N_i sends E_i → BS
    Based on LEACH, CH selection is done.
    CHs sends ADV packets.
    N_i sends JOIN packets to the closest CH
    Cluster formation completed.
end for
for Nodes in the cluster (N_cj) do
    Construct a graph G(V, E)
    where V = {CH_i, N_c1, N_c2, ..., N_cj} & E = Weighted links between nodes.
    From G, construct a MST, T.
    From T, optimal path is chosen.
```

E. Inter-Clustering Chaining Framework

In this framework, similar chaining procedure is followed, but instead of normal nodes, CHs of different cluster are included in the chain. As soon as the chaining processes within clusters are over, the CHs in different clusters send the distance as well as residual energy to the BS. The BS then constructs another graph, $G_{CH}(V_{CH}, E_{CH})$, where the $V_{CH} = \{CH_1, CH_2, \ldots, CH_i\}$ and E_{CH} consists all the links within the CHs and BS. Again similarly, based on the graph, G_{CH}, a *MST* T_{CH} is obtained and from there the optimal path based on the criteria of energy and distance, the chain formation is initiated from the farthest cluster-head in the system to the nearest node to the sink, shown in figure (2).

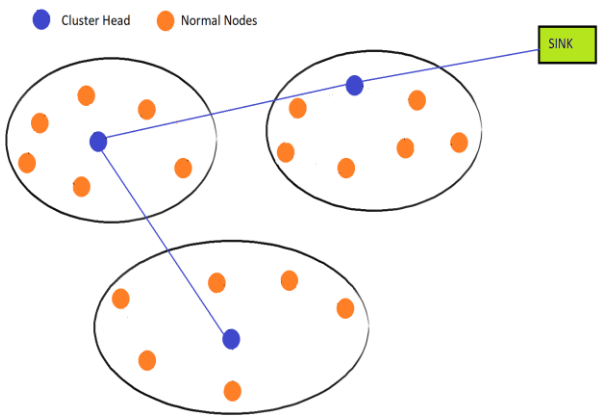

Figure 2: Inter-cluster Chaining Framework Architecture

Algorithm 3: Inter-Cluster Chaining Framework

Total no. of CHs=CH_nch
for CH_i=1 : CH_nch do
  Construct Graph, $G_{CH}(V_{CH}, E_{CH})$
  where $V = \{CH_1, CH_2, \ldots CH_{nch}\}$ & E = Edges connecting CHs and BS.
  From G_{CH}, construct minimal spanning tree, T_{CH}.
  From T_{CH}, obtain optimal path from farthest CH to nearest CH to BS.
end for
  =0

F. Experimental study

In this section, the implementation of the proposed framework (GIICCF) is discussed, and is compared with other well known clustering protocols as well as with chaining protocols in WSN. This section incorporates network area of 100 X 100 m^2 (Figure 3). Other parameters relating to the experimental processes are provided in Table 1. These experiments were performed on a network simulator, named NS-2.35 [24].

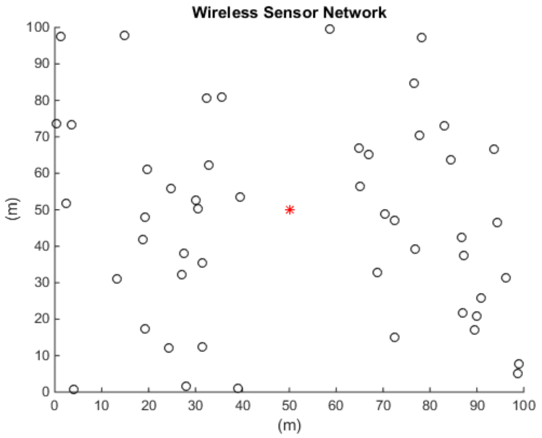

Figure 3: Distribution of "50" sensor nodes over network area of 100m x 100m

Table 1: **Table containing the details of parameters.**

Parameters for Scenario	
Parameters	**Parameter values**
Network Area	100 m X 100 m
No. of Nodes	50 nos.
Base station position	(50m, 50m)
E_{elec}	50nJ/bit
EDA	5nJ/bit
ε_{fs}	10 pJ/bit/m^2
ε_{mp}	0.0013 pJ/bit/m^4
D_O	87.7m
Size of data frames	2000 bit

As discussed earlier, the framework proposed is a method which is implemented with only existing protocols. Thus this section is divided into two sections; first section discusses the performance enhancement over clustering protocols when implemented with GIICCF and in the later section the performance enhancement over chaining protocols are shown when the protocols are implemented with the proposed framework.

A. GIICCF over Clustering Protocols

Here, for the performance comparison of GIICCF on clustering protocols, three protocols are taken in to consideration, wiz, LEACH, EE-LEACH, and LEACH-M. All the mentioned clustering protocols are based purely on clustering protocols. In figure (4), the comparisons of alive nodes for these three protocols are shown, and in figure (5), these protocols when attached with GIICCF, their comparison of alive nodes is shown.

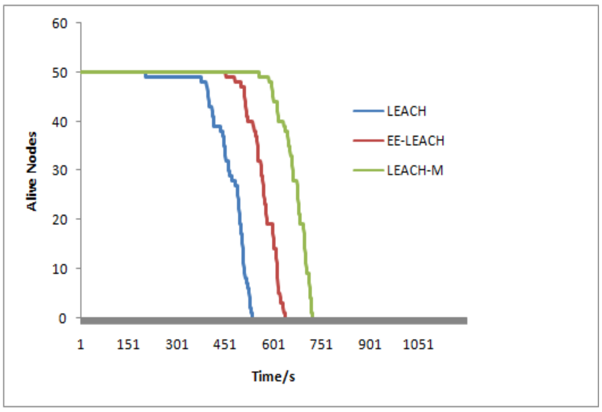

Figure 4: Comparison of network lifetime for LEACH, EE-LEACH and LEACH-M

From the above two comparisons, it could be seen that, when protocols attached/implemented with the proposed framework (GIICCF), outperforms the original protocols. Hence the life-time of all the nodes in the network increases with a huge margin. The figure (6) below provides a brief idea of nodes death over a period of time for these above mentioned protocols. It contains the details of first node deaths (FND), half node deaths (HND) and last node deaths (LND) for all the original protocols as well as enhanced one with GIICCF.

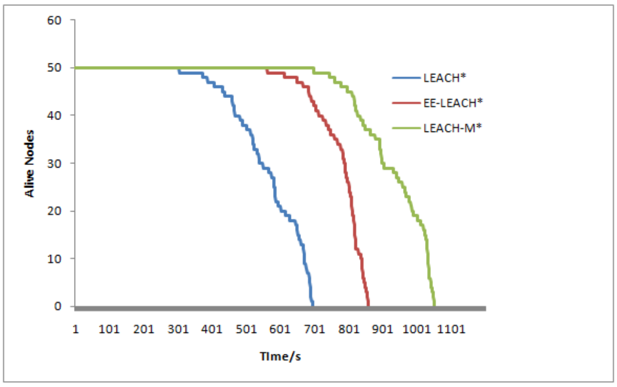

Figure 5: Comparison of network lifetime for LEACH, EE-LEACH and LEACH-M when implemented with GIICCF.

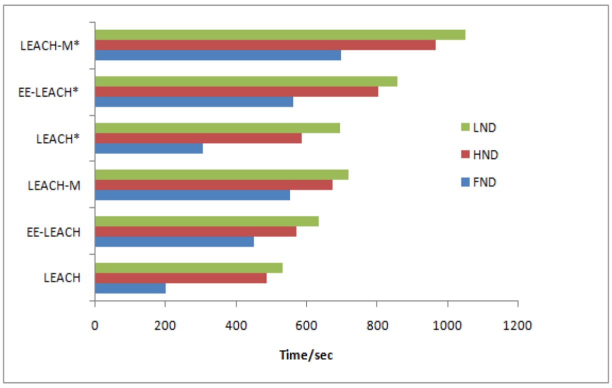

Figure 6: Comparison of node deaths for original and enhanced protocols.

Packet Delivery Ratio (PDR) is the ratio between packets delivery by the nodes to the BS and total packets sent.

$$PDR = \frac{sum\ of\ packets\ received}{sum\ of\ packets\ sent} \qquad (10)$$

PDR suggests that, the higher the value of PDR, better the performance of the protocol. On simulations, it was found that for LEACH, EE-LEACH and LEACH-M when applied with GIICCF framework the performance of the system (PDR) increased exponentially. Figure (7) and (8) presents the PDR values for the same.

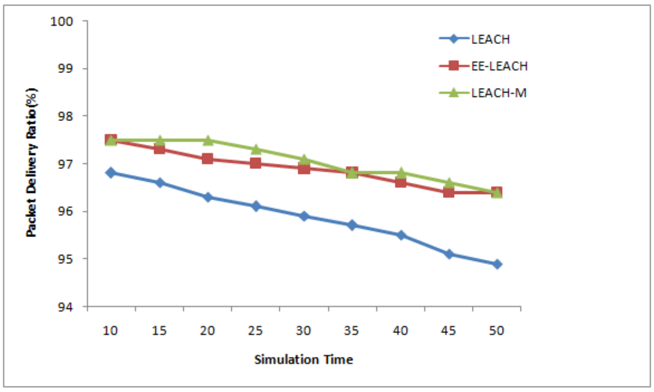

Figure 7: PDR for LEACH, EE-LEACH and LEACH-M.

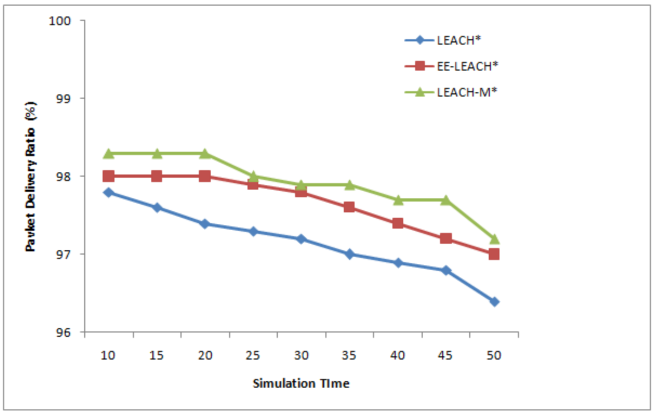

Figure 8: PDR for LEACH, EE-LEACH and LEACH-M when implemented with GIICCF.

B. GIICCF over Chaining Protocols

Here also, for the performance comparison of GIICCF on chaining protocols, three protocols are taken into consideration, namely, PEGASIS, DPEGASIS, and CCMAR. In figure (9), the comparisons of alive nodes for these three protocols are shown and in figure (10), these protocols when attached with GIICCF, their comparison of alive nodes is shown.

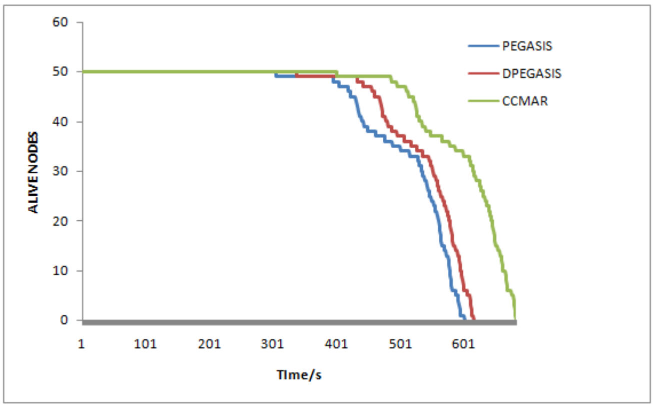

Figure 9: Comparison of network lifetime for PEGASIS, DPEGASIS and CCMAR

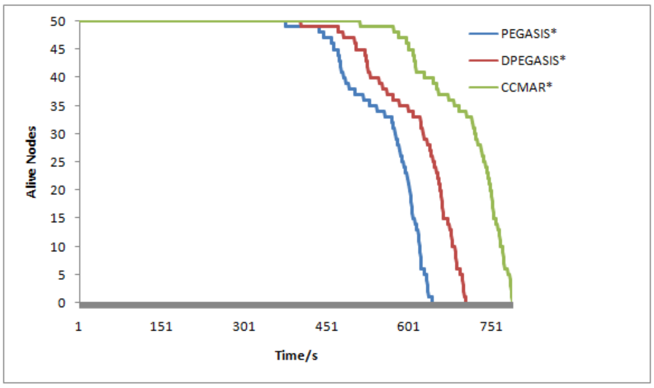

Figure 10: Comparison of network lifetime for PEGASIS, DPEGASIS and CCMAR when implemented with GIICCF

From the above two comparisons, it could be seen that, when protocols attached/implemented with the GIICC framework, outperforms the original protocols.

Hence the life-time of every nodes in the network increases with a huge margin. The figure (11) below provides a brief idea of nodes death over a period of time for these above mentioned protocols. It contains the details of first node deaths (FND), half node deaths (HND), and last node deaths (LND) for all the original protocols as well as enhanced one with GIICCF.

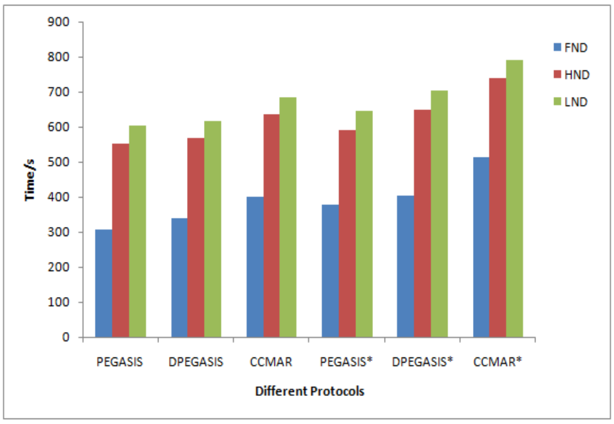

Figure 11: Comparison of node deaths for original and enhanced protocols

Based on equation (10), PDR of PEGASIS, DPEGASIS and CCMR are provided in figure (12). On implementing the GIICCF on the said protocols, it was found that the system has outperforms the original protocols (figure (13)).

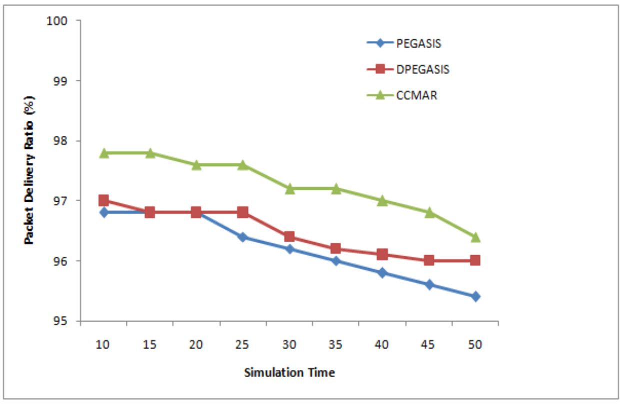

Figure 12: PDR for PEGASIS, DPEGASIS and CCMAR

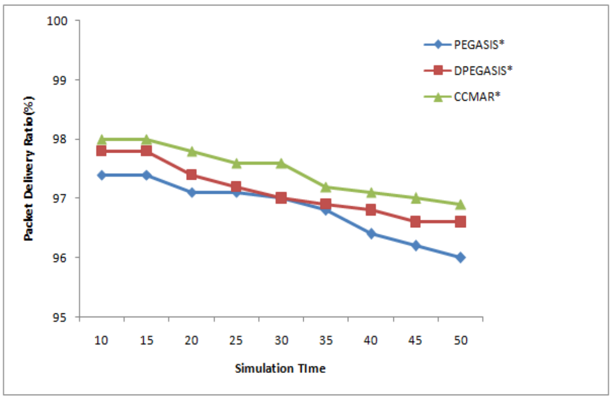

Figure 13: PDR for PEGASIS, DPEGASIS and CCMAR when implemented with GIICCF

IV. CONCLUSION

In this article, through the above simulation results, it could be seen that protocols based on clustering and protocols based on chaining, when implemented with the proposed framework, that is, Generalized Intra and Inter Cluster Chaining Framework (GIICCF), the performance of the protocols increases significantly. In GIICCF, chaining is done at both the levels, that is, at the cluster level and even at the network level. Where the nodes within the cluster (intra-cluster) elect one cluster/chain head and form different chains to relay the sensed data to the cluster/chain head. Again at the network level (inter-cluster) the cluster/chain heads of different clusters form chains to relay data to the base station. This reduction in energy dissipation while transmitting the data either to the heads or to the base station has made the framework more energy-efficient as well as has made the system better performing one. Thus, if generalized intra and inter cluster chaining framework is implemented upon other cluster-based protocols and chain-based protocols the performance of these protocols subsequently increases exponentially.

REFERENCES

1. Heinzelman WB, Chandrakasan AP, Balakrishnan H. An application-specific protocol architecture for wireless microsensor networks. IEEE Transactions Wireless Communication 2002; 1(4):660–70..
2. W. Rabiner Heinzelman and H. Balakrishnan, 2000. Energy-Efficient communication Protocol for Wireless microsensor networks, IEEE, Proceeding of the 3rd Hawali International Conference on System Science.
3. S. Lindsey and C. S. Raghavendra, “Pegasis: Power-efficient gathering in sensor information systems,” in Aerospace conference proceedings, 2002. IEEE, vol. 3. IEEE, 2002, pp. 3–1125.
4. K. Benkic, M. Malajner, P. Planinsic and Z. Cucej, "Using RSSI value for distance estimation in wireless sensor networks based on ZigBee," 2008 15th International Conference on Systems, Signals and Image Processing, Bratislava, 2008, pp. 303-306.
5. A. M. Bongale, A. Swarup and S. Shivam, "EiP-LEACH: Energy influenced probability based LEACH protocol for Wireless Sensor Network," 2017 International Conference on Emerging Trends and Innovation in ICT (ICEI), Pune, 2017, pp. 77-81.
6. J. Kulshrestha and M. K. Mishra, "DPEGASIS: Distributed PEGASIS for chain construction by the nodes in the network or in a zone without having global network topology information," 2017 International Conference on Multimedia, Signal Processing and Communication Technologies (IMPACT), Aligarh, 2017, pp. 13-17.
7. Gopi Saminathan Arumugam and Thirumurugan Ponnuchamy, "EE-LEACH: development of energy-efficient LEACH Protocol for data gathering in WSN," EURASIP Journal on Wireless Communications and Networking (2015) 2015:76.
8. Liang Zhao, Shaocheng Qu and Yufan Yi, "A modified cluster-head selection algorithm in wireless sensor networks based on LEACH," EURASIP Journal on Wireless Communications and Networking (2018) 2018:287.
9. Zhi Ren, Pengxiang Li, Jun Fang, Hongbin Li and Qianbin Chen. "SBA: An Efficient Algorithm for Address Assignment in ZigBee Networks," Wireless Pers Commun (2013) 71:719–734
10. Jiasong Mu, Wei Wang, Baoju Zhang and Wei Song, "An adaptive routing optimization and energy-balancing algorithm in ZigBee hierarchical networks," EURASIP Journal on Wireless Communications and Networking 2014, 2014:43
11. ZigBee Standard Organization, ZigBee Specification Document 053474r17(ZigBee Alliance, San Ramon, 2007)

12. S. Sasirekha and S. Swamynathan, "Cluster-Chain Mobile Agent Routing Algorithm for Efficient Data Aggregation in Wireless Sensor Network," in Journal of Communications and Networks, vol. 19, no. 4, pp. 392-401, August 2017.
13. Hongju Cheng and Xiaohua Jia, "An energy efficient routing algorithm for wireless sensor networks," Proceedings. 2005 International Conference on Wireless Communications, Networking and Mobile Computing, 2005., Wuhan, China, 2005, pp. 905-910.
14. P. V. Kallapur and N. N. Chiplunkar, "Topology Aware Mobile Agent for Efficient Data Collection in Wireless Sensor Networks with Dynamic Deadlines," 2010 International Conference on Advances in Computer Engineering, Bangalore, 2010, pp. 352-356.
15. P. K. Biswas, H. Qi, and Y. Xu, "Mobile-agent-based collaborative sensor fusion," Inform. Fusion, vol. 9, no. 3, pp. 399–411, July 2008.
16. T. Shepard, "A channel access scheme for large dense packet radio networks", *Proc. ACM SIGCOMM*, pp. 219-230, 1996-Aug.
17. Tripatjot Singh Panaga, J.S. Dhillon. Dual head static clustering algorithm for wireless sensor networks. In International Journal of Electronics and Communications (AEU) 88 (2018) 148–156.
18. Jie Huang. A Double Cluster Head Based Wireless Sensor Network Routing Algorithm. In 8th IEEE International Conference on Software Engineering and Service Science (ICSESS); Beijing, China, 2017.
19. N. Kumar, Sandeep, P. Bhutani and P. Mishra, "U-LEACH: A novel routing protocol for heterogeneous Wireless Sensor Networks," 2012 International Conference on Communication, Information and Computing Technology (ICCICT), Mumbai, 2012, pp. 1-4
20. Mohammed Zaki Hasan , HussainAl-Rizzo, Melih Günay,"Lifetime maximization by partitioning approach in wireless sensor networks," EURASIP Journal onWireless Communications and Networking (2017)
21. Nguyen Duc Nghia and Huynh Thi Thanh Binh (2008). Heuristic Algorithms for Solving Bounded Diameter Minimum Spanning Tree Problem and Its Application to Genetic Algorithm Development, Greedy Algorithms, Witold Bednorz (Ed.), ISBN: 978-953-7619-27-5, InTech,
22. B. Dey and S. Nandi, "A Scalable Energy Efficient and Delay Bounded Data Gathering Framework for Large Scale Sensor Network," 2011 Second International Conference on Emerging Applications of Information Technology, Kolkata, 2011, pp. 227-230.
23. Huarui Wu, Huaji Zhu, Lihong Zhang, and Yuling Song,"Energy Efficient Chain Based Routing Protocol for Orchard Wireless Sensor Network," Journal of Electrical Engineering {\&} Technology, 2019
24. NS2 official website, http://www.isi.edu/nsnam/ns/

AUTHORS PROFILE

Biswanath Dey worked as one of the senior faculty members in Dept of Computer Science and Engineering at National Institute of Technology, Silchar, India. His areas of interests are ubiquitous surveillance systems, Wireless Sensor Network, Natural Language Processing, Mobile Ad-hoc Network.

Navajyoti Nath has completed his Masters degree from Department of Computer Science and Engineering, National Institute of Technology, Silchar, India in the year 2019. Presently he is working in Department of Computer Science and Engineering, School of Technology, Assam University (Central University), Silchar, India. His areas of interests are Wireless Sensor Network, Mobile Ad-hoc Network.

Prof. Sivaji Bandyopadhyay obtained his Bachelor of Computer Science and Engineering (BCSE) from Jadavpur University in 1985, Master of Computer Science and Engineering (MCSE) from Jadavpur University in 1987 and PhD (Engg.) from Jadavpur University in 1998. He is Professor in Computer Science and Engineering at Jadavpur University (currently on-lien) since 2001. He has joined as the Director of NIT Silchar on 1st December, 2017. Prior to that, he was the Head, Computer Science and Engineering Department, Jadavpur University during 2012-2014, Dean, Faculty of Engineering and Technology, Jadavpur University, during 2013-2016, Director, Computer Aided Design Centre, Jadavpur University during 2012-2017, Coordinator, TEQIP-II, Jadavpur University during 2013-2016 among other responsibilities.

Professor Bandyopadhyay has supervised over 11 PhD students and a total of 12 PhD scholars are currently working under his supervision. He has published around 49 research articles in reputed journals and 250 research publications in reputed conferences, workshops or symposiums. He has also authored two books. He has completed 4 international research and development projects - with France, Mexico, Japan as the Principal Investigator in the area of Sentiment Analysis, Question Answering, and Textual Entailment. He was the Chief Investigator of 8 National level consortium mode projects in the areas of Machine Translation - English to Indian languages and Indian language to Indian languages, cross lingual information access, development of tree bank for Indian languages among others. Currently, he is executing three international projects funded by SPARC (MHRD) with Germany, ASEAN (DST) with Indonesia and Malaysia, DST and CNRS with France. The Center for Natural Language Processing (CNLP), a research center has been established at NIT Silchar under his leadership. Professor Bandyopadhyay has various International research collaborations and visited several countries to deliver invited talks. He is regularly organizing the workshop series "Sentiment Analysis where AI meets Psychology (SAAIP)". He was the Program Chair of the 14th International Conference on Natural Language Processing (ICON 2017). He has started the International Conference on Big Data, Machine Learning and Applications (BigDML) in the Department of Computer Science and Engineering at NIT Silchar to be held in December, 2019. His research area is Language Technology, Artificial Intelligence, Communication Technology and Networks, Information processing over Networks.

Prof. Sukumar Nandi is one of the senior faculty members and is working as Professor in the Department of Computer Science and Engineering, Indian Institute of Technology, Guwahati, Assam. He is also the Head, Centre for Linguistic Science & Technology, Indian Institute of Technology Guwahati. He received his PhD degree from Indian Institute of Technology, Kharagpur, West Bengal. He is a Fellow of Indian National Academy of Engineering, Senior Member ACM, Senior Member IEEE, Fellow of the Institution of Engineers (India) and Fellow of the Institution of Electronics and Telecommunication Engineers (India). His area of interests are Networks (Specifically: QoS, Wireless Networks), Computer and Network Security, Data Mining, VLSI, Computational Linguistic.