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# Cluster based Smart Random Walk for Data Aggregation in Wireless Sensor Network

प्रज्ञानम् ब्रह्म


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# Introduction

- **Wireless sensor networks** (**WSNs**) refer to networks of spatially dispersed and dedicated sensors that monitor and record the physical conditions of the environment and forward the collected data to a central location[1].
- In WSNs, the energy is consumed in different ways in different nodes however, the primary energy cost is in data transmission once the networks have been organized.
- Data transmission is generally very expensive in terms of energy consumption [2].
- Data transmission depends on the routing strategy.

# Introduction

## Routing Strategy in WSNs

- Routing schemes in WSN are divided based on the used topology such as [3]:
  - Flat-based
  - Chain-based
  - Tree-based
  - Cluster-based

## Clustering in WSNs

- Clustering reduces energy consumption in WSN [4].
- It divides the sensors node into two groups:
  - Cluster head
  - Cluster member
- Cluster head(CH) collects the sensed data from member nodes and perform aggregation.

# Survey on Existing Research

Various researchers tried to improve the energy efficiency and load distribution of routing algorithm with the use of clustering.A detailed literature survey of data aggregation schemes is provided in below Table:

| Papers | Advantages | Research Gap |
|---|---|---|
| [8], [9], [10] | The basic idea of LEACH is that in each round, it selects the CHs from available live nodes and other non-CHs nodes choose the nearest CH from a set of CHs. Few papers have been used LEACH for routing in clustered environment. | During the CH formation phase, due to ignorance of residual energy of nodes LEACH will not select CH optimally and efficiently, Also in each round energy overhead is increased due to dynamic selection of cluster heads. |
| [11], [12] | In C-LEACH the average energy of the system is considered as threshold. So in every round nodes who have energy greater than the threshold energy will take part in CHs formation. | Energy overhead still exists when average energy node transfer his information to BS. |
| [13] | Energy Delay Index for the Tradeoff (EDIT) protocol to overcome the delay and energy consumption issues. EDIT select CHs with help of backoff timer mechanism and an objective function. Objective functions consider dynamic parameters like distance to BS, number of neighbour nodes and residual energy to evaluate. | EDIT protocol still does not guarantee a homogenous deployment of CHs in the topological field. |
| [14] | Hybrid algorithms use clustering and routing algorithms to transmit data in WSNs to reduce communication cost. For routing the shortest path and random walk both are good choices. | A random path is much more efficient than a shortest path in terms of communication cost. |
| [15], [16] | Using random steps, RW collects correlated data, It continues to add readings from sensors nodes which it leads through and lastly for CS recovery processes sends combined readings to BS. | Deadlock condition is missing where random walk lock in loop. |
| [17] | This paper proposed a RW based on the centrality choice parameter to compute the communication path. They used a centrality choice parameter to break deadlock. Experiment results showed that suggested approach can find out the network route with less number of hopes compared to other RW protocols. | Uniform distribution of cluster heads to meet realistic scenarios. Therefore there are high chances that we encountered many cases in which CHs are present very distant from BS and not connected to neighbouring CHs. Given situation is not considered in this paper. |

# Motivation

- In WSNs, usually resource constraint sensor nodes are deployed into harsh environments without a predesigned framework.
- Data transmission is generally very expensive in terms of energy consumption compared to data processing[5] .
- In direct transmission protocol, if Base Station(BS) is far away from the nodes, it will consume more energy in transmission .
- The problem with multi hop routing is that it does not provide load balancing.
- In LEACH, Cluster head sends the data directly to the BS after data aggregation, this consumes more energy for the CHs (BS is far away) [6].
- Direct implementation of Random Walk(RW) on deployed area is not suitable for large scale WSNs. As, it suffers from high packet delay as network depth increases [7].

# Problem Description

- From literature survey, we encountered many cases where multiple CHs are present beyond the communication range from BS. Further they may or may not be connected to other neighbouring CHs thus hindering data delivery from CH to BS in a data collection round.
- The main objective of this paper is to handle such cases while maintaining the load balancing and packet delivery ratio in a clustered environment along with provisions of minimal number of intermediate hops.

# Network Model's Assumptions

In our network we consider homogeneous nodes and non deterministic deployment. Following are the assumptions:

- After deployment, base station and nodes become stationary.
- Nodes are distributed in uniformly random manner and have the same capabilities [6].
- All the nodes are aware of their geographical location [18].
- Base station have unlimited energy resources, can perform computation and have memory capacity. BS is aware of locations of all nodes[19].
- At least one CH should be within communication range of the BS.

# Methodology

In our proposed Cluster Based Smart Random Walk (CBSRW) we are trying to achieve a better packet delivery ratio and load balancing by implementing an improved version of random walk which ensures reliability of messages.

So, we divided our proposed scheme into two phases.

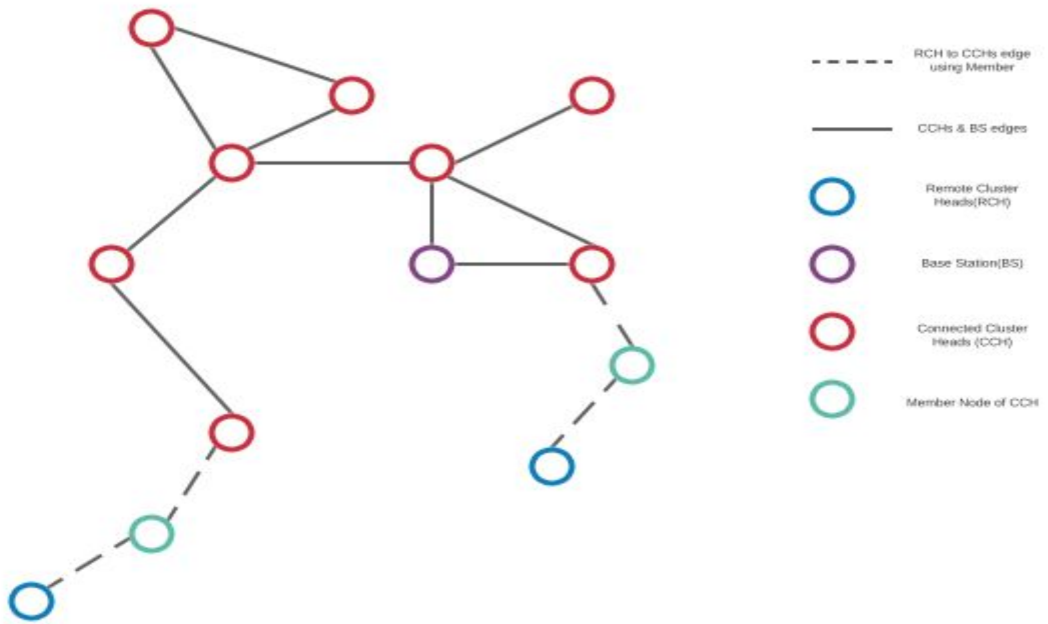
1. Cluster formation & data aggregation phase.
2. Routing phase.

- **Cluster formation & data aggregation Phase:** In this phase all the nodes take part in Selecting of Cluster Heads (CHs) based on the randomized rotations.

$$T(n) = \begin{cases} \dfrac{P}{1 - P \times (r \times mod \frac{1}{P})}, & if\ n \in G \\ 0, & otherwise \end{cases}$$

# Methodology

- **Routing phase:** In this phase, all the cluster head use an smart random walk algorithm to deliver our aggregated data to the base station.
- From BS, Breadth First Search (BFS) is initiated to find reachable nodes(vertices). So the BFS algorithm divides our vertices into two sets:
  - Connected set
  - Remote set



**Algorithm 1: Smart Random Walk**

***Input***: Communication radius, Set of Cluster Heads

***Steps***:

1) **for** All the cluster heads **do**
2) for vertex v, Calculate euclidean distance from each cluster head and base station.
3) **if** Distance(v,u) < communication radius **then**
4) Create undirectional edge from v to u.
5) **end if**
6) **end for**
7) Divides vertices into two sets: connected and remote sets using BFS.
8) **for** all the remote set vertices **do**
9) Find the nearest member node whose Cluster head is present in connected sets.
10) Transmit data to that nearest member node.
11) Nearest node will transmit received data to cluster head.
12) **end for**
13) **for** all the connected set vertices **do**
14) **if** Node is unvisited **then**
15) Initialise a single random walker algorithm 2 from that node to BS.
16) Mark all the nodes visited from which this random walker visits.
17) **end if**
18) **end for**

**Algorithm 2: Single Walker Algorithm**

***Input***: Graph(V,E), Source S, Destination D, threshold T, Transition Probability Matrix(TPM) and Visited array V(u)

***Output***: Gives path from source to destination.

***Steps***;

1) **for** All the node in G **do**
2) Calculate closeness centrality C(u).
3) **end for**
4) for node u **while** walk length < T **And** Destination node is not reached **do**
5) Select a neighbour node v using TPM.
6) Increment V(v) count for neighbour node.
7) Update TPM(u,v)=TPM(u,v)*Choice(u).
8) Increment walk length by one.
9) u=v.
10) **end while**

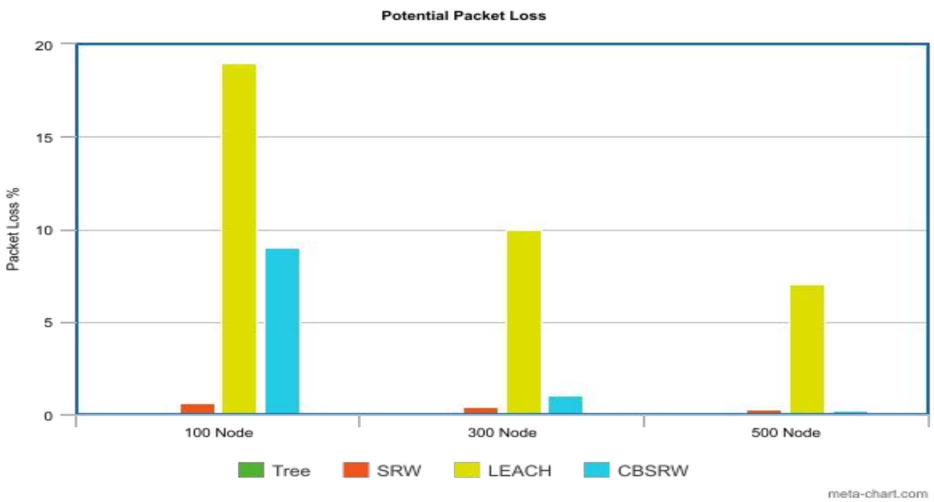
# Simulations, Result and Analysis

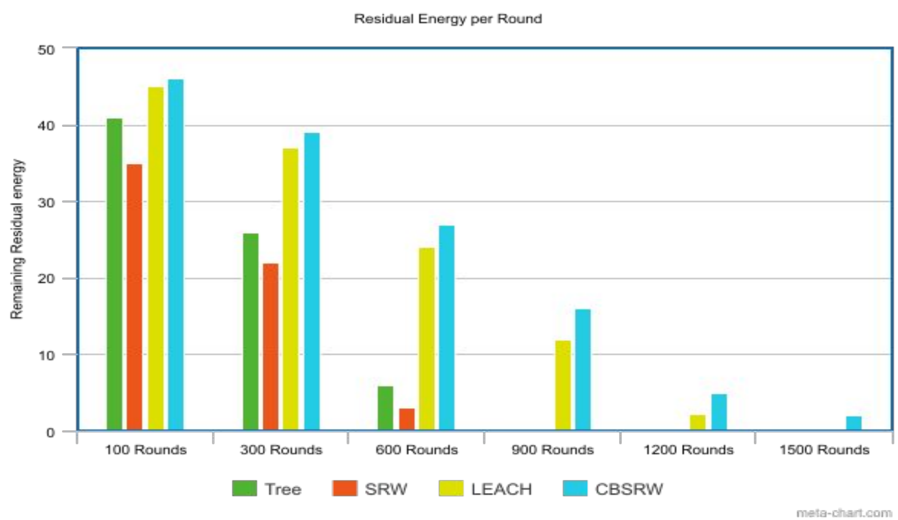
- For our experiment, we use the MATLAB-2018a simulator.
- We compare the performance of Cluster Based Smart Random Walk (CBSRW) with TREE, Smart Random Walk (SRW) and LEACH protocols.
- For performance evaluation of CBSRW, we consider network stability, packet delivery ratio, residual energy and in-network transmission parameter.

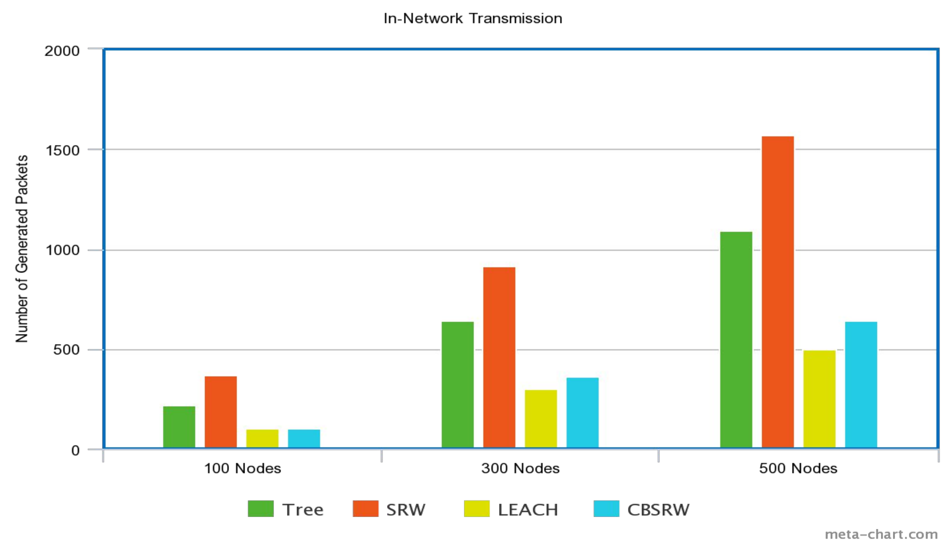
| Parameters | Values |
|---|---|
| $E_0$ | $0.5J$ |
| $E_{elec}$ | $50 \times 10^{-9} J/bit$ |
| $E_{amp}$ | $1.3 \times 10^{-16} J/bit/m^2$ |
| $N$ | 100, 300, 500 |
| $E_{fs}$ | $10 \times 10^{-12} J/bit/m^2$ |
| $R_{Tx}$ | 20m |
| $R_{com}$ | 20m |
| $d_0$ | 87.7m |
| Area | $100 \times 100 m^2$ |

**Simulation Parameters**

# Simulation, Result and Analysis

# Conclusion

- The problem of balancing the network lifetime with reliable packet delivery is explored in this paper.
- Many available routing schemes try to improve energy efficiency but fail to increase reliable packet delivery. In order to fill this gap CB-SRW scheme is proposed for WSNs.
- The proposed method is suitable for the networks where packet delivery and network lifetime both are critical.
- In future, an event driven environment can be considered with heterogeneous nodes for simulation purposes to observe the results obtained from the proposed scheme. Also an improved CH selection scheme may be integrated with the proposed scheme to increase its efficiency.

# References


[1] X.-H. Li and Z.-H. Guan, "Energy-aware routing in wireless sensor networks using local betweenness centrality,"International Journal of Distributed Sensor Networks, vol. 9, no. 5, p. 307038, 2013.

[2] W. Osamy, A. M. Khedr, A. Aziz, and A. A. El-Sawy, "Cluster-tree routing based entropy scheme for data gathering in wireless sensor networks,"IEEE Access, vol. 6, pp. 77 372–77 387, 2018.

[3] M. Inam, Z. Li, Z. A. Zardari, and F. M. M. Mokbal, "Energy efficient clustering and shortest-path routing protocol (eecsrp) in wireless sensor networks," 2019.

[4] M. T. Nguyen, "Minimizing energy consumption in random walk routing for wireless sensor networks utilizing compressed sensing," in 2013 8th International Conference on System of Systems Engineering.IEEE, 2013, pp. 297–301.

[5] H. Tian, H. Shen, and T. Matsuzawa, "Random walk routing for wireless sensor networks," in Sixth International Conference on Parallel and Distributed Computing Applications and Technologies (PDCAT'05). IEEE, 2005, pp. 196–200.

[6] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks," in Proceedings of the 33rd annual Hawaii international conference on system sciences.IEEE,2000, pp. 10–pp.

[7] Z. M. Zahedi, R. Akbari, M. Shokouhifar, F. Safaei, and A. Jalali, "Swarm intelligence based fuzzy routing protocol for clustered wireless sensor networks,"Expert Systems with Applications, vol. 55, pp. 313–328, 2016.

[8]W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy efficient communication protocol for wireless microsensor networks," in Proceedings of the 33rd annual Hawaii international conference on system sciences. IEEE, 2000, pp. 10–pp.

[9] Z. M. Zahedi, R. Akbari, M. Shokouhifar, F. Safaei, and A. Jalali, "Swarm intelligence based fuzzy routing protocol for clustered wireless sensor networks," Expert Systems with Applications, vol. 55, pp. 313– 328, 2016.

[10] M. Shokouhifar and A. Jalali, "Optimized sugeno fuzzy clustering algorithm for wireless sensor networks," Engineering applications of artificial intelligence, vol. 60, pp. 16–25, 2017.

# References


[11] W. B. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks," IEEE Transactions on wireless communications, vol. 1, no. 4, pp. 660–670, 2002.
[12] M. T. Rahama, M. Hossen, and M. M. Rahman, "A routing protocol for improving energy efficiency in wireless sensor networks," in 2016 3rd International Conference on Electrical Engineering and Information Communication Technology (ICEEICT). IEEE, 2016, pp. 1–6.
[13] A. Thakkar and K. Kotecha, "Cluster head election for energy and delay constraint applications of wireless sensor network," IEEE sensors Journal, vol. 14, no. 8, pp. 2658–2664, 2014.
[14] M. Nguyen and Q. Cheng, "Efficient data routing for fusion in wireless sensor networks," Signal, vol. 1000, no. 8, p. 11, 2012. [15] V. K. Singh, S. Verma, and M. Kumar, "Odecs: An on-demand explosion-based compressed sensing using random walks in wireless sensor networks," IEEE Systems Journal, vol. 13, no. 3, pp. 2466–2475, 2019.
[16] M. Sartipi and R. Fletcher, "Energy-efficient data acquisition in wireless sensor networks using compressed sensing," in 2011 Data Compression Conference. IEEE, 2011, pp. 223–232.
[17] S. Simi and A. Sherin, "A centrality based random walk approach for topology formation in networks," in 2017 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET). IEEE, 2017, pp. 1468–1472.
[18] A. Shivhare, V. K. Singh, and M. Kumar, "Anticomplementary triangles for efficient coverage in sensor network-based iot,"IEEE Systems Journal, vol. 14,no. 4, pp. 4854–4863, 2020.
[19] A. Hussien, S. Al-Shammari, and M. Marie, "Performance evaluation of wireless sensor networks using leach protocol,"Indones. J. Electr. Eng. Comput. Sci.,vol. 19, no. 1, 2020.

THANK YOU !