Relay Node Placement in Wireless Sensor Networks: A Survey

Manpreet Kaur[1] Er. Abhilasha Jain[2]
[1,2]Department of Computer Science & Engineering
[1,2]GZS PTU Campus Bathinda, Punjab, India

Abstract— Recently, wireless sensor networks (WSNs) have been immensely used in many real-life outlines, and have become very important. These sensors sense some physical phenomenon and then gathered information is processed. Sensor nodes may be affected from a huge distortion in severe surroundings, that causes the network to get split into multiple disjoint segments. Now to join these segments (in WSNs) is very crucial. However, if the connectivity of the network has been more dense, it will get more rough. In this paper a Relay node placement scheme in WSNs that unites disjoint segments with less number of Relay nodes is considered. Number of techniques are used for implementing it.

Key words: LSSA, Sink Node, Relay Node

I. INTRODUCTION

Wireless Sensor Networks **(**WSN) consists of various wireless sensing nodes. Each node can be assumed as stationary node or moving node. These nodes senses the data from its environment and send that data to the sink node. Different networks of this nature can be formed from various types of applications like such as disaster management, forest fire detection, plant automation that requires the deployment of an array of nodes which have to operate for long time inactively on limited power supply. This is because of the miniaturization and integration of the hardware combined with the low cost .More and more applications which employ some kind of network sensors are devised.

In WSNs, a sensor node senses the data and sends the obtained data to the sink. Due to the special arrangement that sink nodes are generally far away from the data sources, direct transmission of data from source to sink is usually not practical. Therefore, a multi-hop routing is appropriate for data transmitting on a long path, and the clustering topology is a good choice to achieve network scalability.

In recent years we have witnessed an almost explosive development in the area of sensor networks in general, and wireless sensor networks (WSN) in particular, in the civilian fields [1]. Much because of the miniaturization and integration of the hardware, combined with the low cost associated, more and more applications which employ some kind of network sensors are devised. These applications such as disaster management, forest fire detection, plant automation - require the deployment of an array of nodes which have to operate inactively for long time, on limited power supply. Major deployments consist of hundreds of nodes interconnected at a logical level, in accordance to topologies, and also at a physical level, wirelessly. One of the major issues that can be identified is the depletion of the battery's energy [2], [3], [4]. Such situations can cause issues with network's topology because some of the relaying nodes which are not able to forward data causing partitioning of the network and disruption of the services.

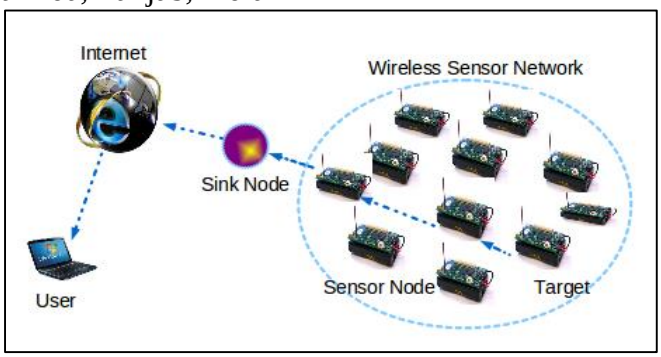

Fig. 1: Wireless Sensor Network

Figure 1 explains how the sink node receives the data from WSNs and provides range of applications:

1) Military Applications*:* Targeting, Nuclear, biological, and chemical attack detection, Monitoring friendly forces, equipment, and ammunition
2) Environmental Applications*:* Forest fire detection, flood detection, air and water pollution.
3) Health Applications: Tele monitoring of human physiological data, tracking and monitoring doctors and patients inside a hospital, drug administration in hospital.
4) Other commercial applications: Environmental control in office building, interactive museums, detecting and monitoring car thefts, managing inventory control, vehicle tracking and detection.

In WSN, devices are battery operated and unrechargeable, to meet out these challenges, energy efficient operation of the WSN is the need of the hour. Despites this, there are some limitations of wireless sensor networks:

1) WSN does not make sensing quantities in buildings easier.
2) WSN does not reduce costs for installation of sensors.
3) WSN does not work with a wired system.

To overcome such problems we will focus on Relay node placement schemes.

Relay node works like amplifiers that amplifies the signal and passes it to the base station. The basic function of Relay node is to relay the data generated by sensor nodes, without sensing the whole surroundings. Its main role is to inform sensor nodes and other Relay nodes. Therefore placement of Relay node plays an important role in system's performance. One or more Relay nodes can be placed between the sensor nodes and sink depending upon the problem. When the distance between the sensor node and sink node is greater than the transmission range means sensor node is not able to send data directly to the sink, so there is need for Relay node placement as shown in figure 2. The placement of relay node plays a critical role in the system performance. One or more relay nodes can be placed between the sensor nodes and sink depending upon the situation.

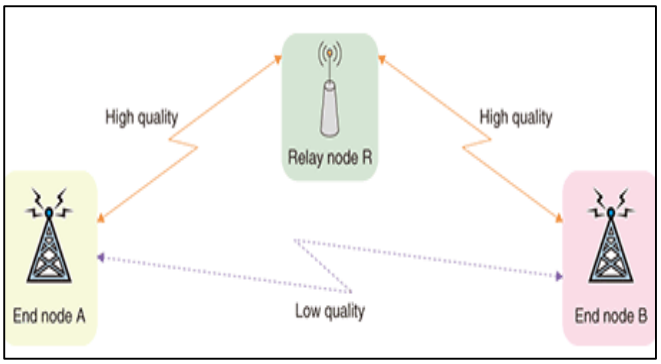

Fig. 2: Placement of Relay Node

II. LITERATURE SURVEY

[1]Bao yu et. Al (2015): In Wireless Sensor Networks (WSNs), node placement plays a significant role to meet design goals such as cost effectiveness, connectivity, lifetime, and data latency. In this paper, a new algorithm to assist in the placement of nodes for a WSN which monitors an underground tunnel infrastructure is proposed. To improve WSN's nodes utilization rate, a minimization problem of distances between two relay nodes, which are used in a multi-hop WSN for tunnel monitoring is defined. A relationship between self-organized neighbor clusters which are composed of a multi-hop route to collect monitoring data is found. The relationship leads to a multi-objective optimization problem. Therefore, they make use of particle swarm algorithm (PSO), which is appropriate to a multi-objective optimization problem, to search for an optimized results. Its result would be helpful for saving the cost of nodes deployment and improve the efficiency of energy in a linear WSN.

Issue: As this network of wireless sensor nodes are placed to monitor underground tunnel infrastructure. Its main focus is to reduce the distance between two relay nodes so that utilization rate of the sensor nodes can be increased. But by increasing the distance between sensor node and relay node results in increasing the energy consumption of the nodes.

[2]Chaofan Ma el. At (2015): In two-tiered Wireless Sensor Networks (WSNs) relay node placement considering resource constraints and high overhead of the relay nodes plays a key role in extending the network lifetime. Therefore, approaches that support fewer relay nodes are desired to cover the WSNs. In this paper, the relay node placement problem as a Geometric Disc Covering (GDC) problem, and propose a novel local search approximation algorithm (LSAA) to solve the GDC problem is formulated. In the proposed LSAA, the sensor nodes are allocated into independent groups and then a Set Cover (SC) for each group is performed. The set of the SC for each group constitutes a SC of the GDC problem. LSAA is extensively investigated and analyzed by rigorous proof and the simulation results presented in this paper clearly demonstrate that the proposed LSAA outperform the approaches reported in literature in the reduction in deployed relay nodes.

Issue: In this paper they have used geometric disk covering. For this LSAA technique is used. This technique uses the process of local approximation to identify the set cover. Once position will be identified it places a relay node on to specific position. For identifying the set cover for GDC requires large computations will indirectly increases the computation complexity.

[3]Alexandru Iovanovici el. At (2015): Applications like civilian and military real world applications requires deployments of large sensor networks. However, problems like limited energy supply, tough environments, data latency and integrity causes adverse effects on large topologies of sensors. This paper presents a novel approach in designing the placement of relay nodes in a sensor network. By using concepts from the area of social network analysis and mapping them to the already classical field of sensor networks we succeed to add improvements to the costs implied with deploying the infrastructure. By socializing the topology with the concepts of centrality and community structure, our research is focused around a flexible design space exploration algorithm we have devised, which offers a balance between the performance and cost of deploying relays in a sensor network. As a result, our WSN design achieves a relevant improvement over the state of the art solutions.

Issue: But there analysis is spanning in two major directions defined by the two varying parameters: the community granularity, which provides an insight into the smallest possible cluster of nodes and the already classical wireless coverage area of each node.

[4]Jihed Eddine Said el. at (2014): Wireless sensor networks (WSNs) have received significant research focus due to their widespread applicability in military, health care, agriculture, environment monitoring applications. These applications require WSNs to be self organized and mobile. Clustering techniques are particularly important in the success of WSN implementations especially when sensor nodes are moving at different speeds. Many existing clustering algorithms assume that sensor nodes move at the same speed which is not true in many practical cases. Thus, in this paper, they introduce a velocity-based clustering algorithm and implement a relay placement technique in order to maintain seamless network connectivity.

Issue: The wireless nodes working with different speed are sometimes possible to go beyond transmission range in between to the communication get completed.

III. RELAY NODE PLACEMENT TECHNIQUES

Some of the techniques are discussed below:

A. Minimum-Energy Transmission Model

In the minimum-energy transmission model, nodes located closer to the base station relay data at more rate than the nodes which are away from the base station. This rough energy distribution among the nodes may lead to the faster death of the burdened nodes, assuming that initial energy provisioning for all nodes are equal. To solve the problem of balancing of energy dissipation in the network, relay nodes can be placed in the transmission path of longer distances. Stars, Steiner Minimum Tree are the two techniques used for optimal relay node placement**.**

1) Star Technique

In this technique sensor node and sink are in line of sight so as to minimize the energy consumption as energy consumption is directly proportional to the distance. When

distance between sensor nodes and sink increases, more energy will be needed. So Star topology is the most efficient structure for minimizing the distance between sensor nodes and sink as shown in figure 3. In this technique each of the sensor nodes sends data to the sink. Relay nodes are placed in a straight line between each of the sensor node and sink.

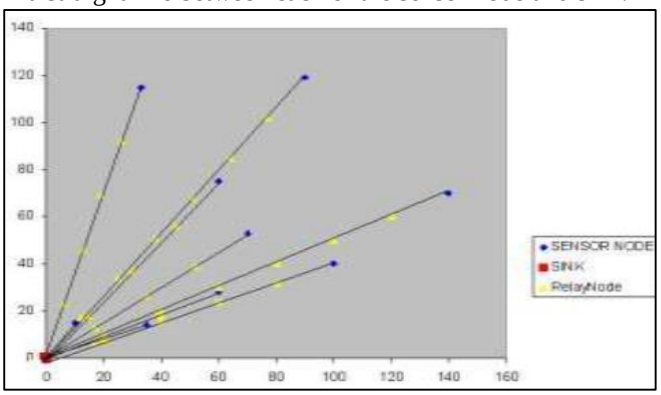

Fig. 3: Sensor networks consisting of 9 sensors required 29 Relay nodes

2) Steiner Minimum Tree

In Steiner Minimum Tree, minimum number of Relay nodes is needed to maintain the network connectivity. We can show a transmission structure SMT, which connect the whole sensor network using the approximate minimum number of Relay node, such that every node can send their data directly to one or more than one hope. The main idea is to start with a beginning structure generated from SMT and then slowly adding the remaining Relay nodes in order to reduce the average energy consumption of the network and increase the system capacity. SMT will provide a transmission structure that requires the minimum number of relay nodes at the price of very high energy consumption. SMTII algorithm provides an energy efficient relay node placement and transmission structure with limited number of available relay nodes. Energy consumption can be significantly reduced by slightly increasing the number of relay nodes over the minimum number necessary to maintain connectivity. Further increasing the number of relay nodes will not make much improvement in energy efficiency.

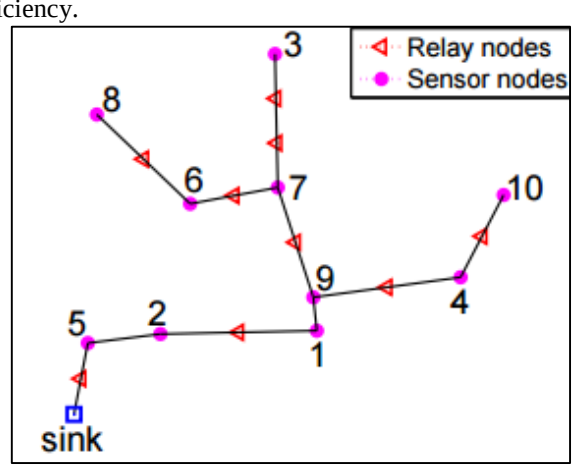

Fig. 4: SMT requires 9 relay nodes.

B. Single-Tiered Network Model

Its main function is to deploy minimum number of relay nodes in a WSN so that between every pair of sensor nodes, there is a connecting path consisting of relay and sensor nodes such that each hop of the path is not longer than the common range of the sensor nodes and the relay nodes.

C. Two-Tiered Network Model

It overcomes the problem of long communication, between base and edge node. It uses binary integer algorithm.

Based upon the location of relay node, calculate power for each relay node to maximize its capability. ii. Make optimal relay routing table using BIP which provides mapping from edge nodes to the relay nodes. iii. Update each relay node position using clustering method.

D. Scheduling Based LSAA

In this technique first whole network will be subdivided into smaller networks. Each network consists of specific no. of stationary sensor nodes. Each nodes set cover will be identified. Mobility based relay node is to be scheduled such that moving relay node moves to fixed position and collect the data by sending and receiving a signal. Later one will transfer the whole collected data to the base sink node. Each time mobile relay time is scheduled such that overall life time can be increased.

E. Hierarchical Architecture

Each sensor nodes belongs to only one cluster. Cluster nodes acts as a *Relay* node as shown in figure 5. In heterogeneous wireless sensor networks, sensor nodes possess different transmission ranges.

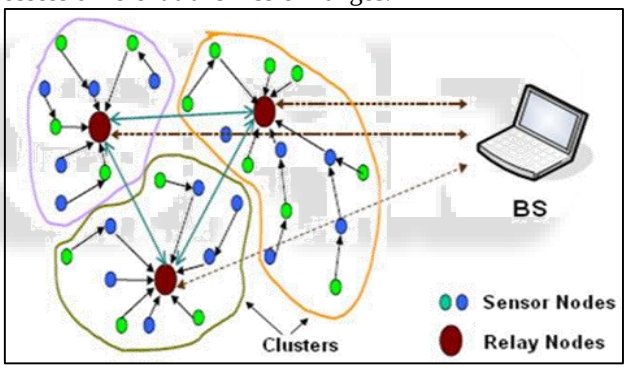

Fig. 5: Hierarchical Architecture

In this table work analysis of various researchers is done. The comparisons are made on basis of their work done.

Researcher	Work Done	Limitation
Bao yu et. al (2015)	we analyzed band-type wireless sensor network in mtWSNs environment	it is not fit for prolong entire networks
Chaofan Ma el. At (2015):	a novel LSAA approach has been proposed	relay node deployment problem with the consideration of energy efficiency and time delay performance
Alexandru Iovanovici el. At	using concepts from the area of social network analysis and mapping them to the already classical	represented by a higher level tiering of the relay network

	field of sensor networks	
Jihed Eddine Said	clustering algorithm based on relay placement, which is capable of handling heterogeneous velocity of sensor nodes.	They plan to tackle other mobility patterns where nodes can move with more degree of freedom.

Table 1:

IV. Conclusion and Future Scope

In wireless Sensor Networks (WSNs), node placement plays a significant role to meet design goals such as cost effectiveness, connectivity, lifetime, and data latency. According to the base paper technique first step includes separation of the grouping phase and local search phase. Specifically, LSAA first allocates the sensor nodes into independent groups and then searches a set cover (SC) for each group. In the Set-Covering Strategy, each relay node is represented by the sensor nodes covered by it, correspondingly, the Set-Covering Strategy searches a minimum set cover of the given sensor nodes. Two-tiered network architecture is proposed to extend the network lifetime in WSNs. In this approach a small number of relay nodes with ample power and suitable wireless communication range are placed to serve as the relay nodes. The relay nodes function like the cluster heads to collect sensed information from one-hop-neighbor sensor nodes and transmit the data to the sink node.

Each time identifying the set cover to position the relay node to build a two tier topology involves time and energy consumption. Each time relay node consumes large amount of energy to identify the set cover and position itself at the point where there is minimum set cover for the wireless sensor nodes. In our research work we will position the relay node at fixed position to build a two tier topology. Our technique will first subdivide a network in smaller groups. Each group will be having stationary sensor nodes. Each sensor node has fixed area of coverage. We can position each group with a relay node. This relay node will be having fixed position. It does not have to identify the set cover each time. Because each time identifies the set cover will waste large amount of energy. In this technique energy through put will be increased. That will save energy and same energy will helps in covering more area by producing more powerful signals to send the collected data to the sink node. Results can be compared with base paper on two aspects:

1) Life time
2) Throughput

Acknowledgment

I am thankful to Er. ABHILASHA JAIN (HEAD OF CSE DEPARTMENT) and special thanks to Er. MANPREET KAUR who has given me the chance to present this paper and for their encouragement in work and support. I am also thankful to my family members who always help me. Last but not least this I am grateful to this institute for providing wonderful platform.

References

[1] Bao yu1*, Wang Yuanping1, Zhao Liang 2, Hu Yuan1, Zhang Aijuan1, "Relay Node Deployment for Wireless Sensor Networks Based on PSO" Computer IEEE 2015
[2] Chaofan Ma1;2;3, Wei Liang1;2 Meng Zheng1;2 and Hamid Sharif4, "Heterogeneous Mobility and Connectivity-based Clustering Protocol for Wireless Sensor Networks" IEEE, 2015.
[3] Alexandru Iovanovici, Alexandru Topirceanu, Mihai Udrescu, and Mircea Vladutiu, "Design Space Exploration for Optimizing Wireless Sensor Networks using Social Network Analysis, 18th International Conference on System Theory 2014.
[4] Jihed Eddine Said1, Lutful Karim2, Jalal Almhana1 and Alagan Anpalagan3, "Heterogeneous Mobility and Connectivity-based Clustering Protocol for Wireless Sensor Networks," IEEE, 2015.
[5] X. Z. Cheng, D. Z. Du, L. S. Wang, and B. G. Xu, "Relay Sensor Placement in Wireless Sensor Networks," Wireless Networks, vol. 14, no. 3, pp. 347–355, 2015.
[6] W. Zhang, G. Xue, and S. Misra, "Fault-tolerant Relay Node Placement in Wireless Sensor Networks: Problems and Algorithm," Proc. of the IEEE Infocom Conf., pp. 1649-1657, 2014.
[7] R. J. Fowler, M. S. Paterson, and S. L. Tanimoto, "Optimal Packing and Covering in The Plane are NP-Complete," Information Processing Letter, vol. 12, no. 3, pp. 133–137, 2013.
[8] D. S. H¨ochbaum and W. Maass, "Approximation Schemes for Covering and Packing Problems in Image Processing and VLSI," J. ACM, vol. 32, no. 1, pp. 130–136, 2014.
[9] T. Feder and D. Greene, "Optimal Algorithms for Approximate Clustering," Proceedings of the 20th Annual ACM Symposium on the Theory of Computing, pp. 434–444,2013.
[10] J. Tang, B. Hao, and A. Sen, "Relay Node Placement in Large Scale Wireless Sensor Networks," Computer Comm., vol. 29, no. 4, pp. 490– 501, 2012.
[11] M. Franceschetti, M. Cook, and J. Bruck, "A Geometric Theorem for Approximate Disc Covering Algorithms," Electronic Technical report ETR035, http://www.paradise.caltech.edu/ETR.html, 2011.
[12] B. H. J. Tang and A. Sen, "Relay node placement in large scale wireless sensor networks," in Computer communications, vol. 29. Elsevier Science, Amsterdam, PAYS-BAS (1978) (Revue), 2006, pp. 490–501.
[13] Al-Turjman F, Alfagih A, Hassanein H, Ibnkahla M. Deploying fault-tolerant grid-based wireless sensor networks for environmental applications. In Proceedings
[14] Ghosh A, Boyd S. Growing well-connected graphs. In Proceedings of the IEEE Conference on Decision and Control: San Diego, CA, 2006; 6605–6611.
[15] Boyd S. Convex optimization of graph Laplacian eigenvalues. In Proceedings of the International Congress of Mathematicians 2006; **3**(63): 1311–1319.

[16] Lloyd EL, Xue G. Relay node placement in wireless sensor networks. IEEE Transactions on Computers 2007;56(1):134–138.
[17] Cheng X, Du D-z, Wang L, Xu B. Relay sensor placement in wireless sensor networks. Wireless Networks 2008; 14(3): 347–355.
[18] Xu K, Wang Q, Takahara G, Hassanein H. Relay node deployment strategies in heterogeneous wireless sensor networks. IEEE Transactions On Mobile Computing 2010; **9**(2): 145–159
[19] Lee S, Younis M. Optimized relay placement to federate segments in wireless sensor networks. IEEE Transaction on Selected Areas in Communications 2010;
28(5): 742–752.
[20] Man Wah Chiang, Zeljko Zilic, Katarzyna Radecka, Jean-Samuel Chenard, "Architectures of Increased Availability Wireless Sensor Network Nodes" IEEE, Vol.2, pp 1232-1240, Feb 2004.
[21] M.Kaur, A.Jain and A.K.Goel,"Energy efficient two level distributed clustering scheme to prolong stability period of wireless sensor network", Advances in Computing, Communications and Informatics (ICACCI,2014 International conference on, New Delhi,2014,pp.6873.doi:10.1109/ICACCI.2014.6968535).

