IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661,p-ISSN: 2278-8727, Volume 21, Issue 6, Ser. II (Nov - Dec 2019), PP 75-85
www.iosrjournals.org

An Efficient Approach for Providing Full Connectivity in Wireless Sensor Network

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Abstract:
As Wireless Sensor Network has gained more focus in the recent years, coverage, redundancy, connectivity, network lifetime are considered as very important issues to be addressed. Connectivity issue is considered to be addressed in this paper as it is one of the important issues of wireless sensor network. Connectivity is required to provide the communication among all the sensor nodes deployed in given region of interest. Without connectivity among sensor nodes and between base station and sensor nodes, the information collected by sensors cannot be sent to base station. An efficient connectivity algorithm is proposed in this paper to provide full connectivity among all the sensors nodes without any duplicate communication links. It also provides connectivity between base station and sensor node closest to it in wireless sensor network. The simulated results show that the proposed approach provides full connectivity and full coverage with very less number of sensor nodes.
Keywords: *Coverage, Connectivity, Random Deployment, Redundancy, Wireless Sensor Network.*

I. Introduction

Wireless sensor network (WSN) comprises of base station(s) and number of nodes called wireless sensors. The environmental conditions like pressure, sound, humidity, moisture and temperature are monitored by these networks and the necessary data are transmitted to the desired location through the network. Two different methods are used for deployment of An Efficient Approach For Providing Full Connectivity In Wireless Sensor Network sensor nodes in WSN. They are deterministic and random. In deterministic deployment method, the region of interest (RoI) can be covered completely as the optimal locations of sensor nodes are known in advance. But, in case of random deployment method, optimal locations, where sensor nodes are to be placed exactly are not known prior to random deployment [1]. As a result of random deployment, few places are covered with more sensor nodes and few other places are covered with less sensor nodes. So after random deployment, any of the coverage enhancement algorithms can be used to determine optimal positions of sensor nodes [2][3]. Later, these sensor nodes are repositioned at optimal positions. But, once the sensor nodes are moved from their original random position to the optimal positions, there are chances that, same position/location may be covered by two or more sensors. This process results in overlapping of sensor nodes and causes redundancy. Redundancy has both advantages and disadvantages. Increased data accuracy, sensing reliability, lifetime of Wireless Sensor Network (WSN) and security are some of the advantages of redundancy. Redundancy elimination also saves the large amount of energy consumption, because, it involves the movement of less number of sensors. But, exhaustion of energy for receiving data, transferring replicated data and unnecessary execution of repetitive tasks are some of the disadvantages of redundancy. The redundancy present in RoI can be eliminated and the coverage can be preserved using one of the existing coverage preserving redundancy elimination algorithms [4].

In WSN, all the deployed sensor nodes exchange information through wireless communication. In order to transfer the information from one sensor node to another sensor node and also to the base station, all the active sensor nodes should be connected. If each and every sensor node can send and receive the information to or from each of the other sensors then WSN is said to be completely connected. But, it is difficult to achieve full connectivity in WSN. Hence, it is required to develop an efficient technique to provide full connectivity as it is not addressed properly in literature. The work presented in the literature suffers from presence of duplicate nodes duplicate links and more number of sensor nodes to provide full coverage and full connectivity. An efficient approach is designed and developed for providing full connectivity in WSN (EAPFC) while preserving the complete coverage without any redundancy. The inputs considered for implementation of the proposed approach are optimal positions of sensor nodes without any redundant and overlapping nodes. It is assumed that redundant and overlapping nodes are already removed using one of coverage preserving redundancy elimination algorithms like [4].

EAPFC first determines the sensor node called, SClose that is closest to the base station. SClose is one of the nodes deployed at optimal positions without any redundant and overlapping nodes. It then determines all the neighboring sensor nodes of SClose that are within communication range of SClose and then establishes communication link between the SClose and all of its neighboring sensor nodes, provided no communication link already exists among them. This process is repeated for all the neighboring nodes of each node connected to SClose until connectivity is established amongst all the nodes in the region of interest in WSN. This approach ensures that no duplicate communication link exists between any two nodes in WSN. Since, connectivity is established between all the nodes, without any duplicate communication links, which are within communication range of each other, nodes can communicate with each other, exchange information gathered and send the same to base station.

The proposed algorithm also provides connectivity between base station and the sensor node closest to it. This closest node acts as an intermediate node between base station and the Region of interest in WSN. The network connectivity in WSN is illustrated in the form of a graph, represented by G = (V, E). Where, collection of sensor nodes is represented by V and collection of communication links is denoted by E [5]. Two sensor nodes are called neighbors of each other, provided, Euclidean distance between them is not more than communication range, R_C. Since the proposed approach considers only nodes positioned at optimal positions without any redundant and overlapping nodes as inputs, very less number of nodes are required to provide 100% coverage. Further, it provides full connectivity amongst all the nodes without any duplicate communication links between any two nodes and also between the closest node and base station. This is not addressed in the literature.

Paper is organized as follows. Section 2 discusses literature review/related work. Section 3 describes system model used for development of proposed algorithm. Section 4 presents the proposed algorithm. Section 5 illustrates the results. Section 6 presents the conclusions drawn and section 7 presents the future work.

II. Related Work

An enormous amount of research work has been carried out in literature on providing connectivity in WSN. Yun Wang et al. [5] presented a fundamental study on coverage and connectivity in WSS using theoretical analysis, mathematical modeling and performance evaluation perspectives. It was observed that, a large number of sensor nodes is used for providing the full coverage and full connectivity which in turn leads to more distance moved by the sensors and more energy consumed by them during movement. Tahiry Razafindralambo and David Simplot-Ryl [6] have considered self-deployment of sensor nodes in WSN and presented a mechanism which preserves network connectivity while deploying mobile wireless sensors. Since, the connectivity is preserved during deployment of sensor nodes at the beginning itself, it is required to eliminate the redundancy after the deployment. Thus it is difficult to maintain the connectivity amongst the deployed nodes while removing the redundancy. Further, the existence of redundancy causes the duplicate communication links to be present in WSN. So, the connectivity has to be reestablished after eliminating redundancy and duplicate communication links.

Ji Li et al. [7] determined optimal locations for relay nodes and normal sensor nodes to ensure connectivity. Since, it considers normal nodes for providing connectivity, the normal nodes may be redundant or overlapping nodes also. Hence, there will be redundant communication links in WSN. The existence of redundant communication links consume more power. Yu Guo [8] proposed an efficient distributed actor deployment strategy for addressing maintenance of connectivity and optimization of coverage issues in WSN by considering the unknown sensors' locations. Unknown sensors are detected by using an artificial potential force based algorithm and redundant communication links are deleted by using a fully distributed link deletion algorithm. Since, redundant communication links are removed after establishing connectivity, it consumes more time for checking and removing redundant communication links.

A. Balamurugan and T.Purusothaman [9] proposed a concept of Integer Programmed Sensor Deployment (IPSD) strategy using a set of relay nodes. A triangular lattice is constructed using grid based approach, to provide maximum coverage and connectivity. Integer Linear Programming (ILP) was brought into force to eliminate unused relay nodes and also to enhance coverage and connectivity using less number of relay nodes. But, it does not provide full coverage and full connectivity. Chia-Pang Chen et al. [10] developed a maximum connected load balancing cover tree (MCLCT) strategy to provide full coverage and also connectivity between Base Station and each sensing node using dynamically formed load-balanced routing cover trees. Since, it provides connectivity between base station and each sensing node, the amount of energy / power consumed for transmitting the information/data will be high.

B.

Xiaole Bai et al. [11] proposed an optimal deployment strategy to provide full connectivity and complete coverage in WSN. But, removal of redundant and overlapping nodes is not addressed in [11]. Hence, there will be duplicate communication links in the WSN. Abdelmalik Bachir et al. [12] presented a mathematical model to provide the better operation of the network by preserving coverage and connectivity. This model also does not address removal of redundant and overlapping nodes. Presence of such nodes in WSN causes duplicate communication links to exist in WSN. S. Mini et al. [13] proposed a Low-Energy Adaptive Clustering Hierarchy (LEACH) model to transmit the data to the base station, where a cluster is considered as a set of sensor nodes satisfying M–connectivity and required level of coverage. This approach does not eliminate duplicate and overlapping nodes while satisfying M-connectivity. Further, number of nodes are used to provide given region of interest. Huping Xu et al. [14] proposed heuristic algorithms such as connected cover formation (CCF) algorithm and the cover formation and relay placement using redundancy removal (CFRP-RR) algorithm to form a connected network by placing the minimum number of sensors that provides complete coverage of all grid points.

III. Methodology

A Two-Dimensional area called region of interest is considered for the deployment of sensors randomly. All the sensors considered for random deployment in a given RoI are homogeneous with same sensing and communication range. The given RoI is said to be fully covered, if and only if, each and every point in RoI is covered by atleast one sensor. At the beginning, all the sensors nodes are randomly deployed in the given RoI. The RoI is divided into number of small grids with identical size. The total number of grid points is dependent on the size of the grid (length × width). The optimal positions are determined to obtain the better coverage using the coverage enhancement algorithms like [2][3]. The Euclidian distance, Ed, between center of any two optimal nodes must be 1.5RS <= Ed <= 2RS. The inputs considered for implementation of connectivity algorithm proposed by us are the set of optimal sensor nodes positioned at optimal positions. It is assumed that the redundant and overlapping nodes which result after the movement of sensors to optimal positions are eliminated using one of algorithms like [4].Connectivity is established among sensor nodes already positioned at the optimal positions, using sensing and communication range of sensor nodes deployed. The sensor node, SClose, which is closest to the base station is chosen and connected to the base station and all the other optimal nodes are then connected to their neighboring nodes of Sclose which are within their communication range of a sensor. This sensor node, SClose, is considered as a mediator between all other sensors nodes positioned at optimal positions in WSN and base station. The optimal sensor nodes that are within the communication range of a sensor are connected with each other without any duplicate communication link amongst any two nodes.

3.1. Assumptions

- The Region of Interest covered by sensor nodes is plan surface with coordinates (X, Y) and sensor node is a disk with center (xi, yi) and radius RS.
- All sensors are homogeneous with same sensing range, R_S and communication range, R_C, where ($R_C >= 2 R_S$).
- Sensors get information about their locations through the Global Positioning System (GPS) and base station gets information about location of each sensor.
- Each sensor node is located at optimal position and no redundant or overlapping node exist in the WSN.
- A centralized architecture algorithm is developed for implementing the connectivity which is executed at base station.
- Signal strength between two connected nodes is high.
- Background interference is nil.

Parameters Used

Table 1 lists all the parameters used in the implementation of the proposed algorithm.

Table 1 Parameters Used

Parameter	Meaning
N	Number of Optimal Sensor Nodes in WSN
Si	ith Sensor located at optimal position
Rs	Sensing Range of Sensor
Rc	Communication Range of Sensor
RoI	Region of Interest
Ed	Euclidian Distance between two sensors
BS	Base Station (Sink Node)
SClose	Sensor node that is closest to Base Station
Nnbrs	Single dimensional array that Stores number of neighbors of a sensor
Nbrs	Two dimensional array that stores all neighbors of each optimal node
NLink	Two dimensional array that stores number of links between any two nodes

IV. Proposed Algorithm

Most of WSN applications use random deployment technique for deploying sensor nodes in given RoI. These randomly deployed sensor nodes are moved to optimal positions to enhance the coverage using one of the coverage enhancement algorithms like [2][3]. The Euclidian distance, Ed, between center of any two optimal nodes must be 1.5RS <= Ed <= 2RS. Later, the redundant and overlapping sensor nodes are eliminated using one of the coverage preserving redundancy elimination algorithms like [4]. An efficient approach is developed for providing full connectivity (EAPFC) in WSN. EAPFC works in three phases, which are discussed below. MATLAB (12Ra) has been used for implementation of the EAPFC. Phase-1 determines the closest node, called SClose which is closest to Base Station. Phase-2 determines the neighbouring nodes of each node positioned at optimal position. Phase-3 establishes a connectivity between each optimal node and its neighbours without any duplicate communication link. Finally SClose is connected to Base station. Phases are as discussed below.

Phase-1: A set of nodes positioned at optimal locations is considered as input for Algorithm-1 and an optimal sensor node that is closest to base station is determined using communication range of sensor nodes deployed. This node acts as an intermediate node between all the other nodes deployed in RoI of WSN and Base station. Further, it is assumed that the RoI in WSN does not contain any redundant and overlapping nodes. Hence, their coordinates are not considered as inputs. The algorithm-1 presents determination of sensor node closest to base station for transmission of data/information from all the other sensor nodes to Base station (sink node) and vice-versa.

Algorithm-1: Find node closest to Base Station.

1. Set Shortest-dist to Rc.
2. Set SClose to 0.
3. for i=1 to N do

a. Determine Ed between Si, and BS.

b. if (Ed is less than Shortest-dist) Then

i. Set Shortest-dist to Ed.

ii. Set SClose to Si.

Phase-2: In this phase, the neighbouring nodes of each optimal node are determined to establish the communication link. All the neighbouring nodes, which are within R_C of an optimal sensor node are determined. For instance, if R_C and R_S of all sensor nodes is 20m and 7m respectively and Node B is at a distance, d, of 2Rs <= d <= R_C from the sensor node A, the node B is considered as the neighbouring node of node A. Like this, all sensor nodes which are at a distance of "d" from node A are determined. Thus, the neighbouring nodes of each sensor node located at optimal position are determined. Algorithm-2 illustrates determination of neighbouring sensor nodes of each sensor node.

Algorithm-2: Determine neighbouring nodes.

1. for i = 1 to N

a. Set count to 0.

b. Set Nnbrs (Si) to 0.

c. for j = 1 to N

if (Si is not equal to Sj) Then

a. Compute Ed, between Si and Sj.
b. if (Ed >= $2R_S$ and Ed <= R_C)

i. increment count by 1.

ii. Set Nbrs(Si, count) to Sj.

iii. Increment Nnbrs(Si) by 1.

Phase-3: In this phase, first, initialize the number of communication links between Sensor Si and its neighbours Sj (for j=1 to number of neighbours of Si) to zero and set it to 1 after connectivity is established. This is done to ensure that no duplicate communication link exist in WSN. Thus, the communication link is established between the sensor node Si (for i = 1 to

N) and its corresponding neighbouring nodes provided no communication link already exists between Si and its neighbouring node. Finally, the base station, BS is connected to the closest sensor node, SClose, determined in phase-1 as illustrated in Algorithm-3. Since, Algorithm-3 avoids duplicate communication link to be present in WSN amongst any two sensor nodes, the amount of energy consumed for transmission of data is also reduced.

Algorithm-3: Establish Connectivity.
1. for i = 1 to N
for j=1 to Nnbrs(Si)
i. Set Sensor1 to Nbrs(Si, j)
ii Set NLink(Si, Sensor1) to zero
2. for i = 1 to N
for j=1 to Nnbrs(Si)
i. Set Sensor1 to Nbrs(Si, j)
ii.If (NLink Si,Sensor1) is equal to 0)
Establish communication link between Si
and Sensor1
Increment NLink(Si, Sensor1) by one.
3 Connect SClose to Base Station, BS.

4.1. Advantages of Proposed Approach

- No redundant and overlapping nodes present in WSN.
- Less number of optimal nodes are used to provide 100% coverage without redundant nodes.
- Less number of optimal nodes are used to provide 100% connectivity without any duplicate communication links.
- Since, no duplicate communication links exist, time and energy required for transmitting the information/data to sink node/base station and vice-versa will be very low.

V. Results And Discussion

5.1. Placement of Sensor Nodes at Optimal Positions

Consider the region of interest of 50m ×50m, sensing range RS of 7m and communication range R_C of 20m. Figure 1, Figure 2, Figure 3 and Figure 4 show final configuration of 20, 30, 40 and 50 sensor nodes moved to optimal positions to enhance the coverage after their initial deployment. The final configuration does not include any redundant and overlapping sensor nodes. It is assumed that the redundant and overlapping sensor nodes are already removed using one of the redundancy elimination algorithm like Coverage Preserving Redundancy Elimination [4]. It is clear from Figure 2, Figure 3 and Figure 4 that only 25 optimal sensor nodes are used to provide 100% coverage when number sensor nodes deployed is above 24 for RoI of 50m × 50m with R_S of 7m and R_C of 14m. This was made possible because, there are no redundant and overlapping nodes in these figures.

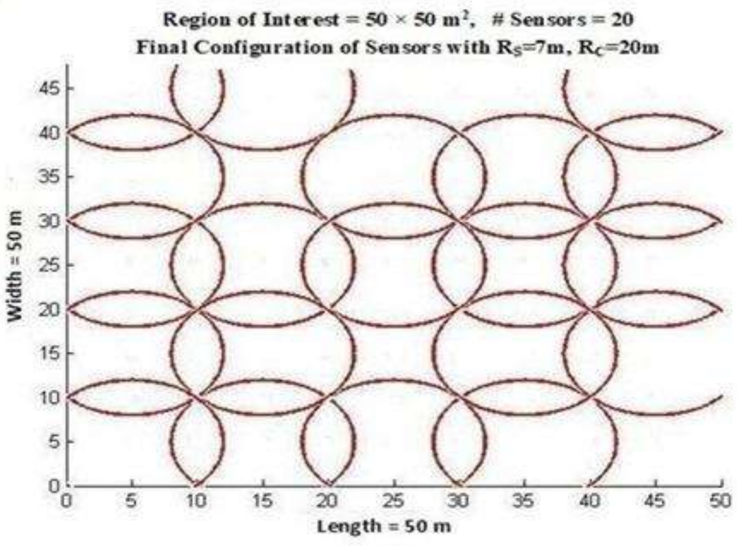

Figure.1 Final configuration of 20 nodes at optimal positions

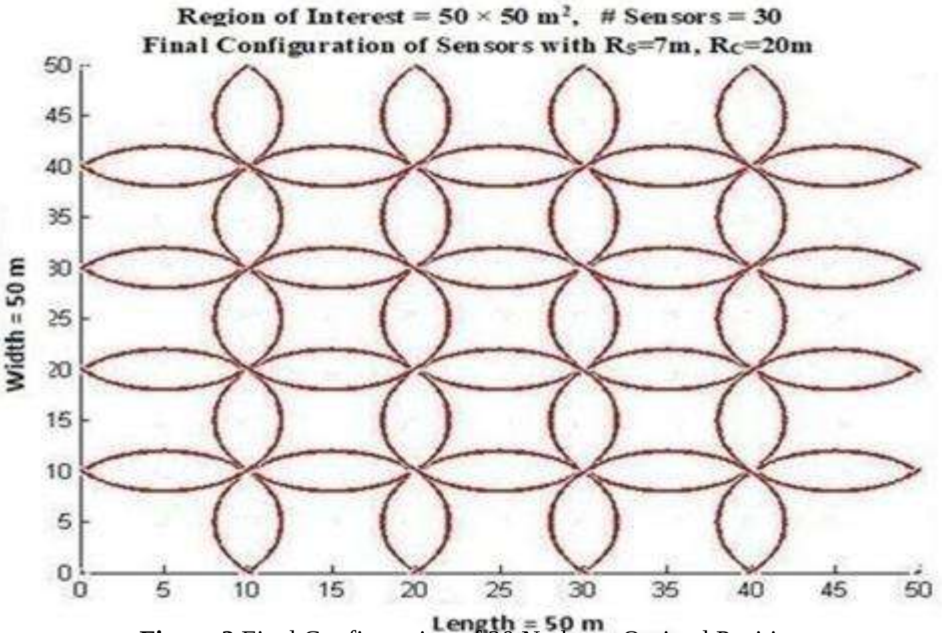

Figure.2 Final Configuration of 30 Nodes at Optimal Positions

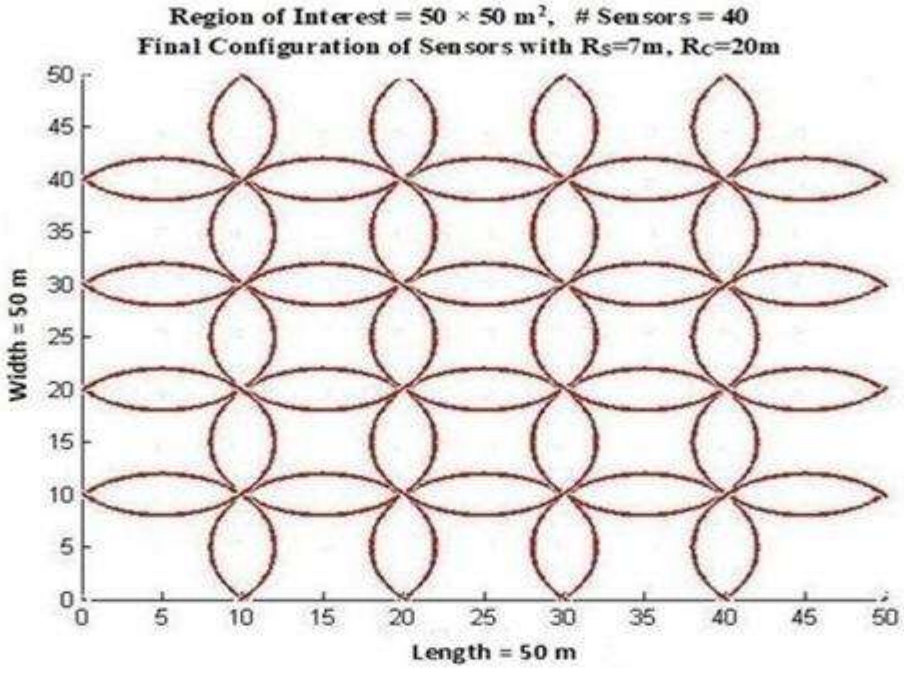

Figure.3 Final Configuration of 40 Nodes at Optimal Positions

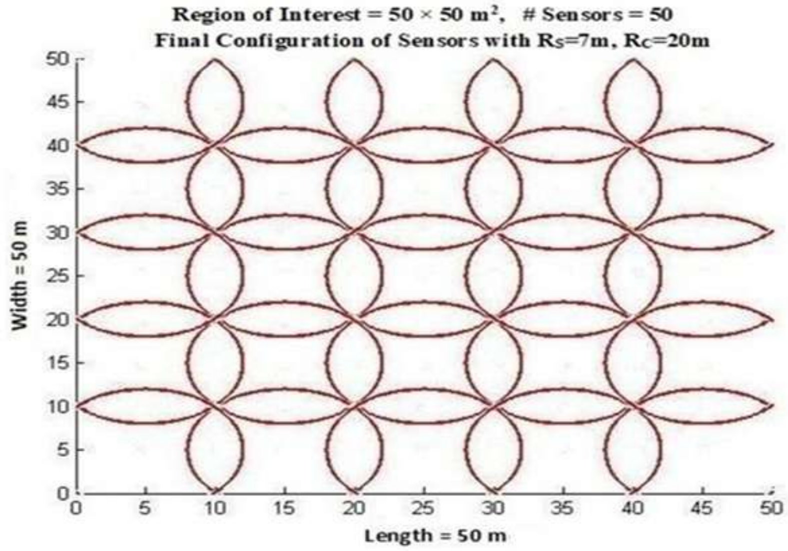

Figure.4 Final Configuration of 50 Nodes at Optimal Positionns

5.2. Establishing Connectivity among Sensors Located at Optimal Positions

Figure 5, Figure 6, Figure 7 and Figure 8 show establishment of connectivity among sensor node Si (for i= 1 to Number of optimal nodes) and its neighbors with R_S of 7m and R_C of 20m in RoI of 50m × 50m. In Figure 5, Figure 6, Figure 7 and Figure 8, BS indicates the base station and SClose indicates the sensor node that is closest to base station, BS. First, the sensor node, SClose that is cl osest to base station is determined using phase-1 of EAPFC. The neighboring nodes which are within the communication range, R_C, of SClose, are determined using Phase-2 of EAPFC. The connectivity is established between Sclosee, and its neighbors without any duplicate communication links using phase-3 of EAPFC. This process is repeated until all the sensor nodes which are within the communication range of neeighboring nodes of SClose are determined and connected using phase-2 and phase-3.

Thus, Connectivity is established among all the sensor nodes possitioned at optimal positions in RoI without any duplicate communication links between any two nodes and also the connectivity is established amongst base station and sensor node whhich is closest to it using phase-2 and phase-3 of EAPFC. Connectivity between BS and closest node, SClose is indicated by a solid line bet ween BS and SClose. All the nodes in the WSN communicate with BS only through this intermediate node, SClose. It is clear from the figures Figure 5, Figure 6, Figure 7 and Figuree 8 that only 25 sensor nodes are used to provide full coverage and full connectivity without any duplicate communication links when nuumber sensor nodes deployed is above 24 for RoI of 50m × 50m with R_S of 7m and R_C of 20m .

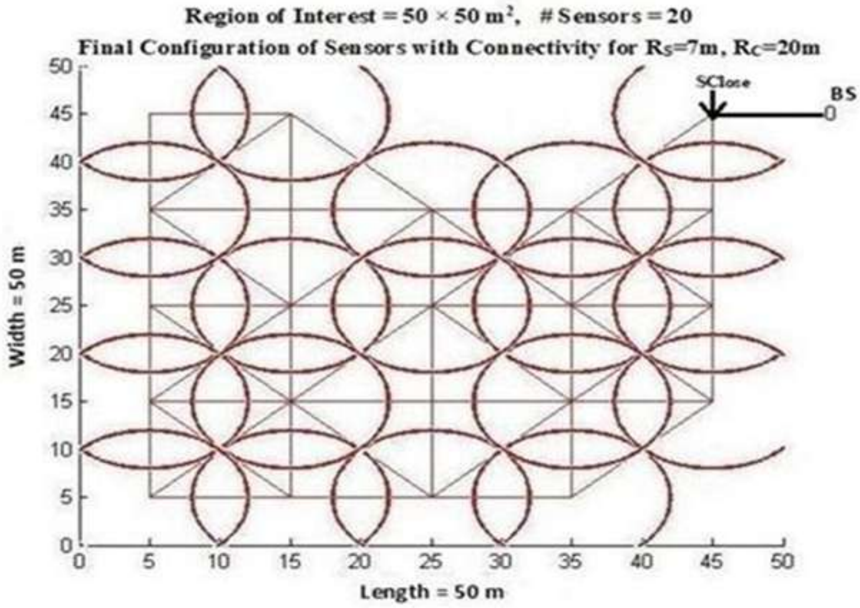

Figure.5 Connectivity among 20 Sensor Nodes and Base Station

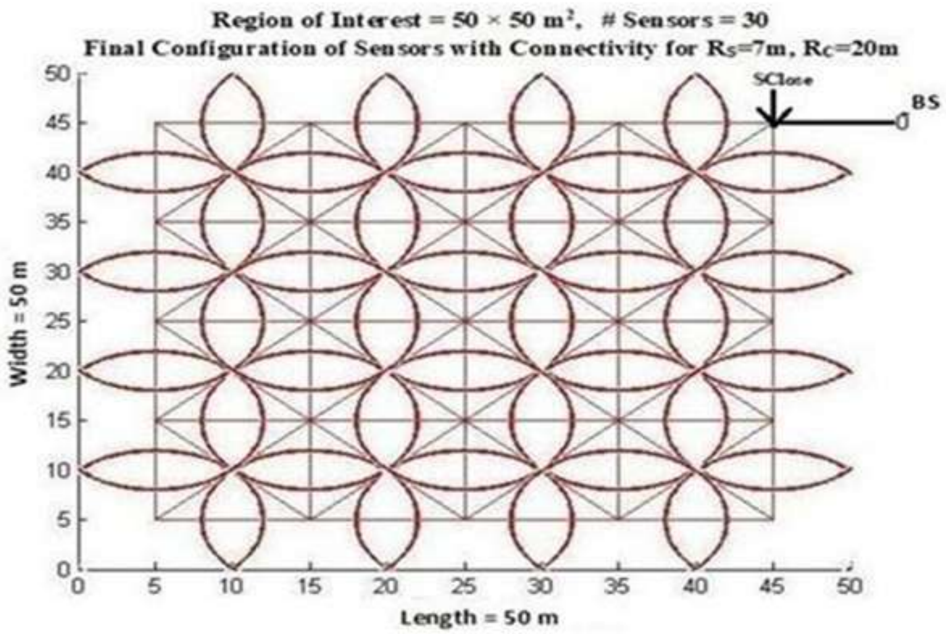

Figure. 6 Connectivity among 30 Sensor Nodes and Base Station

Figure.7 Connectivity among 40 Sensor Nodes and Base Station

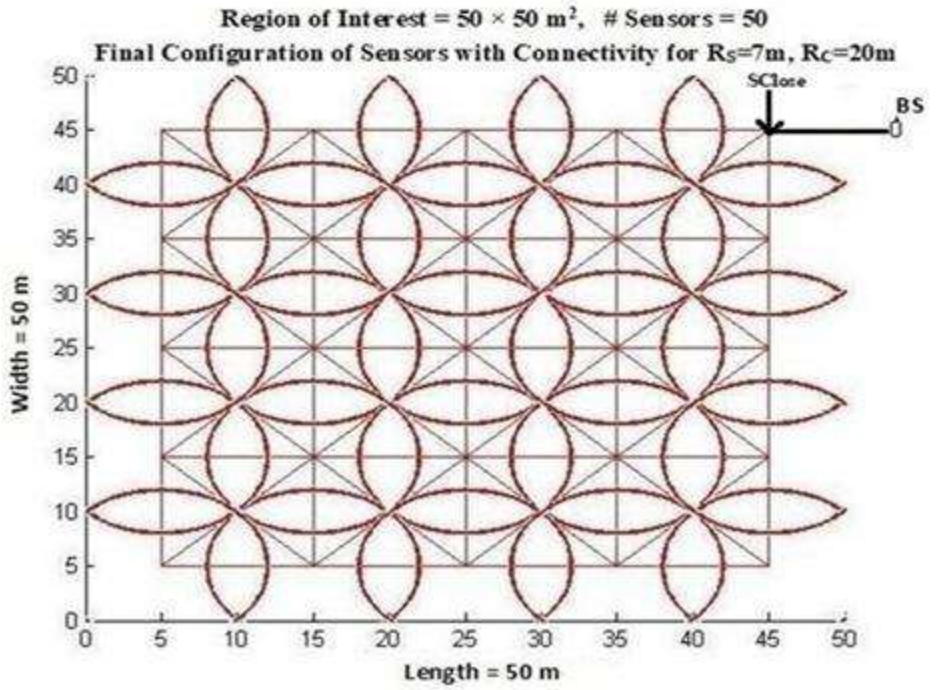

Figure.8 Connectivity among 50 Sensor Nodes and Base station

5.3. Full Coverage and Full Connectivity with Varying R_S

Figure 9 shows the number of nodes required to provide full coverage and full connectivity with sensing range, RS, varying from 2.25m to 7.25m, Communication range, R_C = 5m and RoI= 100m × 100m [5]. Figure 9 shows that the number of optimal nodes required to provide full coverage and full connectivity is reduced from 1000 to 400 when the ratio of (R_S / R_C) is 0.75 [5]. It means that number of optimal nodes will be reduced from 1000 to 400 when Rs =
3.75m and R_C = 5m and number of optimal nodes remain 400 when the ratio R_S / R_C is above
0.75. Optimal values of Rs/Rc is shown by a vertical line in the graph. Hence, for RoI of 100

m × 100m, the optimal sensing range, R_S is 3.75m and optimal communication range, R_C is 5m to provide full coverage and full connectivity with 400 sensor nodes [5].

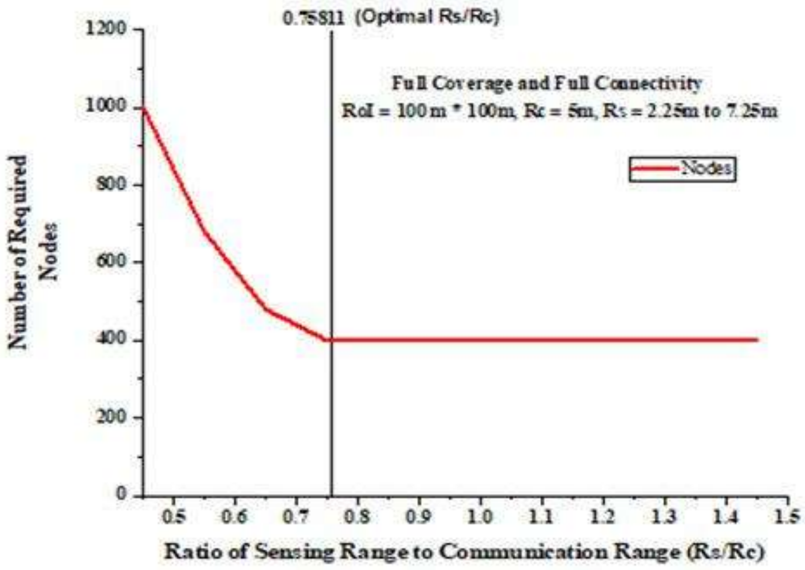

Figure. 9 Varying Sensing Range when R_C= 5m

Figure 10 shows number of nodes required to provide the full coverage and full connectivity which is obtained using proposed EAPFC with sensing range, R_S, varying from 5m to 15m, communication range, R_C = 28m and RoI of 100m × 100m. Figure 10 shows that the number of optimal nodes required to provide full coverage and full connectivity is reduced from 180 to 25 when the ratio of R_S / R_C is 0.5. It means that number of optimal nodes will be reduced significantly from 180 to 25 when Rs = 14m and R_C = 28m and number of optimal nodes remain 25 when the ratio, R_S / R_C is above 0.5. Optimal values of Rs/Rc (0.75811) is shown by a vertical line in the graph. Thus, for RoI of 100 m × 100m, the optimal sensing range, R_S is 14m and optimal communication range, R_C is 28m to provide full coverage without any redundant and overlapping nodes and full connectivity without any duplicate communication links using only 25 sensor nodes. This also reduces the energy required for transmission of data/information.

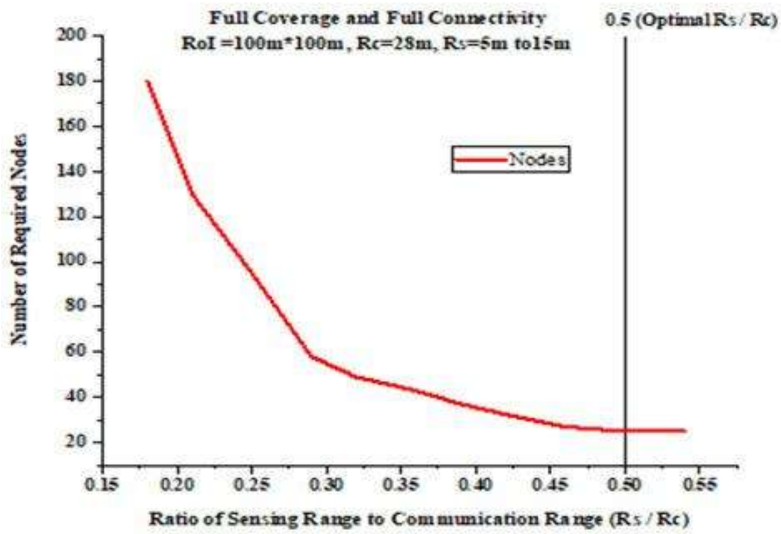

Figure.10 Varying Sensing Range when R_C = 28m

5.4. Degree of connectivity with R_S = 14m

Figure 11 shows the degree of connectivity obtained using EAPFC with communication range, R_C, varying from 22m to 42m, RoI = 100 m × 100m, and R_S = 14m. The experiment is conducted for 100 times and the average results are presented in the Figure 11. Figure 11 shows that the degree of connectivity increases when communication range is above 28m. The minimum degree of connectivity is 2 when R_C is between 22m and 28m and the minimum degree of connectivity increases from 2 to 3 when communication range is between 30m and 42m. Hence, to obtain minimum degree of connectivity of 2, the communication range, R_C should be $1.5Rs \le Rc \le 2Rs$. However, to obtain minimum degree of connectivity of 3, the communication range should be 2Rs ≤ Rc ≤ 3Rs. But. It is clear from results that, for full coverage and full connectivity, the R_C should be $2R_S$, that is $R_C = 2R_S$.

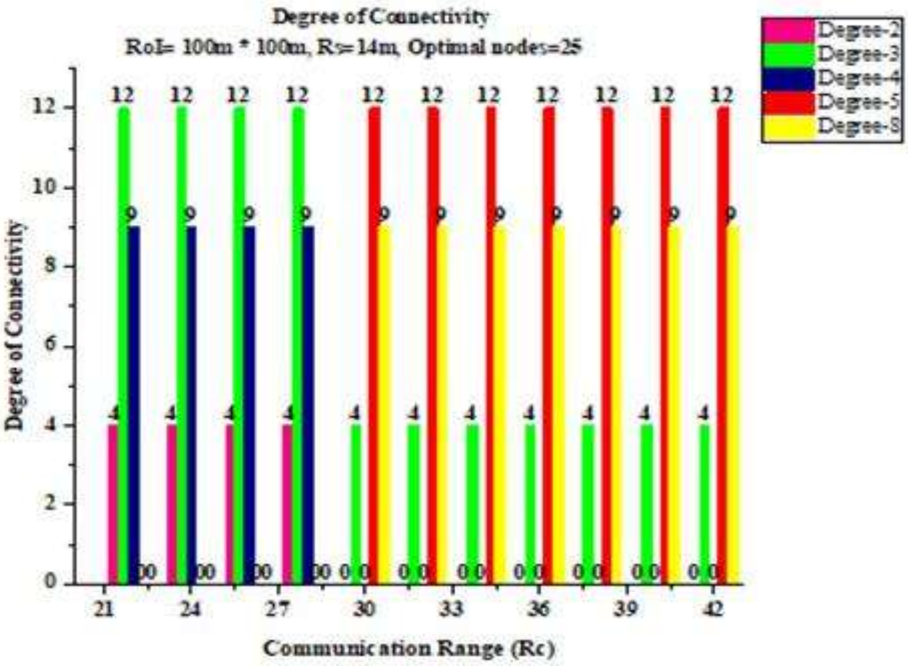

Figure.11 Degree of Connectivity with variable R_C

5.5. Optimal Sensing and Communication Range for Different RoI

Figure 12 shows the optimal sensing range, R_S and optimal communication range, R_C required to provide full-coverage and full-connectivity for region of interest, RoI varying from 50m× 50m to 500m× 500m. The experiment is conducted for 100 times and the average results are presented in the Figure 12. The Figure 12 indicates that to provide full coverage without any redundant and overlapping nodes and full connectivity without any duplicate communication links, the relation between R_S and R_C should be $R_C = 2 R_S$.

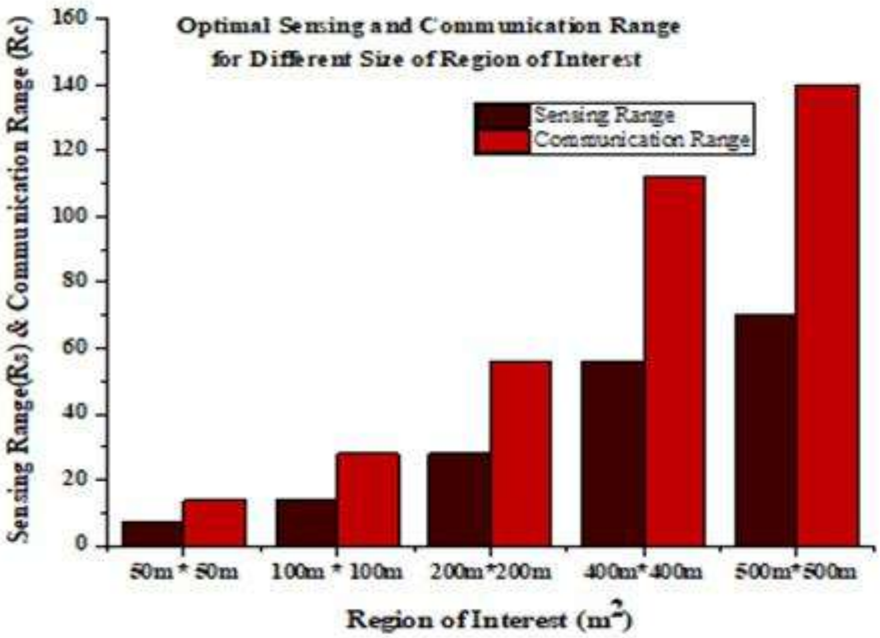

Figure. 12 Optimal R_S and Optimal R_C for varying RoI

VI. Conclusion And Future Scope

The proposed method EAPFC uses very less number of nodes of just 25 to provide full coverage and full connectivity when the ratio of R_S/R_C is only 0.5 against the full coverage and full connectivity with the ratio, R_S/R_C of 0.758 using 400 nodes in [5]. The proposed method EAPFC provides full coverage without any redundant and overlapping nodes and full connectivity without any duplicate communication links when $R_C = 2R_S$ using only 25 sensor nodes. Since, there are no redundant, overlapping nodes and no duplicate communication links, energy consumed is very less. Thus. The proposed approach EAPFC outperforms other similar algorithms in literature with respect to coverage, redundancy, connectivity.

References

[1]. J. Al-Karaki and A. Gawanmeh, "The Optimal Deployment, Coverage, and Connectivity Problems in Wireless Sensor Networks: Revisited", IEEE Access, Vol 5, pp. 18051-18065, 2017.

[2]. M. S. Aliyu, A. H. Abdullah, H. Chizari, T. Sabbah, and A. Altameem, "Coverage Enhancement Algorithms for Distributed Mobile Sensors Deployment in Wireless Sensor Networks", Hindawi Publishing Corporation, International Journal of Distributed Sensor Networks, Vol 2016, pp. 1-9, 2016.

[3]. Shobha Biradar and Mallikarjuna Shastry P M, "Enhancement of Coverage in Wireless Sensor Network", IEEE International Conference on Smart technology for Smart Nation, pp. 982-987,2017.

[4]. B. Carbunar, A. Grama, J. Vitek and O. Carbunar, "Coverage Preserving Redundancy Elimination in Sensor Networks". ACM Transactions on Sensor Networks, Vol. 2, No. 1, 2006.

[5]. Y. Wang, Y. Zhang, J. Liu and R. Bhandari, "Coverage, Connectivity and Deployment in Wireless Sensor Networks", Recent Development in Wireless Sensor and Ad-hoc Networks, Springer, pp. 25-44, 2015.

[6]. T. Razafindralambo and D. Simplot-Ryl, "Connectivity Preservation and Coverage Schemes for Wireless Sensor Networks". Transaction on Automatic Control, IEEE, pp. 2418-2428, 2011.

[7]. J. Li, L.H. Andrew, C. H. Foh, M. Zukerman and H. Chen, "Connectivity, Coverage and Placement in Wireless Sensor Networks", Sensors,Vol. 9, pp. 7664-7693, 2009.

[8]. Y. Guo, Y. Zhang, Z. Mi, Y. Yang and M. S. Obaidat, "A Distributed Coverage Optimization and Connectivity Maintenance Strategy based on Unknown Sensors in WSAN". IEEE, 2016.

[9]. A. Balamurugan and T. Purusothaman, "IPSD: New Coverage Preserving and Connectivity Maintenance Scheme for Improving Lifetime of Wireless Sensor Networks". Wseas Transactions on Communications, Vol. 11, No.11, 2012.

[10]. C. Chen, S. C. Mukhopadhyay, C. Chuang, M. YangLiu and J. Jiang, "Efficient Coverage and Connectivity Preservation with Load Balance for Wireless Sensor Networks". IEEE Sensors Journal, Vol. 15, No. 1, 2015.

[11]. X. Bai, Z. Yun, D. Xuan, T. H. Lai, and W. Jia, "Optimal Patterns for Four- Connectivity and Full Coverage in Wireless Sensor Networks". IEEE Transactions on Mobile Computing, Vol. 9, No. 3, 2010.

[12]. A. Bachir, W. Bechkit, Y. Challal and A. Bouabdallah, "Joint Connectivity-Coverage Temperature-Aware Algorithms for Wireless Sensor Networks". IEEE Transactions on parallel and distributed systems, Vol. 26, No. 7, 2015.

[13]. S. Mini, S. K. Udgata, and S. L. Sabat, "M-Connected Coverage Problem in Wireless Sensor Networks". International Scholarly Research Network ISRN Sensor Networks, 2012.

[14]. H. Xu, J. Zhu and B. Wang, "On the Deployment of a Connected Sensor Network for Confident Information Coverage", Sensors, Vol. 15, No.5, pp. 11271-11294, 2015.

[15]. http://www.iaeme.com/IJCET/index.asp 154 editor@iaeme.com