Self-Configurable Deployment Strategy for Wireless Sensor Network

Umesh M. Kulkarni, Harish H. Kenchannavar, Umakant P. Kulkarni

Abstract**:** ***Wireless Sensor Networks (WSN) is becoming a crucial component of most of the fields of engineering. WSN applications are constrained by the availability of power hence; conserving energy in a sensor network becomes a major challenge. Literature survey shows that node deployments can have good impact on energy conservation. Works show that self-adaptable nodes can significantly save energy as compared to other types of deployment. This work uses the concept of self-configuration of nodes to conserve energy in a WSN. A deployment strategy driven by some dynamic decision making capability can boost the overall performance of a WSN. The work presents an analysis of three types of deployments: like keeping all nodes fixed, all node moving and high energy nodes moving with respect to throughput, delay and energy consumption. Experimental results show that self-configured high energy node moving deployment gives 20% better throughput and 6% better energy conservation than other deployment strategies with respect to energy conservation and number of packets transmitted.***

Index Terms**:** ***Wireless Sensor Network(WSN), Deployment strategy, self configuration.***

I. INTRODUCTION

Wireless Sensor Networks (WSN's) consist of small nodes with sensing, computation and wireless communication capabilities. Recent advances in electronics and wireless communication technologies have enabled the development of large-scale WSN's, which consist of much low power, low-cost and small-size sensor nodes.

The literature review presents sufficient number of methods for best utilization of existing resources. Node Deployment is one of the methods of resource utilization. Deployment of nodes means placing of nodes in an area for sensing of information for specific application. An efficient sensor node deployment or placement strategy can assure efficient resource utilization, network lifetime maximization, less end to end delay and energy utilization as well. Broadly, the deployment strategies in WSN are classified as static deployment and dynamic deployment [4]. Further, the static node deployments are classified as deterministic and random deployment. In a deterministic static deployment strategy, the nodes are deployed in known locations. Whereas, in random static deployments the nodes are deployed at any random locations and once deployed their location become static. This work considers the random static and random dynamic deployments with movements and without movements. Figure 1 shows the deployment classification.

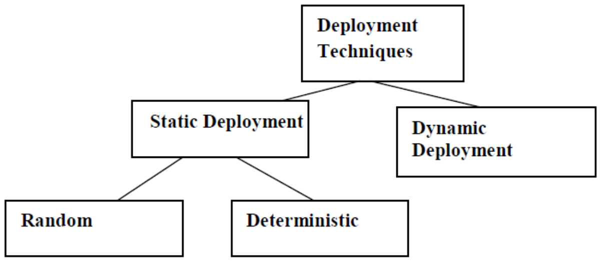

Figure 1. Classification of Deployment Techniques

Designing an efficient sensor node deployment technique using available resources is a basic task in any of the WSN's applications. The performance of such WSN can be measured using different parameters like energy conservation, delay and throughput. Figure 2 shows a generic model considered for the work.

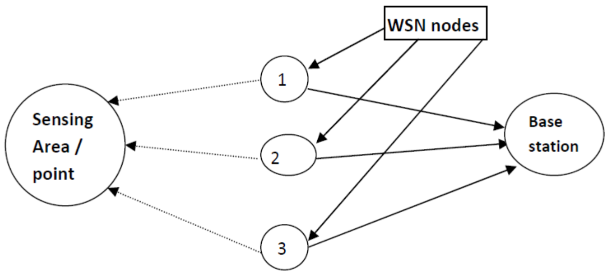

Figure 2. Generic node deployment

Figures 2 show the three major components in a generic node deployment namely:

1. Sensing area/ point: The place for which the sensing needs to be performed.
2. WSN Nodes: The nodes with sensing, computing and communication capability.
3. Base station: The fixed node with more capability than other nodes. All other nodes send the messages to this node.

II. LITERATURE SURVEY

In **[1] [2]**, the importance of deployment strategy is been presented. It is been clearly mentioned that the performance of a deployment strategy is dependent on coverage, network connectivity and lifetime.

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Even mathematical relations are been found for maximum coverage area of a node in a WSN. The correct arrangement or best topology can have better impact on the working of a WSN. The research works carried out even propose a potential based approach for the purpose of efficient deployment or arrangement of nodes. K-connected greedy algorithm was used in the work to better deploy the nodes. This gives a hint about the use of neural networks used for decision making in WSN [3].

Energy conservation model can change according to the types of applications. The threshold distance can be related to the energy directly. Giving a hint about relation between the distance and energy. A battery aware energy efficient transmission approach was presented where the nodes work with the awareness of the energy levels with them [4].

In [5], the research work demonstrates that the energy efficiency can be achieved with respect to clustering, deployment of nodes with some modification in them. The work considers the residual energy and node density as the parameter for clustering. The paper also shows that different levels of energy of different nodes can be best utilized. In [6] [7], several other energy conservation methods like energy aware deployment strategies for video transmission. The work confirms that the energy consumption is directly proportional to the distance of nodes from base station and movement of nodes in the network. Sometimes the packet size also matters for energy conservation.

A swarm intelligence algorithm with artificial ants can increase the self-configuring capability for nodes. This work makes use of the ant colony based algorithm to give the nodes a capacity of self organizing[8]. New algorithms can be developed at MAC layer and network layer for energy efficiency [9].The work show that base station control for sensor network functioning can significantly save the energy. This approach even proposes a sleep scheduling adaptive algorithm that works on concept of source node and root node identification and communication between them.

According to [10] artificial intelligence and machine learning can be used for implementing some basic concepts of wireless networks. The work also discusses about using artificial neural network(ANN) for implementing some of the concepts in WSN. Especially self organizing map (SOM) technique can be used in WSN's for clustering and grouping some of the nodes based on some criteria. The research gives direction for using concept of arrangement of nodes and some decision making capacity to it such that overall energy consumption can be reduced.

Deployment, coverage and energy consumption are inter-linked with each other, as one changes the other will also change. The work even proves that the duration for which the network will be on is directly dependant on the number of active nodes in the network. That is, the work distributes the selected nodes and others are allowed to become idle. The idea behind doing this is to have better and extended sensing effect. The work even suggests that pattern based deployment and random deployment can help in boosting the energy conservation[11]. According to [12] the square grid coverage for WSN is sometimes an NP-complete problem. Coverage can be increased using the mobility of the nodes in heterogeneous networks. Different types f deployments and different energy levels of the nodes can be considered for the study of energy conservation [13].

Summary

It is found from the literature that better sensing effect and energy conservation are the major issues to be considered for hardware or software design of WSN. Deployment of nodes will play an important role in identifying the amount of energy needed for communication. Energy used in computation, communication and distances between the communicating sensors play an important role in extending the network lifetime. Deployment of nodes with respect to the base station and the sensing area can play a vital role in extending the lifetime of network. Self configurable node algorithms that address the energy conservation issue with better sensing effect need to be designed. Hence, a novel approach that addresses this research issue is needed.

III. SYSTEM MODEL

This work mainly focuses on studying the effect of change of position of the nodes in the deployment area. We are considering the three scenarios as shown in Figures 3 to 5.

A. Models

In this work, we are considering three models. In each of these models, the sensing area considered is shown in Figure 3.The Figure shows how the sensing area is divided into different sections Area 1 to Area 4 covered by sensor 1 to sensor 4.

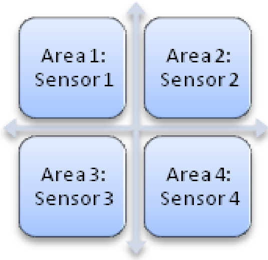

Figure 3. Sensing area and its coverage by sensors

The deployment models considered for the work are as shown in Figures 4 to 5. Every model has different model for energy consumption calculations.

Sensor nodes **S = { S1,S2,……………….Sn},**

Residual energy of every node **E= {E_1, E_2,…….E_n}** respectively.

Transmission energy for every node

Et = {Et_1, Et_2,………Et_n}

Receiving energy for every node **Er = {Er_1, Er_2,………Er_n}**

Movement energy for every node **Em = {Em_1, Em_2,….Em_n }**

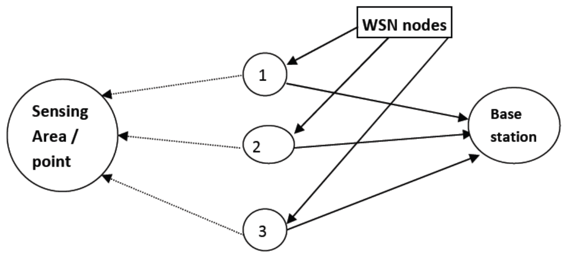

Figure 4. Fixed node deployment

At any interval of time energy of any node **Sn** in fixed node deployment is given by:

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$En=E_n-Et_n-Er_n$……………………..eq. (1)

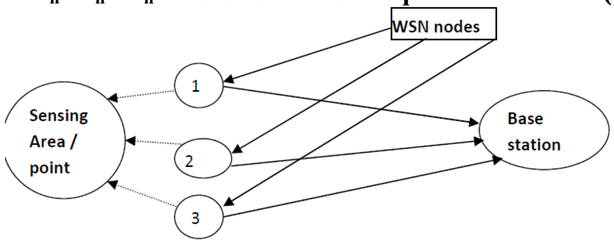

Figure 5. Moving all nodes

At any interval of time energy of any node **Sn** in All node moving deployment is given by:

$En=E_n-Et_n-Er_n-Em_n$……………………..eq. (2)

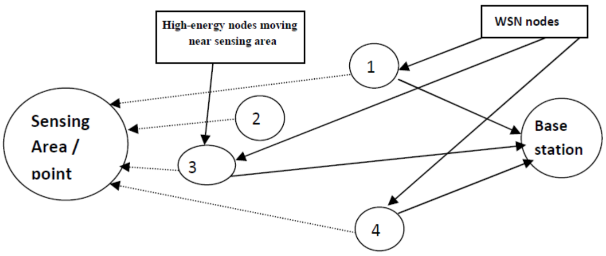

Figure 6. Moving high energy nodes

At any interval of time energy of any sensor node **Sn** in high energy moving node deployment is given by:

$En=E_n-Et_n-Er_n-Em_n$……………………..eq. (3)

Where, Em_n is only for the high-energy moving nodes

Figure 4 represents the scenario where all nodes are fixed and do not move for sensing. They sense the data from the position they are and send the same to base station. Where as in Figure 5 all nodes move towards the sensing point. Figure 6 tries to move selected nodes with high energy capacity and send the data to the base station but, other nodes will not send the data. The nodes are selected by pooling the energy levels of all nodes at base station, find the nodes with more energy than others in the network and make them to self configure to move towards the sensing point.

B. Proposed Algorithm

Following are the steps of algorithm for running the simulation.

1. Deploy all the sensor nodes and the base station in the random positions in the sensing area.
2. Depending on one the following model, make the sensor nodes to act accordingly.

a. Fixed nodes:

i. Initialize Total energy consumed by WSN **$T_{new}(E)$** to zero
ii. Send messages from every node to base station
iii. Find the Total energy **$T_{new}(E)$** at the end of simulation according to following relation:

$T_{new}(E) = E_1+E_2+$…………..$+E_n$

Where, E_1,E_2……E_n computed according to eq.(1) after every transmission

b. All moving nodes

i. Initialize Total energy consumed by WSN **$T_{new}(E)$** to zero,
ii. Send message from every node to base station,
iii. Move all the nodes near sensing area for better sensing,
iv. Find the Total energy **$T_{new}(E)$** at the end of simulation according to following relation:

$T_{new}(E) = E_1+E_2+$…………..$+E_n$

Where, E_1,E_2……E_n are computed according to eq.(2) after every transmission

c. Move selected nodes

i. Initialize Total energy consumed of WSN **$T_{new}(E)$** to zero,
ii. Send messages from every node to base station,
iii. Find high and low energy nodes in the network after a message transmission and move them near sensing area for better sensing,
iv. Find the Total energy **$T_{new}(E)$** at the end of simulation according to following relation:

$T_{new}(E) = E_1+E_2+$…………..$+E_n$

Where, E_1,E_2……E_n are computed according to eq.(3) after every transmission

3. Record the events in the simulation before and after sending the messages for every model mentioned in previous step and analyze the events for different parameters of interest

C. Assumptions

1. A point sensing model is considered for simulations.
2. Number of nodes considered for simulation range from 10 to 50 sensors.

D. Input variables

Input for experimentation is initial energy, number of nodes and other values. Table 1 indicates the input variables and the values acquired by them for the simulation.

Table 1. Input variables

Name of the variable	Range of values
Number of WSN nodes	10,20,30,40,50
Initial Energy(in joules)	10
Sending energy(T_x, in milijoules)	1.8
Receiving energy(R_x, in milijoules)	0.9

E. Parameters for study

The work focuses on observing the change in the energy consumption with respect to the number of packets sent and because the movement of nodes in the sensing area. Hence, throughput, delay between the packets and energy consumption by the network are the parameters considered for study

IV. SIMULATION ENVIRONMENT

The work was simulated on Discrete Event network simulator Ns-2.34 tool, a known tool for conducting Wired, Wireless and Wireless Sensor Networks simulations. The WSN environment considered for the work has set of nodes initially randomly deployed out of which first node is made as base station and others as sensors. According to the type of deployment the sensors are made to send the sensed data (text message) to the base station. The self configuring logic is implemented through the data collected from all the sensors in the base station.

V. RESULTS AND ANALYSIS

Simulation results were recorded for three different parameters of studies, namely throughput, end-to-end delay and energy consumed.

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In each of the tables from 2 to 4, difference column (fifth column) is calculated to compare the high energy moving kind of deployment with respect to other deployments with respect to the parameters of study. It is calculated as difference between the average of fixed and all moving deployments and high energy node movement deployment.

Throughput

Table 2 shows set of values of throughput observed for different number of nodes for simulation

Table 2. Throughput of all packets

Number of nodes	High moving Throughput	All moving Throughput	Fixed Throughput	Difference = (All+ Fixed)/2 - High
10	82.09	83.93	87.14	3.445
20	134.79	138.07	138.32	3.405
30	190.12	201.48	219.85	20.545
40	241.83	258.4	259.91	17.325
50	305.8	321.51	351.36	30.635

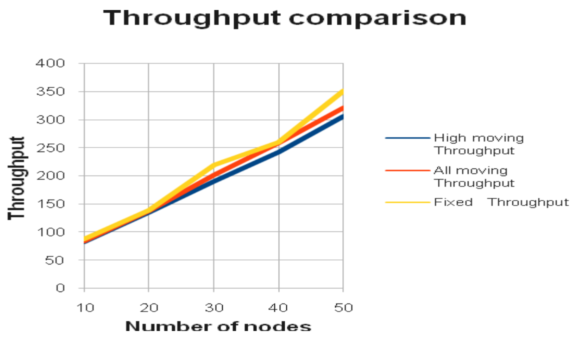

Figure 7. Throughput of all packets in network

Analysis: The number of extra packets sent from the nodes in the fixed and all moving kinds of deployment is found to be more than the high moving nodes in the network. As in each of the first two deployments all nodes are sending the messages to base station. Where as in high energy node deployment, the high energy nodes get self configured, move near the sensing area and send the data to base station. This is done just to ensure that high energy levels of nodes to be utilised instead of using the energy of all nodes in the network. Hence in high moving types of deployment less number of packets are sent from nodes as indicated by Table 2 and Figure 7. It is observed that 20% to 30% decrease in the number of extraa packets transimtted in high energy node movement deployment compared to others with better sensing and better node energy utilisation.

Delay

Table 3 shows set of values of end to end delay between the packets delivered are observed for different number of nodes for simulation

Table 3. End to End delay

Number of nodes	High EtoE delay	All moving EtoE delay	Fixed EtoE delay	Difference = (All +Fixed)/2 - High
10	35.726	37.847	41.157	3.77645
20	24.595	23.260	22.075	-1.9269
30	16.971	14.301	15.471	-2.0854
40	11.386	10.300	10.724	-0.87365
50	8.997	8.872	8.655	-0.23403

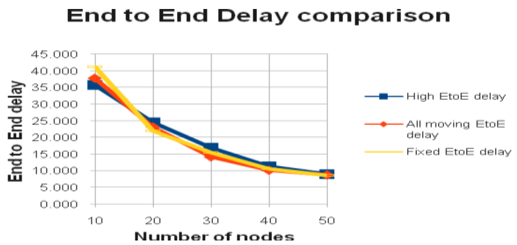

Figure 8. End to end delay of all packets in network

Analysis: As we can observe from the Table 3 and Figure 8 the change in the delay from less number of nodes to more number of nodes in the network . Initially the delay is high in all deployments because all nodes are directly connected to the base station creating the load for base station to handle all the requests. The delay is almost same in all types of deployment but goes on decreasing as number of nodes increases and packet delivery becomes faster via more intermediate nodes. Finally, the delay becomes constant for all types of deployments.

Energy

Table 4 shows a set of values of End to end delay between the packet delivery observed for different number of nodes for simulation

Table 4. Energy consumed by the network

Number of nodes	High moving Energy	All moving Energy	Fixed Energy	Difference = (All+Fixed)/ 2 - High
10	0.2709	0.3584	0.3048	0.060682
20	0.3767	0.4085	0.3570	0.0060195
30	0.3688	0.4132	0.3948	0.035184
40	0.3265	0.3558	0.3226	0.0126765
50	0.2773	0.3541	0.3253	0.062389884

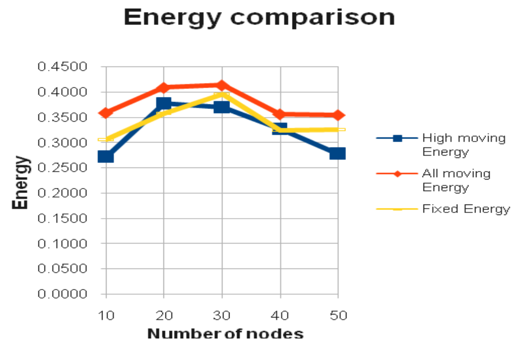

Figure 9. Energy consumed by all nodes in network

Analysis: As we can observe from Table 4 and Figure 9 that the energy dissipation is less for high moving deployment than other deployments. The is because for the reason that all nodes are sending the data and in all moving nodes deployment all nodes are moving towards the sensing point. However, in case of high energy nodes moving kind of deployment, only the selected nodes (the nodes with higher energy levels than the others at a instance of time) are allowed to move and transmit. This will help in best utilizing the available energy of all nodes and have better sensing effect as selected nodes are moving towards the sensing point.

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It is found from the difference column of Table 4 that there is a almost 6% better energy utilization in high energy node movement deployment than other two deployment strategies.

Summary:

In most of the WSN application deployment of nodes play important role in achieving better performance without compromising the better sensing effect. Utilizing the high energy of nodes can reduce the number of access packets transmitted in the network. Even it can help utilizing the energy better than the other deployments without any concession on sensing effect. A better sensing effect means that if a node or nodes move towards the sensing point the quality of sensing definitely increases than the far away nodes.

VI. CONCLUSION AND FUTURE SCOPE

In most of the WSN applications, better sensing is the main objective. To attain this objective the deployment of the nodes and better energy utilization are key factors. Several deployment strategies are proposed for better sensing, less packet transmission, reduced packet delays and increased energy conservation. The work simulated three types of deployments like fixed node, all node moving and high energy node moving deployments and found that high energy moving nodes show better throughput and better energy utilization. It is achieved as high nodes in third type of deployment configure themselves to move towards sensing area for better sensing. Hence, it can be observed from simulation results that deployment strategies with self-configuration logic of nodes can achieve better performance with respect to number of packets transmitted and better energy utilization. In future wok we are planning the heterogeneous WSN to be considered for simulation with some machine learning algorithms for self-configuration.

Ethical clearance - Not required

Source of funding- Self

Conflict of Interest - Self-Configurable Deployment Strategy for Wireless Sensor Network.

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