Study of Challenges in Sensor Node Deployment in Wireless Sensor Network

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Abstract— Wireless Sensor Network is a network which consists of tiny sensors that senses required information from the sorrounding and passes it to the destination for further processing. Deployment of sensor node in wireless sensor network is the way of placing sensors in network for the collection of desired information from environment. Performance of a network in an application depends on the proper deployment of the sensor nodes. Particularly, when it is the case of heterogeneous sensor network, at most focus is required while deploying sensor nodes. Improper deployment reduces the efficiency of the network. It may not be always possible to deploy the sensor nodes easily .Particularly, in harsh environment, it is too difficult to deploy the nodes. In this paper we give a description of the different types of node deployment schemes and challenges developed so far for wireless sensor network.

Keywords-*Sensor nodes deployment; Wireless sensor network,*

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I. INTRODUCTION

Wireless Sensor network(WSN) is a network that consists of tiny devices called sensor nodes which monitors the physical and environmental condition. Now-a-days, WSN is used in many applications starting from health monitoring to battlefield monitoring. There are two types of wireless sensor model: Homogeneous WSN and heterogeneous WSN. In homogeneous WSN, all sensors nodes are similar in terms of battery energy, communication and computation capabilities, and hardware complexity[11]. It is a simplest type of WSN. In heterogeneous WSN more than one and different types of nodes with different battery functionality, communication and computation capabilities, and hardware complexity are used[11]. It is a complex WSN as compared to homogeneous WSN. This is because for good performance of the network, all the components must work in synchronized fashion.

Sensor node deployment is a way of placing sensors at different locations in the network for information collection. The target area where data collection is required may or may not be accessible to human being. The size of the network also matters at the time of node deployment.Continuous sensing with extended network lifetime while maintaining uniform coverage of the target area, proper deployment of node is very important. However, many WSN devices have extremely bad resource constraints in term of memory, computation and energy and by deploying the bottom scenarios which prevents easy access to the device. It has one or more base station or sink located nearby the sensing region. Sink sends commands to the sensor nodes in the sensing region while all nodes come together to complete the sensing task successfully and send the sensed data to the sink. In the meanwhile, sink create a gateway for input and output data. It saves energy while transmission of data. It collects data from the sensor nodes and perform processing on the collected data and sends the relevant data to user through internet.

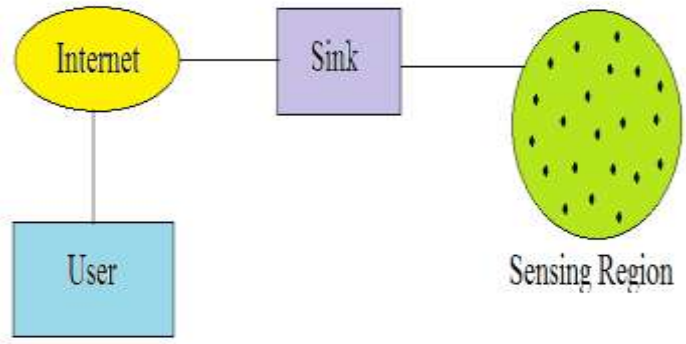

Fig.1. WSN Architecture

To send data, use of single hop long distance is very costly in terms of energy consumption. In sensor network, energy consumed for communication is much higher than sensing and computation. Again, energy loss occurs due to signal fading effect. So, multi hop short distance is highly preferred. In most sensor network, sensor nodes are deployed in concentrated manner and are closed to each other. So, short distance communication is feasible. In multi hop communication sensor nodes transmits its data towards the

sink through one or more intermediate nodes which can reduce the energy consumption for communication.

The characteristics of WSN includes the freely movement of sensor nodes, scalable for large area deployment, It has the capability to stand up in unpleasant environment condition, It is easy and simple to use, heterogeneity of nodes, It can cope up with node failure and the constraints of power consumption of sensor node can be lowered by using battery or energy harvesting.

The advantages of WSN are manyfolds. We can avoida lot of wiring for connecting components.The cost of implementation is low.It is suitable for non- reachable areas. It can be accessed through a centralized system..It has the capability to go through physical partition and can accommodate new devices at anytime and anywhere.

The disadvantages of WSN are: Less secure because hackers can easily get into the access point and get all informations. It has low speed as compared to the wired network. It is more complicated during node deployment. It is costly and consumes a lot of power for short communication range.

II. TYPES OF NODE DEPLOYMENT

Node deployment is a fundamental issue to be solved in Wireless Sensor Networks. A proper node deployment scheme can reduce the complexity of problems in WSNs as, for example, routing, data fusion, communication, etc. Basically, node deployment schemes are categorized into two categories on the basis of movement of sensor nodes: static deployment and dynamic deployment. The static deployment chooses the best location according to the optimization strategy, the location of the sensor nodes remains constant in the lifetime of the WSNs[8]. The dynamic deployment sensors are able to move co-coordinately within the target area[12]. Again, Node deployment can be divided into two category on the basis of the quantity of nodes: dense deployment and sparse deployment. Dense deployment has high number of sensor nodes. It is important when multiple sensor nodes cover an area. Sparse deployment have few nodes. It is used when cost of sensor is high and to achieve maximum coverage using minimum number of sensor. Deployment can be of open area or indoor on the basis of deployment domain: In open area deployment sensor nodes are to be covered in large area while indoor deployment is covered within limited area such as buildings and structures etc. Node deployment can also be categorized on the basis of usage: In blanket deployment, some events may occurred randomly in a target area at any point and its occurrence is of very importance. Detection of that events requires complete coverage by blanket deployment. In Barrier deployment, it is ensured by covering the entire target region with sensor nodes and in Target oriented deployment, some scenarios have more knowledge of region that event has been occurred. This types of deployment is categorized under target oriented where sensor node have been placed precisely. For maximum performance, sensor nodes should move automatically to proper location and then start to work. Depending on the placement of sensor nodes, both categories of deployment schemes have following sub schemes.

A. Random Deployment

This type of deployment is used in both static and dynamic deployment. Random deployment means setting positions of sensor nodes randomly and independently in a target area. The nodes that to be deployed are randomly distributed in an unknown or inaccessible area with unmanned devices or airplanes. In this scenario, the nodes have to discover their neighbors by themselves. In any wireless sensor network, the area covered by sensor node is important[9]. If a node fails to sense the assigned area, then its existence in WSN is meaningless. While in deterministic deployment, placement of sensor may be used for small scale deployment. Random deployment is of three types:

1) Random Scattering

It is a common means of deploying sensor nodes randomly in a large regions by dispersing them from the sky or any unmanned device[10].

2) Point Initiated Relocation

In these deployment schemes sensor nodes are initially placed in a very small area from where they start expanding their vicinity by relocating themselves to cover the entire candidate region[10]. Different relocation scheme are of following types:

a) Virtual Force Driven deployment

Here lazy movement strategy is used as relocation scheme. These schemes determine the direction of movement of sensor nodes in order to spread uniformly within a candidate region[10].

b) Pre-computed Relocation Point based Deployment:

These schemes employ various algorithms to relocate sensor nodes to the geometrically computed locations in order to spread them uniformly within a candidate region[10].

c) Hybrid relocation:

It uses both the virtual force driven method as well as pre-computed relocation scheme. These schemes use both of the schemes in different phases for uniformly deploying the sensor nodes within a candidate region[10].

3) Scattering with Random Relocation

In this type of deployment, at the beginning sensor nodes are deployed by dropping from the flying machine (helicopter, airplane, etc.) over the target region, Base Station (BS) is mostly placed outside the candidate region and have sufficient resources in terms of energy.Inside the candidate region, base station can also be placed. Every sensor node is considered to have limited communication range.

The advantages of random deployment are that it is suitable for large size WSN and to the area which is inaccessible to

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358 – 364

the human being. It's disadvantage is complex deployment scheme and requires proper placement of sensor nodes for correct operation of the network. Otherwise, sensed information may not be reached at the sink. Again, the cost of deployment may be more.

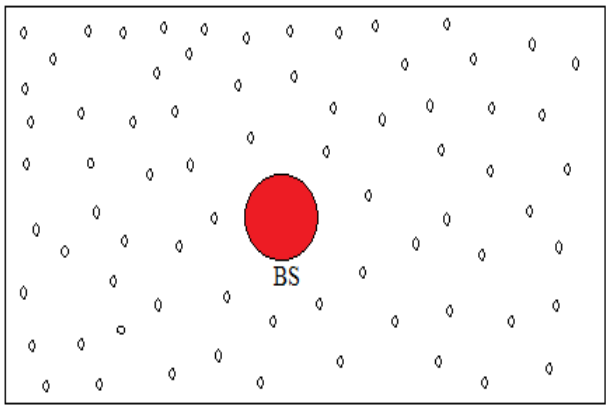

Fig.2. Random deployment of sensor nodes

B. Grid Deployment

It is managed by dropping sensors nodes row by row in the target area**.** It is considered as a good deployment scheme in WSN, especially according to coverage performance. The distance between consecutive dropping is achieved by controlling the time intervals[13].

The advantage of this deployment is that it is suitable for moderate to large sized network and has a less complex deployment scheme than random deployment scheme. The disadvantages of this scheme is the implementation and maintenance cost is high as high redundancy is required to overcome the problem of uncertainty in message arrival at the sink. In this deployment scheme addition of new node is a challenging task and is also not energy efficient.

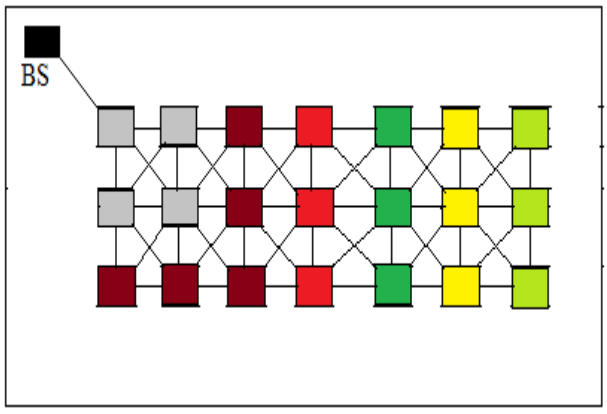

Fig.3. Grid deployment

C. Group Based Deployment

Sensors are deployed in a group which is used to improve the coverage of the target region. It is used to provide connectivity of the network. These networks are set up to collect sensed data from sensors deployed in a large area. These sensor networks often have one or more centralized controllers called base station or sink. Initially sensor deployment is partitioned into multiple small square areas called zones and then sensors deployed in each zones form a group[13].

The advantage of this deployment is sensor nodes can be covered the target area properly. The disadvantages are before deployment, partial knowledge about location is necessary so that high sensor node connectivity can be achieved and also this design can restrict the consequence of attacks within a small range.

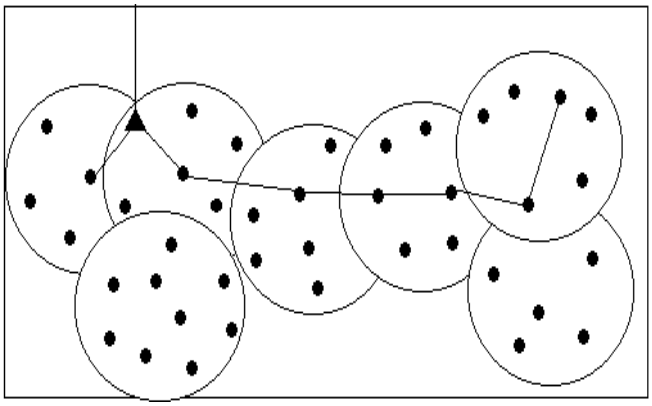

Fig.4. Group based deployment

D. Grid Group Deployment

When nodes are deployed in the target region, all nodes need not communicate with each other in the network. Due to limited battery power ,sometimes, it is not advisable to allow all nodes to communicate with each other. In this type of deployment, the entire region is divided into equal sized square[10].

The advantages of this deployment is that all nodes can communicate with each other directly and nodes which lie in different region can communicate through a special nodes called agent which have more resource than general nodes.
The disadvantages with grid and group based deployment is that it is difficult to compromise an agent than a sensor node, whatever the size of the network, the number of agent in a region is always three. This scheme ensures that even if one region is totally disconnected, the region are not affected, and makes the network more fault tolerant as partial failure of the network do not stop the operation of the network completely.

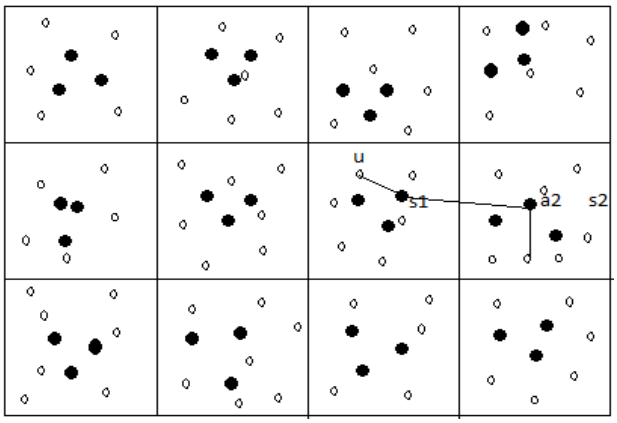

Fig.5. Grid Group deployment

III. CHALLENGES IN NODE DEPLOYMENT

Wireless sensor network has so many challenges which needs attention of researchers. Some of them are:

A. Early node death

A common node problem is node death which may be caused due to energy depletion either by battery discharge or due to short circuits before the completion of the required task. Also, node death can be assumed if a node is no longer considered a neighbor by any other node[2,4,5,7].

Sometime heavy traffic through particular nodes which leads to quick depletion of energy in those nodes may lead to death of nodes in near future and cause network reorganization. Unbalanced loads in the sensor nodes is also a cause of node death[16].

Many commonly used routing protocols requires every node to transmit a beacon message at regular interval of time, for the purpose of synchronization and neighbor management. Failure to transmit any such message for a certain amount of time is an indicator for node death. Node death can also be assumed if a node is no longer considered a neighbor by any other node.

B. Node reboot

Node reboot is the problem of restarting the operation of the node in the middle of message transmission. When a node reboots, its sequence number counter will be reset to an initial value (nearby zero)[2].

The sensor nodes perceives reboot events together with their associated frequency and advices the user side when the frequency is greater than zero[18].

C. Wrong sensor reading

This problem is observed when message of application contains harsh information or wrong sensor reading. It is caused due to the low battery voltage or application is not implemented strongly.

In detecting the malicious or harmful nodes in the presence of faults or events, a smoothing filter evaluation is conducted to enhance the malicious node detection rate. The filter is used to correct some false reading due to transient faults. Thus it effectively reduces the transient fault probability in such a way that malicious nodes can be detected for a wider range.

D. Link problems

It is the problem of transmission link failure in the middle of the message transmission. Transmission link is nothing but a logical path established between sender and receiver just before the message transmission. Link problem may also caused by network congestion due to many concurrent transmission attempts which is another source of message loss[2,3,7].

Depending on node density, a node in sensor network may have a large number of other nodes within a communication range with large different link quality. Most multi hop routing maintains small set of neighbor with quality of link. Regrettably, the nodes choose the set of neighbors cannot observed directly. So, there are two ways to observe the neighbors of a node. In the first way, by overhearing the destination address of message when a node sends message and in second way, by exploiting the link advertisements which is sent by a node to estimate the link quality. By knowing the neighbors of node, it is possible detect the isolated node. If the location of node is known, it is possible to discover the unexpected long links and missing links.

It is not possible to decide whether a node has received a message or not. In many situations, the reception of a message by a node sends acknowledgement for the transmission of another message by that node. If this happen, the failure of second message within a certain amount of time after the first message has been overhead is an indicator of message loss.

The time elapsed between the overhearing of casual message and result message gives an estimation of latency link which also includes the delay processing delay of node.

Link failure may occur during data transmission because of collision, busy nodes and other events. This lead to retransmission of data packets and thus causes more energy loss. Movement of sensor nodes and sink may cause link failure against some existing point to point links[16].

The level of link congestion perceives by sensor node cannot be observed by sensor nodes. The level of congestion experienced by a deployment support node overhearing the traffic that is being addressed to the sensor node can be used as a rough approximation.

In WSN,beacon messages are sent at regular interval of time. A change of the time difference between receipts of beacon message of neighbor message indicates phase shift. Averaging over multiple beacon intervals can help eliminate variables delays introduced by medium access.

E. Path problems

This is the problem of using optimum path distance between sender and receiver for communication. In order to discover the path between two sensor nodes, there is a need to access to the routing information maintained by sensor nodes. A multi-hop path consists of sequence of links for which information may be changed as it is traversing such a path, for example due to data aggregation [1,2].

In order to find the path between two sensor nodes that is from node to sink and sink to node, there is a need to access the routing information maintained by sensor node. For this there are two possible ways. In first way, reconstruct a multi path from source to destination. In second way, overhear the routing message to discovered paths.

Like finding the path, a way is needed to decide whether or not a packets belongs to same multi hop message exchange. If such way exits a message that is addressed to a node the same message which indicates a routing loop.

If path can be discovered, one can easily detect path oscillation and find missing path from node to sink and vice versa.

Since a path consists of a sequence of links, the former inherits many of the possible problems such as asymmetric path, high latency, path oscillations and high message loss.

F. Global problems

These are the problems relating to the global properties of the network. Some of the problems are low data yield, reporting latency, short network lifetime due to message loss, delay in message arrival or insufficient network lifetime are typically due to a combination of different node, link, and path problems[2,4,6,7].

Low data yield means that the network delivers on insufficient amount of informations or messages. This problem may be caused by other problem such as node crashing before message could be forwarded, buffer overflows etc. One of the basic reasons for low data yield is a partitioned network, where a set of nodes is not connected to the base station(BS).

Reporting latency refers to the amount of time elapses between occurrence of a physical event and that event is being reported by the sensor network to the observer.

The short network lifetime refers to network failure which could not cover the target area sufficiently by sensor nodes. This network lifetime is obviously related to the lifetime of individual nodes.

G. Coverage problems

It is the problem of covering the desired area by sensor nodes properly so that no whole area remains in this area unattended. It caused due to not having enough sensor nodes to covered the target area[1,2,7].

This problem can arise in all network stages and can be formulated in many ways. It occurs when sufficient sensor nodes not covered the target areas and also the sensors have limited sensing range that nodes cannot cover the entire target range. In design stage, one should know how many sensor nodes are needed so that every point in target area can be covered. In operation stage, one should know to schedule different sensor nodes in order to increase the network life time. Some other performance matrices such as energy consumption and network connectivity may also need to be considered together with coverage problems.

The following table gives the summary of some of the paper on problems of node deployment in WSN:

TABLE1
SUMMARY OF NODE DEPLOYMENT CHALLENGES

Sl.	Deployment Problems	Reasons behind Problems	Effect on performance	Technique use
1	Early Node death	1.Early Battery Discharge 2.Node Communication difference 3.Longer message	Low network life time	Zigbee[4] Linear deployment scheme[5] Genetic Algorithms[7]
2	Node Reboot	When sequence number of Message is set to its initial value due to node crashes.	High message lost	Set the sequence counter to some value other than initial value[2]
3	Link Problem	1.Multi Sender 2.Very high variability of link quality which result temporary	1. Message Lost 2. Node receive message but fail to	Floyd warshell Algorithms[3]

		link failure 3.More messages	forward message	Genetic Algorithms[7]
4	Path Problem	1. Distance between two sensor nodes 2. Communication Distance	1.Message not reached within time interval 2. High message lost	PSO[1]

Sl.	Deployment Problems	Reasons behind Problems	Effect on performance	Technique use
5	Global Problem	1. Short network lifetimes. 2. Low data Yield due to node crashing and message lost. 3. High reporting latency. 4. Very high variability of link quality which result temporary link failure.	1.Partition network between node and sink 2. Complex interaction within a large portion of the network. 3. Node death	Zigbee[4] Linear deployment scheme[6] Genetic Algorithms[7]
6	Coverage problem	1. Not enough sensor to cover the area. 2. Limited sensing range.	1. Node death 2. Low network life time.	PSO[1] Genetic Algorithm[7]

IV. CONCLUSION

Node deployment scheme is a scheme of placing sensor nodes in a wireless sensor network. In order to achieve better performance, it is required to place the sensor nodes in an efficient manner. While deploying sensor nodes it is required to know the target environment better as the performance of the network is also dependant on the environment. Also, it is required to have an optimum deployment in terms of network lifetime, number of sensors etc..Again, wastage of sensor nodes must be avoid at the time of deployment. If deployed properly, heterogeneous WSN provides more flexibility than homogeneous WSN. There are a lot of limitation with WSN which restricts to fully utilize the capacity of heterogeneous WSN. In this paper, different deployment schemes and the challenges with node deployment are discussed. How different authors have tried to address these challenges are also discussed. Here those limitations are studied and in future, effort will be made to address these problems**.**

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