Study On Node Deployment In Wireless Sensor Network

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Abstract—Node deployment is a fundamental issue to be solved in Wireless Sensor Networks (WSNs). Despite the significant effort made since a decade, the successful deployments and real world applications of sensor network are still scarce and cumbersome to achieve. A proper node deployment technique can reduce the complexity of problems in WSNs, for example, routing, data fusion, communication, etc. Furthermore, it can extend the lifetime of WSNs by minimizing energy consumption.

In this paper, we try to understand the prominent examples of sensor network deployments their interaction with the real world and pinpoint a number of potential causes for errors and common pitfall. We investigate random and deterministic node deployments for large scale WSNs under the following performance metrics: coverage, energy consumption, and message transfer delay. We address the following problem: given the required lifetime of a sensor network, the initial energy of each sensor node, and the area to be covered, what is the minimum number of nodes needed to construct such a network and what is the corresponding deployment scheme. Furthermore, we present methods and tools to be used to pinpoint failures and understand root causes. These instrumentation techniques are specifically designed or adapted for the analysis of distributed networked embedded systems at the level of components, sensor nodes, and networks of nodes.

Keywords-Node Deployment, Coverage, Energy Consumption, Wireless Sensor Network

I. INTRODUCTION
A Wireless Sensor Network (WSN) can be composed of homogeneous or heterogeneous sensors, which possess the same or different communication and computation capabilities, respectively. Although some works consider heterogeneous sensors, many existing works investigate node placement in the context of homogeneous WSNs. Less complexity and a better manageability are the most beneficial effects of homogeneity. Therefore, we consider homogeneous nodes in WSNs. These nodes can be deployed over a network in random or deterministic fashion. While the random node deployment is preferable in many applications, if possible, other deployments should be investigated since an inappropriate node deployment can increase the complexity of other problems in WSNs.

Sensor networks offer the ability to monitor real-world phenomena[1] in detail and at large scale by embedding wireless network of sensor nodes into the environment. Here deployment is concerned with setting up an operational sensor network in a real-world environment. In many cases, deployment is a labor-intensive and cumbersome task as environmental influences trigger bugs or degrade performance in a way that has not been observed during pre-deployment testing in a lab. The reason for this is that the real world has a strong influence on the function of a sensor network by controlling the output of sensors, by influencing the existence and quality of wireless communication links, and by putting physical strain on sensor nodes. These influences can only be modeled to a very limited extent in simulators and lab test beds. Information on the typical problems encountered during deployment is rare. We can only speculate on the reason for this. On the one hand, a paper which only describes what happened during a deployment seldom constitutes novel research and might be hard to get published. On the other hand, people might tend to hide or ignore problems which are not directly related to their field of research. Additionally it is often hard to discriminate desired and non-desired functional effects at the different layers or levels of detail.

II. CLASSIFICATION OF NODE DEPLOYMENT
1. Static Deployment
The static deployment chooses the best location according to the optimization strategy, and the location of the sensor nodes has no change in the lifetime of the WSN. At present, the static deployment includes the deterministic deployment and the randomly deployment. The method of the deterministic deployment is firstly to do the surveyed area meshing and then carries on the network node deployment. In the study of the deterministic sensor node deployment based
on the target coverage, the paper proposes an deployment approach of sensor nodes by using the maximum multi overlapping domains of target points and the genetic algorithm, which reduces the network deployment cost and realizes the optimal allocation of spaces resources in wireless sensor networks. The paper proposes a method with target coverage based on grid scan. It first divide the area into grids. Then the best grid is chosen to place the next sensor. The method can use the least nodes to achieve the target coverage, meet the required level of the whole coverage and get better positions for node deployment. Moreover, the deployment of wireless sensor network in deterministic space with obstacles is researched in paper. Sensor’s detection models and coverage quality evaluation are set up. Based on the probabilistic detection model with false alarm rate, a new deployment method is proposed. Watershed algorithm is employed to choose the deploying sub-area. Then Delaunay triangulation is used to generate the candidate positions for new nodes. Thus, the placement of WSN nodes is realized orderly and efficiently, and the proposed method can attain better detection probability and coverage uniformity compared with some methods. In the paper, the author also presents a deployment method of sensor nodes used in detecting and measuring the changes of temporal traffic patterns in large scale. Different with the deterministic deployment, the random deployment is usually used in dangerous environment without stuff on duty, such as forest surveillance, earthquake observation and battlefield. Large quantity of wireless sensor nodes are thrown in these areas, and then self-organized network formed. The self-organized algorithms is proposed by waking up some sensor nodes or making some sensor nodes sleep. The paper proposed a mixed algorithm for visual sensor network. This algorithm used the virtual potential field to make the sensor nodes shift positions and change directions automatically in detection area based on directional sensing model. With the completion of quality requirements, the algorithm could maximize the coverage rate throughout the detection area. The paper also proposed a strategy of WSN nodes randomly deployment based on Poisson distribution. In this strategy, first established the model of WSN node distribution, and then find the relationship between the percentage of coverage area and the nodes density of target area, lastly find the best range of nodes density to get the optimal deployment.

2. Dynamic Deployment

The dynamic deployment may be backed to the deployment of the robot. In order to make the sensor networks get the maximum performance, sensor nodes need automatically move to proper location, then start to work. Random deployment, namely randomly throw nodes firstly, and then using a variety of optimization algorithm for deployment optimization. Such as Virtual force algorithm, virtual force oriented particles algorithm, simulated annealing algorithm, particle swarm optimization algorithm and simulated annealing genetic algorithm.

III. PERFORMANCE INDICES OF NODE DEPLOYMENT

The key points of the research on node deployment algorithm are to increase the coverage area, enhance network connectivity, prolong the network lifetime, make the load balance, improve the accuracy of the data transmission and strengthen the tolerance of nodes. Obviously, it has the certain difficulty if just using random node deployment to completely meet those design goals. At the same time, how to reduce the deployment cost is still needed to be solved, although it can meet the needs of major and minor deployment objectives. Generally, the optimization of the sensor nodes deployment mainly includes the following performance indices as described in[5].

1. Coverage Area

How to get maximum coverage is always the hotspot of the optimization problem in wireless sensor network deployment. Coverage is an important issue in WSN and is related to energy saving, connectivity, and network reconfiguration. It mainly solves how to deploy the sensor nodes to achieve effective coverage of the service area so that every point in the service area is monitored at least by one sensor node. A good coverage is indispensable for the effectiveness of wireless sensor networks. Assume that the sensor radiation range is the coverage area of disk shape, the radius equal to radiation range, and the ratio of the area covered by node against whole area of deployment is the index of the monitoring area coverage.

2. Net Connectivity

Network connectivity is the communication between the wireless sensor nodes, the node and base station, base station and the client, the client and the server. But in the early days, the network connectivity is not difficult problem. The literature considered the complete coverage and connectivity of the sensor nodes, which are located in the sensing radius of node and are connected. For this, we only need to build routing between the node and base station to send the data.

3. Network Lifetime
One of the most important requirements of WSN is to reduce the energy consumption. Hence, there is a need for energy efficient communication and routing techniques that will increase the network lifetime. The major cause of energy waste is collision. When a node receives more than one packet at the same time, these packets are termed collided, even when they coincide only partially. All packets that cause the collision have to be discarded and retransmissions of these packets are required, which increases energy consumption. The second reason for energy waste is overhearing, which means that a node receives packets that are destined to other nodes. The third energy waste occurs as a result of control-packet overhead. They investigate differences of the behaviour of our agent based SMAC protocols in real deployment compared to the results produced using our custom based simulator, which ignores the lower layers effects, such as packet collision and overhearing.

4. Energy Consumption

Since energy is the most critical issue in WSNs, it is necessary to optimize energy consumption in various ways. Using a proper node deployment scheme, energy consumption can be reduced and can thus extend the lifetime of WSNs. We define a model which concerns the 1bit energy consumption of sensing, transmitting, and receiving for all nodes when communicating to their nearest sinks.

IV. NODE DEPLOYMENT SCHEMES FOR WSN

In WSNs, the major challenge is the deployment of the nodes in the deployment region to satisfy continuous sensing with extended network lifetime while maintaining uniform coverage. Various architectures and node deployment strategies have been developed for wireless sensor network, depending upon the requirement of application we focus on five deployment schemes for sensor networks environments, random deployment, grid deployment, group-based deployment, and grid-group deployment.

1. Random Deployment

Random Deployment means setting positions of wireless sensor nodes randomly and independently in the target area. On the other hand, in precise deployment, nodes are set at exact positions one by one according to the communication range of the nodes. Usually, the positions are chosen to minimize the number of nodes required to achieve certain deployment goal. However, precise deployment method is time consuming even though costing the least number of nodes. Random deployment method is fast in practice though costs a relatively larger number of nodes to achieve the same deployment goal. When practical application scenarios are considered, random deployment is a feasible and practical method, and sometimes it is the only feasible strategy. Random approach for node deployment is deeply discussed in which has considered as one of the competitors. In this deployment, each of the sensors has equal probability of being placed at any point inside a given target field. Consequently, the nodes are scattered on locations which are not known with certainty. For example, such a deployment can result from throwing sensor nodes from an airplane. In general, a uniform random deployment is assumed to be easy as well as cost-effective.

2. Grid Deployment

So far, we have only considered the non-deterministic deployment scheme, random deployment, in which the sensor nodes are thrown randomly to form a network. However, since excess redundancy is required to overcome uncertainty it could be very expensive. In [3], it has state that grid deployment is an attractive approach for moderate to large-scale coverage-oriented deployment due to its simplicity and scalability. In a grid deployment the amount of connectivity and resilience of the sensor nodes against the adversaries when they are deployed in grid fashion. Grid deployment is conducted by dropping sensors row-by row using a moving carrier. Previously many studies have explored the properties of grid deployment in the ideal circumstance where individual sensors are placed exactly at grid points. However, in practice, it is often infeasible to guarantee exact placement due to various errors, including misalignments and random misplacement.

3. Group based Deployment

We have considered the networks in which sensors are deployed in groups such that sensors from a group are closer together on average than sensors from different groups. They refer to this as group deployment of sensors. we assumed that group deployment may be used in order to improve the coverage of the target region by sensors, as it provides more control over the physical distribution of sensors, and also a convenient way of carrying out the deployment: in the case where several vehicles are available for distributing sensors, they could be used to deliver sensors to different portions of the target area simultaneously. However, the main motivation for considering group deployment from the point of view of key distribution is the fact that the partial location knowledge it provides can be used in order to improve the connectivity of the network.

4. Grid-Group Deployment
Grid-group deployment scheme for wireless sensor networks is discussed when nodes are deployed in a region, all nodes need not communicate with all other nodes in the network. Due to limited power, all nodes cannot communicate with all other nodes. So we divide the entire region into equal-sized squares or grids as done in Liu and Ning [2003, 2005], and Huang and Medhi [2007]. In this scheme, the advantage that all nodes within a particular region can communicate with each other directly and nodes which lie in a different region can communicate via special nodes called agents which have more resources than the general nodes as shown in Figure 5. It is also assumed that it is more difficult to compromise an agent than a sensor node. Whatever the size of the network, the number of agents in a region is always three. This scheme ensures that even if one region is totally disconnected, the regions are not affected. In this we assumed that grid-group deployment provides a very good resiliency in terms of the fraction of nodes disconnected and regions disconnected.

5. THT Node Deployment

For coverage calculation, THT is analyzed based on the total number of cells due to the combination of triangle and hexagon. Unlike the square grid, the exact k-coverage of THT cannot be applied directly from a single THT cell. First, we compute the total amount of triangle and hexagon cells inside a given circular field having radius R. After that we compute the relative frequency of the exactly k-covered points by using the k-coverage map of THT. Although the ratio of cells amount does not remain absolutely equal when increasing n, the results for the exact k-coverage are relatively the same. Almost two thirds of the network are covered by 3-coverage whereas the rest is the exactly 2-covered. Of course, a negligibly small percentage of the network is 6-covered. On the other hand, these points are a good playground for sink placement. If a sink has many 1-hop neighbors, these nodes can share the load and can thus reduce energy consumption. Without counting the exact 6-coverage, THT has an average 2.7-coverage with a standard deviation of 0.48. Although THT has the lowest small percentage of the network, it has the best balanced coverage performance. What is more, THT needs less sensing range than the other strategies. While the others use 11m sensing range, THT requires only 10m. Note that although the triangle grid has a better coverage performance does not perform well under other performance metrics.

CONCLUSION

In summary, we believe that THT is a promising node deployment strategy, although its planning overhead must be taken into account. In three performance metrics, THT almost always outperforms the other strategies for energy consumption and worst-case delay. For coverage performance, a square grid is better than the other strategies. It can also be seen that random deployment is not a bad strategy and it is comparable to the popular square grid deployment for the worst-case delay. Of course, we analyzed these metrics based on certain assumptions. Yet, we believe that THT is a well performing node deployment strategy for WSN applications. For future work, other tiling should also be taken into account. A more detailed energy model for WSNs should be considered as well.

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