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Effects of high node density in a WSN and possible methods to overcome problems associated with it

Tripti Sharma
IT Department
Maharaja Surajmal Institute of Technology
New Delhi-110058
tripti_sharma@msit.in

Abstract :Wireless Sensor Network (WSN) refers to a group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of environment and organizing the collected data at a centralized location. These Sensor nodes have a limited amount of power as well as memory. In a randomly deployed WSN, these sensor nodes are distributed in a random manner, thus causing higher density of nodes in some areas as compared to other. In this paper we have surveyed the effects of high node density in a wireless sensor network and possible ways to overcome with the problems associated with it.

Keywords:*WSN, high node density, random node deployment*

I. Introduction

With the fast spread of communication technology and Internet of Things applications, wireless sensor networks (WSNs) are being widely used in many applications such as medical care, military surveillance and environmental monitoring, where they have become an important and effective means of information gathering in various fields. These sensors are fortified with small-capacity, low-cost batteries in most of the case non-rechargeable and irreplaceable.

Whenever these nodes are deployed in random configuration, i.e. no information about the environment is given, this leads to unequal distribution of nodes.The node density impacts routing evaluations since it determines, together with the mobility model, how many neighbors a node has. There are three major drawbacks of high node density:

1. In an area of high node density, multiple nodes will transmit similar data to the sink. This causes a redundancy in data, thus decreasing the efficiency of the whole system.
2. Due to high node density, the topology of the network becomes more and more complex. This leads to an increased number of routers in the path between the sensor node and the sink node. Hence more power is consumed by the intermediate nodes.
3. Due to limited bandwidth, the quality of service is reduced since the network link is carrying more data than it can handle. This is called network congestion. It can further cause packet loss, queuing delay or blocking of new connections.

The rest of the paper is organized as follows: In section 2 we will describe the detailed effects of high node density in the network. Section 3 depicts the review of existing methods to overcome the problems associated with high node density. And finally, section 4 states the conclusion and the future work that can be carried out.

II. Effects of High node density

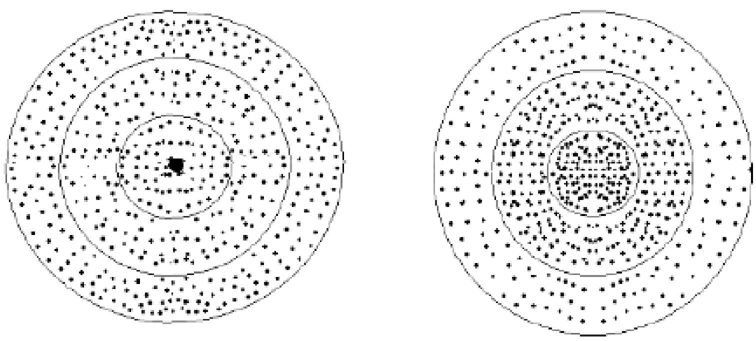
In this section, we discuss the various consequences of increasing the node density in a Wireless Sensor Network.

Redundant Nodes:Practically we observe a disparity in energy consumption rates among different sensors. This disparity results from higher utilization of a small set of deployed sensors in the field leaving these sensors drained out of power. To overcome this problem, it is often required to deploy redundant sensors to act as replacements for a faulty node. A node whose area of coverage overlaps with another node is often regarded as a redundant node. Significant work has been done in estimating the node density and number of redundant nodes required in a WSN application. The density of redundant nodes is estimated based on the distance of a node from the sink while dealing with connectivity and coverage.

Often redundant sensors are deployed around each sensor based on its distance from a sink[1]. The scheme proposed in [1] is most related to our work as we determine an estimate number for these redundant sensors to be deployed in different regions of the network based on its estimated utilization in the course of the network's lifetime.

The data which the redundant nodes will transmit, will be similar to one another. This means that the some data fields can be repeated in the database. Thus, filling the database with unnecessary data and worsening the data storage ability.

In certain cases, it is observed that the nodes closer to the sink tend to experience more traffic than other nodes. As a result, their energy consumption rates tend to be higher than those nodes that are distant from the sink. The nodes closer to the sink tend to die early leaving a hole near the sink and therefore, disconnecting the sink from some nodes in the network. This phenomenon is common in WSNs where the sensor nodes are homogeneous and report events generated at a constant rate to the sink and is known as the energy-hole problem [1], [2].Furthermore, these nodes will also keep on consuming the limited energy and bandwidth allotted to



(a) (b)

Figure 1: Deployment of concentric rings with (a) Uniform sensor distribution, (b) Non-uniform sensor distribution.

the system. This causes an overall reduction in system efficiency.

1. Complex Topology:

The wireless networks have categorized into cellular and ad-hoc networks: Cellular networks required well-built pre-existing infrastructure like base-station. In this network, mobile devices communicate with the nearest base-station in its vicinity and hand-off process occurs when a mobile unit moves out of reach from one base-station to another. Another type of wireless networks is an ad-hoc network, do not require any rugged pre-existing infrastructure [3] and is defined as collection of self-maintaining and self-configuring mobile nodes, without centralized administration. Mobile nodes functions both as a router as well as host to forward the data wirelessly.

The topology of ad-hoc WSN networks is uncertain and unpredictable. Mobile nodes are free to join any network within its vicinity. This further increases the complexity.

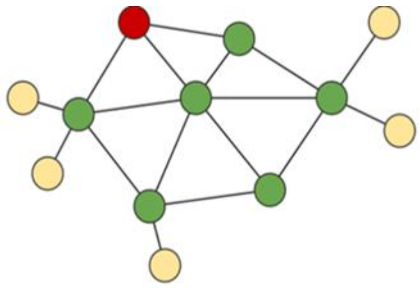


FIG 2: MESH TOPOLOGY OF WSN WITH A STATIC SINK

Usually, the sink and nodes work together to form a mesh network. The gateway maintains a list of nodes (by serial number) that have been authorized for network access. When a node powers up, it scans for available networks, locates either a sink or router, and attempts to join it. If the gateway has the node in its list, the node joins the network, and begins its normal operation of acquiring measurement data.

Since each node joins a network instead of a particular router or sink, it can find a new path back to the sink in the event that the signal is lost or blocked to its existing network route. In this way, the mesh network is inherently self-forming and self-healing. However, this may also cause network throughput to decrease, as there is no way to force a router or end node to join to a particular device in the network. Each time a node joins through a router, the overall throughput of that node is halved, due to the fact that the node must hop to get its messages back to the gateway. When this phenomenon is accompanied with high node density, i.e. an increase in the number of routers, the number of hops increases and thus cause a great power loss.

2. Network Congestion:

Network congestion in data networking is the reduced quality of service (QoS) that occurs when a network node or link is carrying more data than it can handle. Typical effects include queueing delay, packet loss or the blocking of new connections. A consequence of congestion is that an incremental increase in offered load leads either only to a small increase or even a decrease in network throughput.Congestive collapse (or congestion collapse) is the condition in which congestion prevents or limits useful communication. Congestion collapse generally occurs at choke points in the network, where incoming traffic exceeds outgoing bandwidth. Connection points between a two node clusters of high node density, are common choke points. When a network is in this condition, it settles into a stable state where traffic demand is high but little useful throughput is available, packet delay and loss occur and quality of service is extremely poor.

III. Related Work

Redundancy in sensor deployment is an efficient method to ensure uninterrupted data delivery and improved network lifetime [4]. However, a proper estimation of redundancy is required based on the traffic load at different level of the data forwarding tree to ensure complete network lifetime.

Initial deployment of sensor nodes plays a crucial role in prolonging the network lifetime while maintaining connectivity and coverage. Although the area of interest is required to be covered by sufficient number of sensors, the problem of finding minimum number of sensors to satisfy the coverage criteria is NP-hard[5].

To deal with the problems caused by high node density, first of all we will need to find the location of each node and determine how dense the network is. Choosing a sensor localization algorithm for an application depends on requirements such as accuracy and scalability. Apparently, it is preferred an algorithm which can provide a certain degree of accuracy with smaller number of reference nodes. Especially, in case of deploying wireless sensors randomly no given information on environment, forming a network to make wireless sensors collaborate for achieving a goal is challenging task. With the limitation on processing capabilities and power of a wireless sensor, heavy computation and information exchange over the air are not allowed for networking wireless sensors. Even huge number of sensors are deployed over the wide area, configuring a network will be more challenging problem in algorithmic and practical sense, because it is difficult to set all the information for configuring the network on to the wireless sensors before deploying. In [6], the author proposes a new decentralized WSN configuration algorithm which can provide relative location of sensor nodes to the sink node. Another author [7] proposed an analytical model to estimate the hop count between source-destination pairs in a wireless sensor network with an arbitrary node degree when the network nodes are uniformly distributed in the sensing field. They considered both the hop progress and connectivity effect on hop count. Unlike common approaches which consider only hop progress and do not correctly address the effect at low node density, their approach considered both the hop count and connectivity effect on hop count.

After applying the localization algorithm, we can approach the complications arising due to node density. The sensor nodes are deployed in the environment for sensing the data. The sensed data is then delivered to sink via intermediate nodes that are close to sink via the multihop manner using wireless transmission. However, such approach of data collection by sink has a major drawback that is the sensor nodes located closer to sink have to relay number of data packets and thus they have to exhaust more power than the nodes which are farther away from the sink. As a result, the network lifetime reduces significantly. To overcome the problems arising due to static sinks, mobile sinks are utilized in a WSN. One such publication [8], which uses mobile sink in a WSN, proposed a novel scheme for data collection/transmission to the mobile sink. The proposed scheme operates in three phases, that is, master node selection, group-based region formation, and data transmission to the mobile sink. In master node selection, master nodes are selected on the basis of cost value that is calculated by receiving the Hello Packet sent by the mobile sink. The nodes are other than the master nodes called member nodes transmitting data towards their master node. Furthermore, agent node selection prolongs the network lifetime by swapping of their role with the master node. This swapping of the role of the master node is based on their residual energy. In [8], the proposed scheme achieves better throughput, increase in a number of data collections by the mobile sink, and achieves considerable high energy efficient packet reception ratio.

Designing the predefined trajectory that the mobile sink can move along to collect sensing data has attracted the extensive attention of many researchers. By fully exploiting the predefined mobility, the network coverage is improved and the number of transmissions is decreased to some extent. Ghafoor proposed a mobile sink trajectory design method based on the Hilbert space-filling curve [9], in which the trajectory was designed by analysing the network size. However, in networks with non-uniform or uneven node deployment, this method would result in a significant decrease in packet delivery ratio for high re-transmission rates. To address this problem, Yang proposed a path-constrained mobile sink trajectory design method, in which the trajectory is designed based on the node density in each subarea[10].

A WSN with high node density presents the problem of congestion. Congestion is one of the major issues which adversely affect all the QOS parameters [11]. Congestion is considered to be occurred when any of the node or link gets the data more than its processing capacity. Congestion occurs due to high reporting rate, node density as large number of packets thumbed into the network. There are two means to reduce congestion either by congestion avoidance and congestion detection.

In [12], Zhang proposed Distributed Congestion Feedback Algorithm (DCCA). DCCA helps in solving the congestion at the sink for multi-hop WSN. DCCA uses cross layer communication which uses queue based congestion level detection scheme in the MAC layer and then adopts hop-by-hop feedback notification scheme in the transport layer to solve the congestion problem.

The multipath routing scheme should be able to provide the services with bandwidth guaranteed multi-paths, which help these services be run over secure and reliable network architecture. Congestion can be truncated by using multipath routing protocols such as the one proposed in [13]. Here, SM-AODV is used in which, the packets are delivered across multipath using a secure and reliable scheme, which decouples the node's capabilities for applications and offers optimization alternatives not available in current schemes yet. SM-AODV adopts an adaptive congestion control scheme, which is effective even in the case that node or link failure occurs frequently.

Yet another method to deal with congestion and energy dissipation is clustering. Clustering is one of the widely used solutions to decrease the number of network's internal transference. In clustering, sensor nodes are divided into number of clusters and one node is selected as cluster head in each cluster. The cluster members then transmit the received data to its corresponding cluster head. Cluster head combines the received data and sends it to base station. A process to select the cluster head in elaborated in [14], where Hexagonal Node Deployment technique is used. Here cluster heads are chosen on the basis of Fuzzy Logic.

High node density also effects the data routing. As the number of nodes in a network increases, the network topology becomes more and more complex. This complexity further increases when mobile sinks are used instead of static sinks. Routing protocols plays a significant role in the ad-hoc networks to forward packets from one host to another wirelessly. The mobile node determines its topology by listening from the neighbouring nodes because nodes do not know the network topology when they are free to join or leave the network. The main purpose of the routing protocols is to provide an energy efficient route between the nodes for the successful delivery of packets. In [15], classification of routing protocols, evaluation and comparison with different routing protocols to choose the best routing protocol for FTP and HTTP applications is done.

As the node density increases, number of hops for data routing tends to increase. However, this causes the routers to dissipate their energy more because they would have to receive the data packets, then process the data and then retransmit the data. Hence, it becomes a necessity to decrease the power consumption in order to prolong the lifetime of the WSN. One way to decrease power consumption is proposed in [1]. Here a gradient based node deployment strategy for data gathering in sensor network with sleep based energy saving considering the trade-off among coverage, connectivity, fault-tolerance and redundancy is proposed. Another such technique is proposed in [16], where dynamic network routing and improved sleep scheduling is proposed which ultimately obtains the best network performance results over the LEACH and InFRA for the different nodal scenario.

IV. Conclusion

In this paper, we have surveyed the effects of high node density in a wireless sensor network and possible ways to overcome with the problems associated with it. We analyzed the latest research, which will help in determining the trade-off between various advantages and disadvantages of increasing the number of redundant nodes and consequently increasing the node density in wireless sensor network.

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