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# Congestion Control in Wireless Sensor Networks: Mobile Sink Approach

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**Abstract:** ***Congestion severely affects the performance of a wireless sensor network in two aspects: increased data loss and reduced lifetime. This paper addresses these problems by introducing a mobile sink for congestion avoidance and lifetime maximization in wireless sensor networks. Also, in the proposed scheme data only has to travel a limited number of hops to reach the mobile sink which helps to improve the energy consumption of the sensor nodes. We have considered various parameters like packet delay, packet loss and throughput for evaluation. Through simulation we show effectiveness of the proposed scheme in terms of congestion avoidance and increased lifetime of the wireless sensor network.***

**Keywords:** Congestion avoidance, lifetime maximization, mobile sink, wireless sensor network.

## 1. Introduction

A wireless sensor network (WSN) is a network made of hundreds or thousands of sensor nodes to cooperatively monitor different condition, such as temperature, sound, vibration, pressure and motion at different locations which is the common task of sensor node is to collect the information from the scene of event and send the data to a sink node. Wireless Sensor Networks (WSNs) are self organizing, infrastructure less and multi-hop packet forwarding networks. There is no concept of fixed base station. So, each node in the network acts as a router to forward the packets to the next node. Wireless networks are capable of handling of topology changes and malfunctions in nodes. It is fixed through network reconfiguration. For instance, if the node leaves the network and causes link breakages, affected nodes can request new routes and problem will be solved.[6][7]

The phenomenon of congestion can be observed in different types of wired and wireless networks even in the presence of strong routing algorithms. Congestion in wireless sensor networks (WSN) mainly occurs because of two reasons -- when multiple nodes want to transmit data through the same channel at a time or when the routing node fails to forward the received data to the next routing nodes because of the *out-of-sight problem*.

Applications of WSNs in the areas of environment and habitat monitoring require the sensor nodes to periodically collect and route data towards a sink. Also, it is known that each sensor node can only be equipped with a limited amount of storage, so if at any given routing node the data collection rate dominates the data forwarding rate congestion starts to build up at this node. Such type of congestion and data loss normally occurs at the nodes located in the vicinity of a static sink. Data loss at these nodes occurs due to the fact that at any given point of time a sink can only communicate with one or a limited number of sensor nodes.[1][7]

To mitigate this *static sink problem*, new strategies have been developed by exploiting the mobility of a sink to better balance the problem of congestion and the energy consumption among the sensors. That is, the mobile sink traverses the monitoring region and rest at some locations to collect sensed data. It has been demonstrated that sink mobility is a blessing rather than a curse to network performance including the network lifetime, packet delay, packet loss and throughput.

The lifetime of the sensor network is another important aspect in environmental and habitat monitoring based applications of the WSN. Lifetime of a WSN can be defined as the time interval between the deployment of the sensor field and the time when the first sensor node fails due to complete energy dissipation.[1][2][6][7]

The main contribution of this paper is that we have done the analysis of the effect of mobile sink in reducing congestion and increasing lifetime of the sensor network by considering various parameters. The same parameters are considered for the sensor network using static sink. It has been shown that, sensor network with a mobile sink performs better to reduce congestion as compared to sensor network with a static sink.

The rest of the paper is organized as follows: Section II summarizes related work, Section III presents the sink mobility model, in Section IV a brief description of AODV routing protocol is given. Simulation setup and analysis of results are given in Section V and Section VI respectively and section VII concludes the paper.

## 2. Related Work

In this section a summary of currently available congestion avoidance techniques and their removal is discussed. It also elaborates the recent work done on investigating the use of mobile sink in WSNs.

### A. Congestion avoidance and Control Techniques

In WSN, there are mainly two reasons that result in congestion- (i) the packet arrival rate exceeding the packet service rate. This occurs at sensor nodes which are in the vicinity of the sink as they usually carry more upstream traffic. (ii) Contention, interference and bit error rate on a link also results in congestion.[6][7]

Congestion has a direct impact on energy efficiency and application QoS. It can cause buffer overflow, packet loss and can also degrade link utilization. Thus, congestion in WSN must be efficiently controlled. Typically, there are three mechanisms that can deal with this problem:

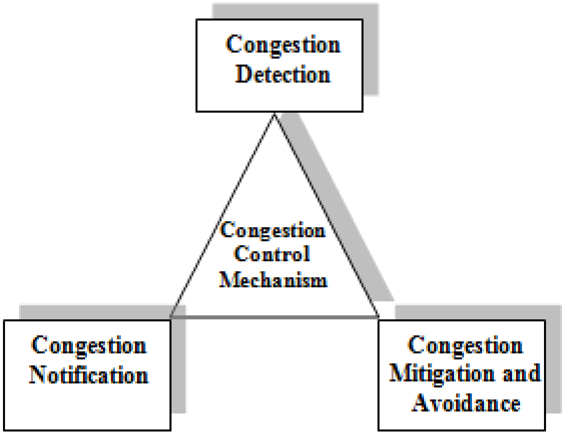


**Figure 1:** Congestion Control Mechanisms

a) ***Congestion Detection:*** For congestion detection in WSN, a common mechanism is to use queue length, packet service time or the ratio of packet service time over packet inter-arrival time at the intermediate nodes. In a network, channel loading can be measured and can be used as an indication of congestion.

b) ***Congestion Notification:*** Once the congestion is detected, a transport protocol needs to propagate the congestion information from the congested node to its upstream nodes or the source node that contributes to congestion. The information can be transmitted using a single binary bit, called as congestion notification (CN) bit. It can also give information such as allowable data rate, degree of congestion etc. Congestion notification can be either *Explicit or Implicit.*

c) ***Congestion Mitigation and Avoidance:*** There are two general approaches to mitigate and avoid congestion- ***Network resource management*** which tries to increase network resources to mitigate the congestion when it occurs. ***Traffic Control*** controls congestion by adjusting the traffic rate at source nodes or intermediate nodes. Traffic control can be end to end or hop by hop.

### B. Congestion Control Protocols

Several congestion control protocols have been anticipated for upstream convergent traffic in WSNs. They differ in congestion detection, congestion notification, or rate -adjustment mechanisms. Some of the protocols have been discussed below:

a) ***Fusion:*** It is a hop by hop congestion control protocol for upstream traffic. Congestion detection is based on queue length. It uses implicit congestion notification using CN bit. Due to broadcast nature of wireless channel, the neighboring nodes of the congested node stops forwarding packets to the congested node and thus eliminate congestion quickly.

b) ***Congestion detection and avoidance (CODA):*** It detects congestion based on current buffer occupancy. It used a suppression message to explicitly notify whether there is congestion or not to the upstream nodes. Thus, upstream nodes will gradually reduce their sending rates. The suppression messages used in CODA consumes additional energy and results in decreased reliability.

Other protocols are *PCCP, ARC, Siphon* etc. recently proposed for congestion control in WSN. The presented protocols for WSNs have two primary restrictions. First, sensor nodes may have different importance in specific applications. For example, they can be equipped with different kinds of sensors and deployed in different environmental locations. Therefore, sensor nodes can generate sensory data with different characteristics and have different importance with respect to reliability and bandwidth necessities. However, most existing protocols do not consider nodes' different importance. Second, the existing transport protocols for WSNs assume that single – path routing is used at the network layer. Scenarios with multipath routing are not considered except PCCP. It is not clear whether these transport protocols can be directly applied to WSNs employing multipath routing. [1][6][3]

## 3. Data Routing Towards Mobile Sink

Over the past few years the use of a mobile sink has increased in WSNs to achieve better performance, in particular for balanced utilization of the sensor field energy and to prolong the lifetime. The sink can follow three basic types of mobility patterns in a WSN: random mobility, predictable/fixed path mobility, and controlled mobility.

*Random mobility*: In case of random mobility, the sink follows a random path in the sensor field and implements a pull strategy for data collection from the sensor nodes. Data can be requested from either one hop or *k* (where, k>1) hop neighbors of the sink. On the other hand, with random sink mobility it is not possible to guarantee data collection from all the sensor nodes positioned in a WSN.

*Predictable/fixed path mobility:* The longest lifetime for the sensor network can only be achieved if the mobility route of the sink is along the *periphery* of the sensor field. Increased data latency and packet loss are major problems that happen due to the sink mobility in wireless sensor networks. One potential drawback of their scheme is that whenever the sink moves, routing paths need to be updated. Moreover, when the sink pauses at any point along the boundary, then the situation becomes comparable to that of a static sink case that leads to increased data loss in the vicinity of the sink.

*Controlled mobility:* Use of controlled sink mobility is also analyzed in WSNs for increasing the lifetime. Controlled sink mobility based schemes are a good option if compact data latency is required, but they are less cost effective than random/fixed path mobility. If data latency is permissible, then the best routing strategy that incurs minimum data loss due to sink mobility and also provides maximum lifetime of the sensor network with minimum cost is obtained if the sink follows a discrete mobility pattern along the boundary of the sensor field.

To summarize, if data latency is permissible, then the best routing strategy that incurs minimum data loss due to sink mobility and also provides maximum lifetime of sensor network with minimum cost is obtained if the sink follows a discrete mobility pattern along the boundary of the sensor field.[1][8]

## 4. Network Simulator and AODV Routing Protocol

### A. Network Simulator

The network simulator 2 (ns-2) is a popular tool for the simulation of packet-switched networks. It provides substantial support for simulation of TCP, routing, and MAC protocols over wired and wireless networks. The simulator core is written in C++. It has an OTcl (Object Tool Command Language) interpreter shell as the user interface and allows input models written as Tcl (Tool Command Language) scripts to be executed. Most network elements in ns-2 simulator are developed as classes, in object-oriented fashion. It is freely distributed and all the source code is available. Fig. (ii) shows basic structure of ns-2. The network topology and traffic agents etc are specified in the TCL file. It is parsed by the oTCL interpreter. The C++ library has all the implementation details. When ns-2 is run, the resulting data could be obtained in a trace file format. The trace file contains time stamp and information about each packet that is sent, received or dropped. It also has information about the packet size, type of packet etc. A base station and a subscriber station can be set up as a node in ns-2. As the number of nodes in the simulation increase, the packets that are sent and received increases. This makes the trace file very large.

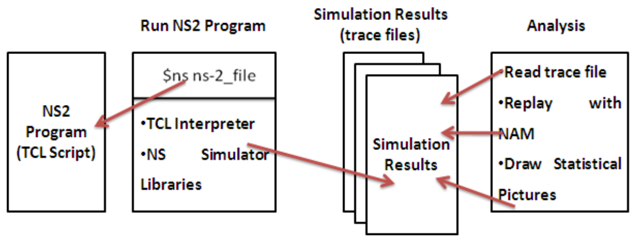


**Figure 2:** Basic Structure of NS2

Performance Metrics encompasses Quality of Service to the end user in terms of several generic parameters. The perceived quality of service can be quantitatively measured in terms of several parameters. In the analysis, the throughput, packet delay, packet loss, energy were considered. [5][9][10]

### B. Adhoc On Demand Distance Vector Routing Protocol

AODV routing protocol is an on demand routing protocol. In order to find a route to the destination, the source node floods the network with Route Request packets. The Route Request packet creates temporary route entries for the reverse path through every node it passes in the network. When it reaches the destination a RouteReply is sent back through the same path the Route Request was transmitted. Every node maintains a route table entry which updates the route expiry time. A route is valid for the given expiry time, after which the route entry is deleted from the routing table. Whenever a route is used to forward the data packet the route expiry time is updated to the current time plus the Active Route Timeout. An active neighbor node list is used by AODV at each node as a route entry to keep track of the neighboring nodes that are using the entry to route data packets. These nodes are notified with Route Error packets when the link to the next hop node is broken. In turn, each such neighbor node forwards the Route Error to its own list of active neighbors, thus invalidating all the routes using broken link.[5]

## 5. Simulation Environment

In the presented model, we consider 22 nodes out of which 21 nodes are WSN nodes and 1 node is a sink node. The wireless sensor nodes are uniformly but randomly deployed. Nodes are responsible for sensing and reporting their readings at constant time to the sink. Sensor nodes are grouped into clusters and each cluster has a head node that is responsible for forwarding the received data from neighboring client nodes towards sink.

**Table 1:** Simulation Parameters

| Parameter | Value |
|---|---|
| Channel Type | Wireless Channel |
| MAC Protocol | IEEE 802.11 |
| Frequency/ Bandwidth | 2.4 GHz/ 250kbps |
| Interface Queue Type | Queue/ Droptail |
| Traffic Type | CBR |
| Antenna Model | Omni directional Antenna |
| Sink Speed | 2m/s |
| No. of nodes | 22 |
| Maximum Packets in Interface Queue | 50 |
| Packet Size | 512 Bytes |
| Routing Protocol | AODV |
| Simulation Time | 80 Sec |
| Simulation Area | 1500 x 900 |

We have considered the above parameters for wireless sensor network with a static sink as well as wireless sensor networks with a mobile sink. The following metrics have been selected for evaluating the effect of mobile sink in order to reduce congestion and increase the lifetime of the sensor network. The comparison is shown in the VI section.

***1. Packet Loss:*** It is the ratio of number of packets lost in the network to number of packets generated by the sensing nodes.

$$\textit{Packet Loss} = \frac{\textit{No.of Packets Lost in the Network}}{\textit{NO.of Packets Generated by the sensing Nodes}}$$

Packet loss in the network should be as low as possible to increase the reliability of the network.[11]

***2. Packet Delay:*** Packet delay is the total latency experienced by a packet to traverse the network from the source to the destination. At the network layer, the end-to-end packet latency is the sum of processing delay, packet, transmission delay, queuing delay and propagation delay. The end-to-end delay of a path is the sum of the node delay at each node plus the link delay at each link on the path. [5][11]

**3. *Throughput***: It is the average rate of successful packet delivery over a Sensor Network. The throughput is usually measured in data packets per second**.**

$$\textbf{\textit{Throughput}} = \frac{\sum(\text{Packet Size})}{(\text{Packet Arrival Time}) - (\text{Packet Start Time})}$$

A high network throughput indicates a small error rate for packet transmission and the low level for contention in the network.[5][11]

***4. Lifetime:*** Lifetime is the important aspect in WSN. It is defined as the interval between the deployment of the sensor field and the time when the first sensor node fails due to complete energy dissipation. [1]

***Simulation Scenario***

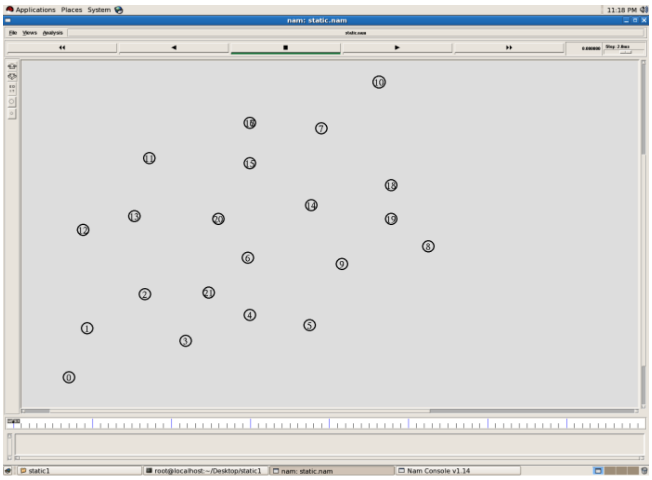

**Figure 3:** Simulation Environment

Fig. (iii) Shows the simulation Environment which typically consists of 22 nodes out of which 21 nodes are wireless sensor nodes and one node is a sink node. The same environment is considered for both static as well as mobile sink scenarios and the above parameters are considered for the comparison. Later we present the graphical analysis of both the scenarios.

## 6. Result Analysis

Besides running independently, both the simulations are capable of obtaining the graphs which shows the packet lost in the network, packet delay and throughput. It can be seen from the simulation results that in a wireless sensor networks with a static sink, the nodes which are located in the vicinity of a static sink, gets congested as it is heavily burdened due to the fact that it is responsible for carrying the traffic of the neighboring nodes. Once congestion starts to build up in the network, the battery of the congested node drains out quickly, which ultimately results in node failure.

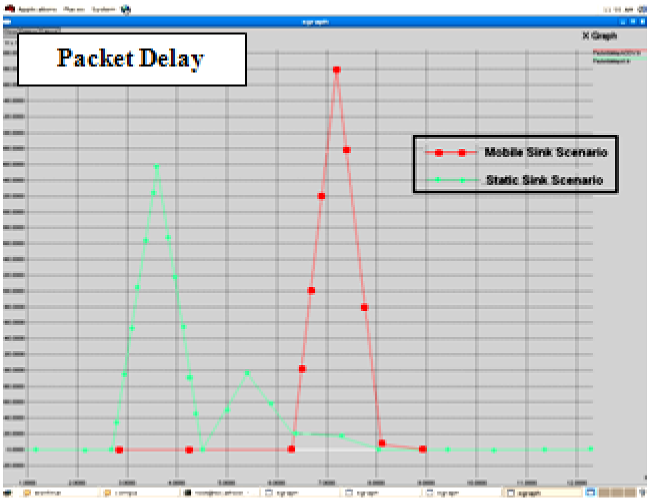


**Figure 4:** Graph of Time Vs. Packets Transmitted

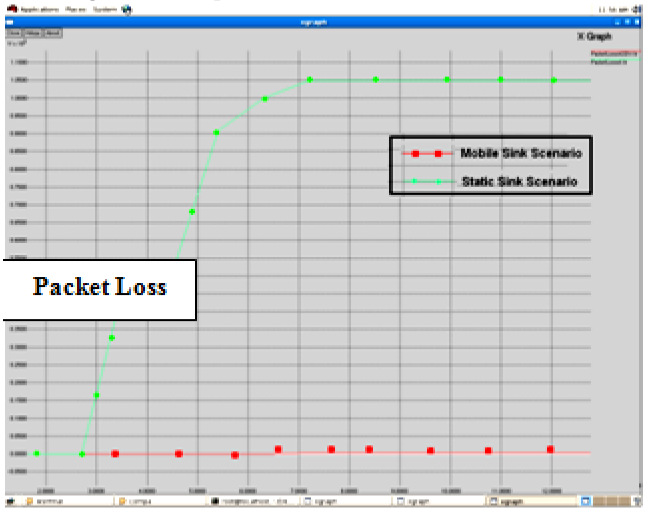


**Figure 5:** Graph of Time Vs. Packet Loss

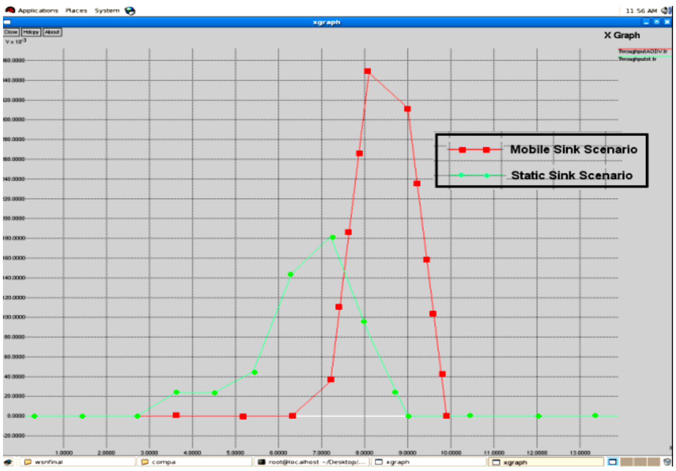


**Figure 6:** Graph of Time Vs. Packets delivered successfully

Referring to the above three figures we present a comparison of Wireless Sensor Network with a static sink and wireless sensor network with a mobile sink by considering the three parameters as shown in the Fig. iv, v and vi.

**Table 2:** Comparison of Parameters

| **[1] Parameter** | **[2] Static Scenario** | **[3] Mobile Scenario** |
|---|---|---|
| **[4] Packet Delay** | [5] More | [6] Less |
| **[7] Packet Loss** | [8] Heavy | [9] Reduced |

| | | |
|---|---|---|
| **[10] Throughput** | [11] Less | [12] Increased |
| **[13] Lifetime** | [14] Reduced | [15] Increased |

From the table it is clear that in case of wireless sensor network with a mobile sink there is less packet delay, reduced packet loss and throughput is almost double as compared to wireless sensor network with a static sink. We conclude that congestion is thus reduced in the WSN thereby increasing the lifetime of a sensor network.

## 6. Conclusion

The Simulation results obtained from the presented model, we conclude that, congestion, which is a major factor affecting the performance of a Wireless Sensor Network, has reduced drastically by using a **Mobile sink** as data has to travel only minimum number of hops. Also, congestion has a direct impact on the lifetime of the sensor network. By reducing congestion, we are able to increase the lifetime of the sensor network.

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