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# Evaluation of AODV and DSR Routing Protocols of Wireless Sensor Networks for Monitoring Applications

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# ABSTRACT

Deployment of sensor networks are increasing either manually or randomly to monitor physical environments in different applications such as military, agriculture, medical transport, industry etc. In monitoring of physical environments, the most important application of wireless sensor network is monitoring of critical conditions. The most important in monitoring application like critical condition is the sensing of information during emergency state from the physical environment where the network of sensors is deployed.

In order to respond within a fraction of seconds in case of critical conditions like explosions, fire and leaking of toxic gases, there must be a system which should be fast enough. A big challenge to sensor networks is a fast, reliable and fault tolerant channel during emergency conditions to sink (base station) that receives the events.

The main focus of this thesis is to discuss and evaluate the performance of two different routing protocols like Ad hoc On Demand Distance Vector (AODV) and Dynamic Source Routing (DSR) for monitoring of critical conditions with the help of important metrics like throughput and end-to-end delay in different scenarios. On the basis of results derived from simulation a conclusion is drawn on the comparison between these two different routing protocols with parameters like end-to-end delay and throughput.

## LIST OF ACRONYMS

| | |
|---|---|
| **AODV** | Ad-hoc On Demand Distance Vector |
| **APS** | Ad-hoc Positioning System |
| **ATD** | Analog to Digital |
| **ASYM** | Asymmetric |
| **CPU** | Central Processing Unit |
| **DD** | Directed Diffusion |
| **DSR** | Dynamic Source Routing |
| **EAR** | Energy Aware Routing |
| **FTP** | File Transfer Protocol |
| **GEAR** | Geographic and Energy Aware Routing |
| **IC** | Integrated Circuit |
| **MAC** | Medium Access Control |
| **MECN** | Minimum Energy Communication Network |
| **SMECN** | Small Minimum Energy Communication |
| **MMSPEED** | Multi path and Multi Speed |
| **OPNET** | Optimized Network Engineering Tool |
| **QoS** | Quality of Service |
| **RREQ** | Route Request |
| **RREP** | Route Reply |
| **SAR** | Sequential Assignment Routing |
| **SYM** | Symmetric |
| **TORA** | Temporally ordered Routing Algorithm |
| **UART** | Universal Asynchronous Receive and transmit |
| **WSN** | Wireless Sensor Network |
| **WLAN** | Wireless Local Area Network |

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**FIGURE** **DESCRIPTION**



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# Chapter 1: INTRODUCTION

The advancements in wireless communication technologies enabled large scale wireless sensor networks (WSNs) deployment [30]. Due to the feature of ease of deployment of sensor nodes, wireless sensor networks (WSNs) have a vast range of applications such as monitoring of environment and rescue missions [31]. Wireless sensor network is composed of large number of sensor nodes. The event is sensed by the low power sensor node deployed in neighborhood and the sensed information is transmitted to a remote processing unit or base station [21].

To deliver crucial information from the environment in real time it is impossible with wired sensor networks whereas wireless sensor networks are used for data collection and processing in real time from environment [21]. The ambient conditions in the environment are measured by sensors and then measurements are processed in order to assess the situation accurately in area around the sensors. Over a large geographical area large numbers of sensor nodes are deployed for accurate monitoring. Due to the limited radio range of the sensor nodes the increase in network size increases coverage of area but data transmission i.e. communication to the base station (BS) is made possible with the help of intermediate nodes.

Depending on the different applications of wireless sensor networks they are either deployed manually or randomly. After being deployed either in a manual or random fashion, the sensor nodes self-organize themselves and start communication by sending the sensed data. These sensor networks are deployed at a great pace in the current world. Access to wireless sensor networks through internet is expected within 10-15 years [1]. There is an interesting unlimited potential in this wireless technology with various application areas along with crisis management, transportation, military, medical, natural disaster, seismic sensing and environmental. There are two main applications of wireless sensor networks which can be categorized as: monitoring and tracking.

In general the two types of wireless sensor networks are: unstructured and structured. The structured wireless sensor networks are those in which the sensor nodes deployment is in a planned manner whereas unstructured wireless sensor networks are the one in which sensor nodes deployment is in an ad-hoc manner. As there is no fixed infrastructure between wireless sensor networks for communication, routing becomes an issue in large number of sensor nodes deployed along with other challenges of manufacturing, design and management of these networks. There are different protocols that have been proposed for these issues. The critical condition monitoring application is studied in this thesis by evaluation of two routing protocols with the help of some performance metrics considering applications demand as well.

## 1.1 BACKGROUND:

The use of different wireless devices like cell phones, GPS devices, laptops, RFID and other electronic devices have become more pervasive, cheaper and important in today's life. The demand for communication and networking among these various wireless devices has been increased for different applications. Wireless sensor networks from this point of view are the latest trend [34].

Mobile Ad Hoc Network (MANET) that is connected by wireless links is a self configuring network of mobile nodes. The devices freely move in any direction and links among these devices are changed frequently [5]. A cooperative network organized by collection of sensor nodes is a wireless sensor network [5]. Both of these networks fall into the category of infrastructure less wireless networks as they do have any requirement regarding infrastructure during the deployment. Wireless Local Area Networks (WLANs) and cellular networks fall into the other category of wireless networks that require infrastructure during their deployment.

These two categories which are infrastructure less and infrastructure based have their own cons and pros. In the first category which is the infrastructure based networks, both voice and data with good quality of service from source to destination is carried but infrastructure is required. In second category which is infrastructure less networks have constraints with limitation in bandwidth, power and range. Despite of the constraints these infrastructures less networks have many advantages [41].

A wide range of wireless sensor network applications are:

- Underwater sensor networks that are used for monitoring of fisheries and coral reefs [32]. The underwater sensor network is composed of mobile and static nodes.

- The installation, deployment and maintenance process is accelerated by using WSN in volcanic monitoring. As these networks use equipments that are lighter, smaller and less power consumption. This application of WSN has many challenges that include data collection, event detection, high data rates and sparse deployment of nodes.

Other applications of WSN include [32]:

- Outdoor/indoor monitoring of environment.
- Monitoring of health.
- Factory and process automation.

## 1.2 PROBLEM DEFINITION:

Today the extensive progress made in the two disparate areas of research that are low power embedded systems and distributed robotics due to which mobile sensor networks came into creation [2]. The free mobility of nodes not only has brought its own challenges but also the problems which are associated with static sensor networks are alleviated. The deployment of large scale networks of both static and mobile nodes for different applications of monitoring of health, environment to military are expected in near future. The problem of monitoring of critical conditions over a large area with the help of wireless sensor networks in order to detect an event and transmit it reliably is investigated in this thesis.

Some of the aspects in wireless sensor networks may be generic but specific requirements of the applications should be carefully considered, as in case of demanding application such as environmental monitoring. Large numbers of sensors are deployed in the field to measure different parameters such as temperature, speed, humidity and direction. To determine what is occurring in environment transmission of data to base station as the event is sensed is one of the important factors for monitoring of critical conditions. There should be a fast, reliable and fault tolerant channel in such emergency conditions like fire in forest and leaking of toxic gases.

Due to the constraints in Wireless sensor networks such as bandwidth, lifetime of battery, speed of processor (CPU) and amount of memory there is an essential need for effective communication techniques for improvement of quality of collected data. Routing protocols from this perspective have a very important role in wireless sensor networks. Reliable dissemination of data in a short time interval to base station (BS) is need of sensors in sensor networks [29] in order to quickly respond to the transmitted information by user from time to time because the information that arrives out of time may cause huge disastrous. Scalability is also one of the important factors in order to increase nodes density, network size and topology. This factor comes out form the fact that range of sensing is lesser than communication and requirement of nodes is larger for coverage of area.

Routing of information differentiate these networks from other ad-hoc networks. The study of wireless sensor network is done by performing simulation that can help in better understanding of behavior of various routing protocols. AODV and DSR are the routing protocols with performance metrics of delay and throughput that are evaluated in OPNET with scalability in the network by increasing its size and then a comparison between the two is made to determine which protocol works best in the required application.

## 1.3 METHODOLOGY:

Following are the steps which were performed to achieve the objectives of this thesis work.

### 1.3.1 Review

In this step any published work or surveying of the literature of the research work done relevant about the study area is gathered for assessment.

### 1.3.2 WSN Architecture

In this step the required background information for the understanding of the subject of this thesis work is provided. Also a general understanding of the new emerging technologies from the wireless communication point of view is given in this step. It is simple to start with MANETs which are the base of WSN for the understanding of WSN.

### 1.3.3 Functionality of Routing Protocols

The explanation of the main characteristics and differences of the routing protocols and how they work for WSNs is presented in this step. This step includes how

- Selection of the path.
- Control messages etc.

### 1.3.4 Simulation Tool

OPNET modeler 14.5 software is used in this study. OPNET is a useful tool in research. The use of OPNET can be broken down into four major steps. Creation of nodes (modeling) is the first step. After modeling choose statistics, execute simulations and finally view results.

### 1.3.5 Simulation

After detail discussion of routing protocols for WSN and necessary implementations, in the next step preparation of model for each routing protocol and analyzing its effect for critical condition monitoring application with the help of different parameters is done. These parameters are average end-to-end delay and throughput.

### 1.3.6 Analysis of Results

The results obtained for the selected routing protocols with the help of different parameters and scenarios from simulation are analyzed in this step.

## 1.4 GOAL:

The main goal of this thesis work is the study, selection and evaluation of routing protocols from the existing one for wireless sensor network and compares the performance of these routing protocols for monitoring application of critical condition.

The particular goals of this thesis work are to:

- Develop and design a simulation model.
- Perform a simulation with different metrics.
- Analysis of the results.
- Deriving a conclusion on basis of performance evaluation.

## 1.5 GUIDELINE OF THESIS:

There are five chapters presented in this thesis work. In next chapter, the architecture, components and applications about WSN is covered. Also the comparison between MANETs and WSN is done in the next chapter.

The third chapter of the thesis work covers the study of the routing protocols and main design issues of WSNs. A detailed explanation of the different types of protocols including their architecture and classification required for the thesis work is also presented.

The simulation tool, network design is explained in the fourth chapter. The two routing protocols AODV and DSR are implemented in the OPNET simulator.

In final chapter the analysis of the results is performed on the simulator by comparison of the selected routing protocols in terms of delay and throughput and observations form results are derived in order to determine which routing protocol works better in different scenarios.

## 1.6 RESEARCH WORK:

In an evaluation of three routing protocols of WSN namely probabilistic geographic routing protocol (PGR), beacon vector, routing protocol (BVR) and flooding protocol (FP) using prowler simulator to determine which one is efficient for scalability through several metrics which are throughput, latency, energy consumption and delay, it was concluded that BVR is most efficient for scalability [17].

AODV, a reactive routing protocol performance is improved by fixing expiry time and analyzing it in QualNet 4.5. On basis of results derived from simulation the shortest routing path is ensured based on IEEE 802.11 and IEEE 802.15.4. This routing protocol is good in case of wireless sensor networks because of frequent movement [8].

The differences in AODV, CBRP, PAODV, DSDV and DSR routing protocols is presented by comparing the size of ad hoc networks, load and mobility. The authors concluded that AODV shows the shortest end-to-end delay and throughput in DSR and CBRP is very high. Routing overhead in DSR is higher than CBRP instead of less number of route request packets, while largest overhead is shown by AODV. The original AODV routing protocol is outperformed by preemptive routing protocol [9].

In another research, comparison of TORA, DSR, FSR and AODV routing protocols is analyzed. In comparison of these routing protocols, an important observation was that TORA was not good choice for vehicular environments, AODV and FSR showed good results in city scenarios. High end-to-end delays were shown by DSR [10].

In comparison of DSDV and AODV routing protocols, it was concluded that AODV performs better than DSDV in terms of bandwidth as AODV do not contain routing tables so it has less overhead and consume less bandwidth while DSDV consumes more bandwidth [18].

Location Aided Routing (LAR1), DSR and AODV, the three on demand protocols for ad hoc networks were compared and following observations made were that LAR1 for high density performed well and show good results in energy consumption in large networks whereas in case of low scale networks DSR shows better energy consumption than others [20].

# CHAPTER 2: WIRLESS SENSOR NETWORK

## 2.1 INTRODUCTION:

Wireless sensor networks are composed of independent sensor nodes deployed in an area working collectively in order to monitor different environmental and physical conditions such as motion, temperature, pressure, vibration sound or pollutants. The main reason in the advancement of wireless sensor network was military applications in battlefields in the beginning but now the application area is extended to other fields including industrial monitoring, controlling of traffic and health monitoring [36]. Different constraints such as size and cost results in constraints of energy, bandwidth, memory and computational speed of sensor nodes.

A wireless sensor node in a network consists of the following components:

- Microcontroller.
- Radio transceiver.
- Energy source (battery).

WSN have the following distinctive characteristics [36]:

- They can be deployed on large scale.
- These networks are scalable; the only limitation is the bandwidth of gateway node.
- Wireless sensor networks have the ability to deal with node failures.
- Another unique feature is the mobility of nodes.
- They have the ability to survive in different environmental surroundings.
- They have dynamic network topology.

Further developments in this technology have led to integration of sensors, digital electronics and radio communications into a single integrated circuit (IC) package [33]. Generally wireless sensor network have a base station that communicates through radio connection to other sensor nodes. The required data collected at sensor node is processed, compressed and sent to gateway directly or through other sensor nodes.

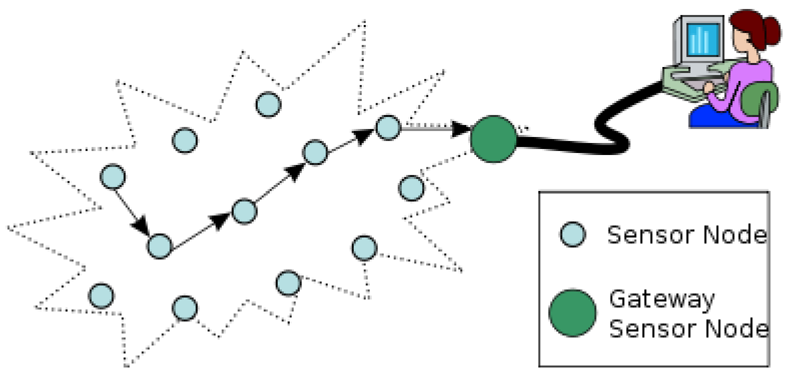



Figure 1: Wireless Sensor Network Architecture [36]

## 2.2 SENSOR NODE ARCHITECTURE:

A wireless sensor node is capable of gathering information from surroundings, processing and transmitting required data to other nodes in network. The sensed signal from the environment is analog which is then digitized by analog-to-digital converter which is then sent to microcontroller for further processing. The block diagram of a sensing node is shown in figure [2]. While designing the hardware of any sensor node the main feature in consideration is the reduction of power consumption by the node. Most of the power consumption is by the radio subsystem of the sensing node [33]. So the sending of required data over radio network is advantageous. An algorithm is required to program a sensing node so that it knows when to send data after event sensing in event driven based sensor model. Another important factor is the reduction of power consumption by the sensor which should be in consideration as well. During the designing of hardware of sensing node microprocessor should be allowed to control the power to different parts such as sensor, sensor signal conditioner and radio. The main functions of microprocessor among various functions are as follows [33]:

- Data collection management from other sensors.
- Power management functions are performed.
- Sensor data on physical radio layer interfacing.
- Radio network protocol management.

Depending on the needs of the applications and on sensors to be deployed, the block of signal conditioning can be replaced or re-programmed. Due to this fact a variety of different sensors with wireless sensing node are allowed for use. To acquire data from base station remote nodes uses flash memory.

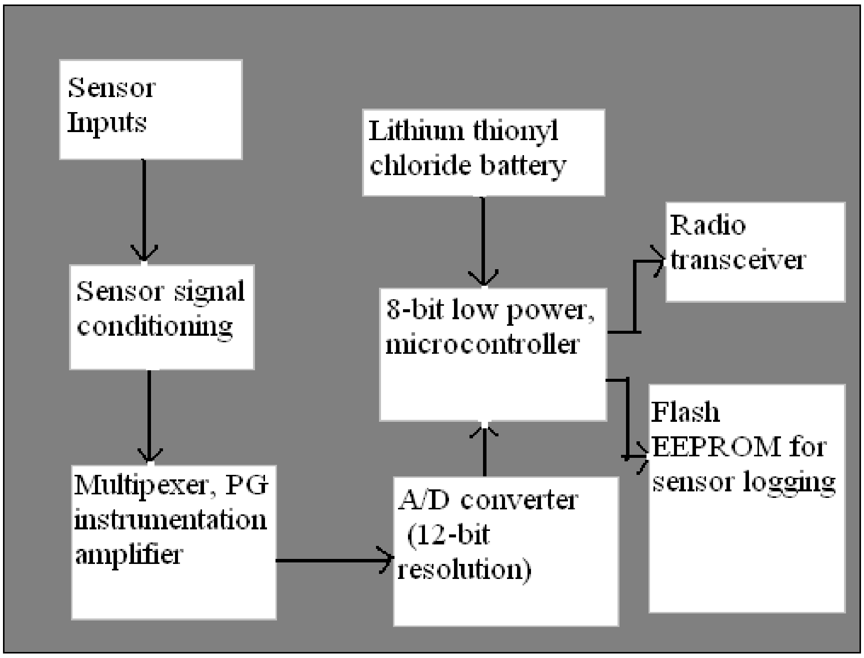



Figure 2: Block Diagram of functional Wireless Sensing Node [29]

## 2.3 SENSOR NODE COMPONENTS:

There are various sensor nodes having capabilities regarding power of microcontroller, radio and capacity of memory. Despite of the variances it can be said that there are four basic sub-systems of sensor nodes; computing subsystem, sensing subsystem, power subsystem and communication subsystem [24].

### 2.3.1 Controlling Component:

In order to control the components of the sensor nodes and perform the required computations this subsystem is responsible for it. There are two sub-units, storage unit and processor unit. There are different operational modes of processors in sensor nodes. They are either Idle, Active or in Sleep modes. In order to preserve power this is important, so processor operates when required.

### 2.3.2 Communication Component:

The sensor nodes due to this component interact with the base station and to the other nodes. Usually this subsystem is a radio of short range but other fields has also been explored like ultrasound, infrared communication and inductive fields [24]. The advantage of radio frequency communication for sensor nodes is that it is not limited by line of sight and low-power radio transceivers with data-rates and ranges depending on the applications are easily implemented with the help of current technology.

### 2.3.3 Power Component:

Power is supplied to sensor nodes by this sub-system in which a battery is contained. Every aspect of the network regarding communication algorithms, sensing devices, localization algorithms should be efficient in terms of energy usage because replacement or recharging of battery is unfeasible in case where large numbers of sensor nodes are deployed. For recharging of battery onsite a power generator should be included.

### 2.3.4 Sensing Component:

In this sub-system the physical phenomena is converted to electrical signals by sensor transducers. So the outside world is linked to this subsystem. Sensors may have analog or digital output. There should be an analog to digital converter (ADC) incase if output is analog.

## 2.4 WSNs COMPARISON WITH MANETs:

In general wireless communication is classified into two main categories as mentioned before. These two categories are infrastructure based and infrastructure less and further infrastructure less networks are divided into two groups which are WSNs and MANETs [41]. The two networks are equivalent but built for different purposes. Both groups of wireless networks are self organizing networks where nodes are connected by wireless links, can move freely and the topology of the network changes constantly. The two groups of wireless networks have similarities as well as differences.

Similarities are:

- The two groups are distributed infrastructure less wireless networks.
- The use of intermediate relay nodes may involve for routing between two nodes, called multi hop routing.
- WSNs and MANETs, both groups are usually powered by battery and there is a big concern on minimizing power consumption.
- Because of the distributed nature of both networks self self-management is necessary.
- These networks use a wireless channel that is prone to interference by other radio technologies operating in the same frequency.

Differences are:

- Sensor networks focus on interaction with environment rather than focus on interaction with human whereas MANETs nodes are always in touch by human beings (e.g. laptop computers, PDAs, mobile radio terminals etc).
- MANETs are used for data and information exchange whereas sensor network nodes are usually embedded in the environment to sense some phenomenon and possibly actuate upon it [41].
- The density of deployment as well as the number of nodes in sensor networks can be orders of magnitude higher than in MANETs.
- The nodes in WSN may fail frequently due to their application nature, e.g. fire or on top of volcano. The mechanisms of reconfiguration will have to be used in these cases, so that network design should consider that nodes are prone to failure [41].
- In majority of applications, nodes in WSN remain static and in rare cases nodes in WSN are mobile, so some issues that are important in MANETs may not be of great importance in WSNs.
- Instead of the ID (e.g., address) of the individual nodes, location becomes a more important attribute for some applications. Communication paradigms are affected the application-specific nature of sensor networks [41].
- In MANETs many users can participate at a time whereas WSNs are mostly deployed and owned by a single user (at BS).
- To avoid the problem of maximum energy usage that may occur around a BS as in WSNs data comes from multiple nodes to the BS, some techniques and methods should be employed.

## 2.5 WSN APPLICATIONS:

WSNs have a wide variety of applications such as environmental monitoring and tracking. The particular applications are tracking of object, monitoring of health, fire detection and control of nuclear reactor. Deployment of sensor nodes in an area for collection of data is a typical application of WSN.

### 2.5.1 Monitoring of Area:

The common application of WSNs is monitoring of area. The events occurring in the environment are monitored by the sensor nodes deployed in the region. Monitoring of area involves detecting enemy intrusion by a large number of sensor nodes deployed over a battlefield. The detected events are then reported to base station for some action.

### 2.5.2 Monitoring of Environment:

A large scale wireless sensor networks are deployed for environmental monitoring including forest fire/flood detection, monitoring of the condition of soil and space exploration [41].

### 2.5.3 Applications in Commercial Area:

Wireless Sensor Networks have a lot of applications concerning commercial are such as office/home smart environments, health applications, controlling of environment in buildings, monitoring of industrial plants.

### 2.5.4 Tracking Applications:

In tracking area, WSN applications include targeting in intelligent ammunition and tracing of doctors and patients inside a hospital. A search and rescue system is designed using connectionless sensor based tracking system using witness (CenWits) [32]. Sensors with different radio frequencies and processing devices are used. This rescue system consists of mobile sensors, access points and GPS receivers. The search and rescue efforts are concentrated on an approximate small area with the help of CenWits.

# CHAPETR 3 ROUTING PROTOCOLS IN WSN:

## 3.1 INTRODUCTION [26]:

Due to the difference of wireless sensor networks from other contemporary communication and wireless ad hoc networks routing is a very challenging task in WSNs. For the deployed sheer number of sensor nodes it is impractical to build a global scheme for them. IP-based protocols cannot be applied to these networks. All applications of sensor networks have the requirement of sending the sensed data from multiple points to a common destination called sink. Resource management is required in sensor nodes regarding transmission power, storage, on-board energy and processing capacity.

There are various routing protocols that have been proposed for routing data in wireless sensor networks due to such problems. The proposed mechanisms of routing consider the architecture and application requirements along with the characteristics of sensor nodes. There are few distinct routing protocols that are based on quality of service awareness or network flow whereas all other routing protocols can be classified as hierarchical or location based and data centric.

The routing protocols which are data centric are based on query and depend on naming of desired data due to which many redundant transmissions are eliminated. The clustering of nodes in hierarchical routing protocol aims to save the energy by cluster heads that can do some aggregation and reduction of data. The routing protocols that are location based relay data to the desired destination instead of the whole network by utilizing positioning information. In some applications there is requirement of QoS along with the routing functions that are based on network flow modeling are included in the last category.

The other factors which effect routing design are the overhead and data latency. Data latency during network latency is caused by data aggregation and multi-hop relays due to which real-time data is infeasible in these protocols. While in some protocols there are excessive overheads created for the implementation of their algorithm which are not suitable for the networks that energy constrained. So data latency and overhead are the two important factors which affect the designing of routing protocols of WSN.

## 3.2 ROUTING PROTOCOLS CLASSIFICATION IN WSN [26]:

### 3.2.1 Data Centric Protocols:

The sink is used to send queries to certain regions and waits for data from sensors that are located in selected region in data centric routing protocols. As queries are used for the requested data, attribute-based naming in order to specify the properties of data is necessary. The first data centric routing protocol between nodes that considers data negotiation is Sensor protocol for information via negotiation (SPIN) for energy saving and elimination of redundant data. A breakthrough in data centric routing is Directed Diffusion that has been developed.

#### 3.2.1.1 Flooding and Gossiping:

In order to relay data in sensor networks without the need for any routing algorithms and topology maintenance the two classical methods are flooding and gossiping. A sensor node broadcast a data packet to all its neighbors and this process continues until destination is found and this technique is known as flooding where as in gossiping packet is not sent to all neighboring nodes but to selected random neighbors which selects another random neighbor and in this packet arrives at the destination.

#### 3.2.1.2 Sensors Protocols for information via negotiation:

The key feature of SPIN is that meta-data before transmission are exchanged between sensors through data advertisement mechanism. The new data is advertised by each sensor node to its neighbors and the interested neighbors which do not have the data send a request message in order to retrieve data. The classic problems of flooding are solved by SPIN’s meta-data negotiation.

#### 3.2.1.3 Directed Diffusion:

In this protocol the idea is to diffuse data by using naming scheme for the data through sensor nodes. To get rid of unnecessary operations of network layer routing in order to save energy is the main idea behind using such a scheme.

### 3.2.1.4 Energy-Aware Routing:

To increase the lifetime of a network the authors Shah and Rabaey proposed to use set of sub-optimal paths occasionally. Depending on the energy consumption of the path, these paths are chosen by means of probability functions. The approach is concerned with the main metric of network survivability. This protocol has the following phases:

- Setup phase.
- Data communication and route maintenance phase.

### 3.2.1.5 Rumor Routing:

Another variation of Directed Diffusion is the rumor routing and is proposed for contexts in which geographic routing criteria are not applicable. The query is flooded in the entire network in Directed Diffusion when there is no geographic criterion to diffuse tasks. Thus the use of flooding is unnecessary in cases where a little amount of data is requested.

### 3.2.1.6 Gradient-based Routing:

Gradient based routing (GBR) proposed by Schurgers is a slightly changed version of Directed Diffusion. In this routing scheme the idea is to maintain number of hops when the interest is diffused through the network. So minimum numbers of hops are discovered by each hop to sink that are called node's height. The gradient is the difference between node's height and that of its neighbor on that link. With the largest gradient a packet is forwarded on the link.

### 3.2.1.7 CADR:

In order to maximize the energy gain and minimizing the bandwidth and latency, the idea is to query sensors and route data in network. Information-driven sensor querying (IDQS) and constrained anisotropic diffusion routing are the two proposed techniques. The information/cost objective is evaluated by each node in CADR and data based on local information/cost gradient is routed.

### 3.2.1.8 COUGAR:

Architecture for sensor database system is proposed by COUGAR where a leader node is selected by sensor nodes to transmit data to sink and perform aggregation. Declarative queries usage is the main idea in order to abstract query processing from the network layer functions in order to save energy by selection of relevant sensors etc.

### 3.2.2 Hierarchical Protocols:

The nodes in hierarchical routing are involved in multi-hop communication within a particular cluster in order to efficiently maintain the energy consumption and the transmitted messages to the sink are decreased by performing data aggregation and fusion. The formation of cluster is typically based on sensor's proximity to cluster and energy reserve of sensors. Networking clustering has been pursued in some routing approaches in order to allow the system to cope with additional load and enable to cover large area of interest without degrading the service. Following are the hierarchical routing protocols:

- LEACH.
- PEGASIS and Hierarchical-PEG ASIS.
- TEEN and APTEEN.
- Energy-aware routing for cluster-based sensor networks.
- Self-organizing protocol

### 3.2.3 Location-based Protocols:

Location information is required for nodes in sensor network in most of the routing protocols. Energy consumption is estimated by calculating the distance between two particular nodes for which location information is required. As there are no schemes like IP-addresses, data is routed in an energy efficient way by utilizing location information. By using the location of sensors the query is diffused only in particular region which is known to be sensed, significant number of transmissions will be eliminated. The protocols are designed primarily for MANETs considering the mobility of nodes whereas they are also applicable to sensor networks in which nodes are fixed or mobility is less. Location–based protocols are as follows:

- Minimum energy communication network (MECN) and small minimum communication energy network (SMECN).
- Geographic Adaptive Fidelity (GAF).
- Geographic and Energy aware routing (GEAR).

### 3.2.4 Network flow and QoS-aware Protocols:

Among the various routing protocols proposed for sensor networks most of them fit in the classification however some pursue somewhat different approach such as QoS and network flow. While setting up the paths in sensor network end-to-end delay requirements are considered in QoS-aware protocols. These protocols are:

- Maximum lifetime energy routing.
- Maximum lifetime data gathering.
- Minimum cost forwarding.
- Sequential assignment routing (SAR).
- Energy-aware QoS routing protocol.
- SPEED.

## 3.3 AODV ROUTING PROTOCOL [25]:

### 3.3.1 Introduction:

There are two types of routing protocols which are reactive and proactive. In reactive routing protocols the routes are created only when source wants to send data to destination whereas proactive routing protocols are table driven. Being a reactive routing protocol AODV uses traditional routing tables, one entry per destination and sequence numbers are used to determine whether routing information is up-to-date and to prevent routing loops.

The maintenance of time-based states is an important feature of AODV which means that a routing entry which is not recently used is expired. The neighbors are notified in case of route breakage. The discovery of the route from source to destination is based on query and reply cycles and intermediate nodes store the route information in the form of route table entries along the route. Control messages used for the discovery and breakage of route are as follows:

- Route Request Message (RREQ)
- Route Reply Message (RREP)
- Route Error Message (RERR)
- HELLO Messages.

#### 3.3.1.1 Route Request (RREQ):

A route request packet is flooded through the network when a route is not available for the destination from source. The parameters are contained in the route request packet are presented in the following table:

| Source Address | Request ID | Source Sequence Number | Destination Address | Destination Sequence Number | Hop Count |
|---|---|---|---|---|---|

Table 1: Route Request Parameters [25].

A RREQ is identified by the pair source address and request ID, each time when the source node sends a new RREQ and the request ID is incremented. After receiving of request message, each node checks the request ID and source address pair. The new RREQ is discarded if there is already RREQ packet with same pair of parameters.

- A node that has no route entry for the destination, it rebroadcasts the RREQ with incremented hop count parameter.

- A route reply (RREP) message is generated and sent back to source if a node has route with sequence number greater than or equal to that of RREQ.

#### 3.3.1.2 Route Reply (RREP):

On having a valid route to the destination or if the node is destination, a RREP message is sent to the source by the node. The following parameters are contained in the route reply message:

| Source Address | Destination Address | Destination Sequence Number | Hop Count | Life Time |
|---|---|---|---|---|

Table 2: Route Reply Parameters [25].

#### 3.3.1.3 Route Error Message (RERR):

The neighborhood nodes are monitored. When a route that is active is lost, the neighborhood nodes are notified by route error message (RERR) on both sides of link.

#### 3.3.1.4 Hello Messages:

The HELLO messages are broadcasted in order to know neighborhood nodes. The neighborhood nodes are directly communicated. In AODV, HELLO messages are broadcasted in order to inform the neighbors about the activation of the link. These messages are not broadcasted because of short time to live (TTL) with a value equal to one.

### 3.3.2 Discovery of Route:

When a source node does not have routing information about destination, the process of the discovery of the route starts for a node with which source wants to communicate. The process is initiated by broadcasting of RREQ as shown in figure 3. On receiving RREP message, the route is established. If multiple RREP messages with different routes are received then routing information is updated with RREP message of greater sequence number.

#### 3.3.2.1 Setup of Reverse Path:

The reverse path to the node is noted by each node during the transmission of RREQ messages. The RREP message travels along this path after the destination node is found. The addresses of the neighbors from which the RREQ packets are received are recorded by each node.

#### 3.3.2.2 Setup of Forward Path:

The reverse path is used to send RREP message back to the source but a forward path is setup during transmission of RREP message. This forward path can be called as reverse to the reverse path. The data transmission is started as soon as this forward path is setup. The locally buffered data packets waiting for transmission are transmitted in FIFO-queue.

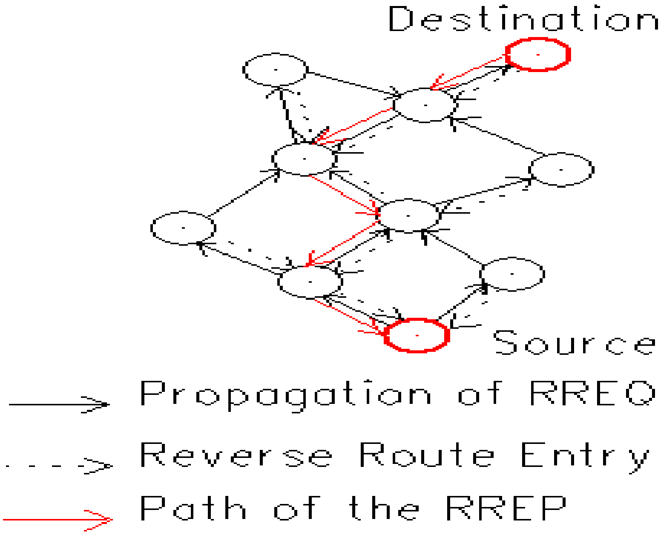



Figure 3: Discovery of Route [28]

# 3.4 DSR ROUTING PROTOCOL [39]:

## 3.4.1 INTRODUCTION:

Dynamic Source Routing (DSR) protocol is specifically designed for multi-hop ad hoc networks. The difference in DSR and other routing protocols is that it uses source routing supplied by packet's originator to determine packet's path through the network instead of independent hop-by-hop routing decisions made by each node.

The packet in source routing which is going to be routed through the network carries the complete ordered list of nodes in its header through which the packet will pass. Fresh routing information is not needed to be maintained in intermediate nodes in design of source routing, since all the routing decisions are contained in the packet by themselves.

## 3.4.2 DSR ROUTE DISCOVERY AND MAINTENANCE:

DSR protocol is divided into two mechanisms which show the basic operation of DSR. The two mechanisms are:

- Route Discovery.
- Route Maintenance.

When a node S wants to send a packet to destination D, the route to destination D is obtained by route discovery mechanism. In this mechanism the source node S broadcasts a ROUTE REQUEST packet which in a controlled manner is flooded through the network and answered in the form of ROUTE REPLY packet by the destination node or from the node which has the route to destination. The routes are kept in Route Cache, which to the same destination can store multiple routes. The nodes check their route cache for a route that could answer the request before repropagation of ROUTE REQUEST. The routes that are not currently used for communication the nodes do not expend effort on obtaining or maintaining them i.e. the route discovery is initiated only on-demand.

The other mechanism is the route maintenance by which source node S detects if the topology of the network has changed so that it can no longer use its route to destination. If the two nodes that were listed as neighbors on the route moved out of the range of each other and the link becomes broken, the source node S is notified with a ROUTE ERROR packet. The source node S can use any other known routes to the destination D or the process of route discovery is invoked again to find a new route to the destination.

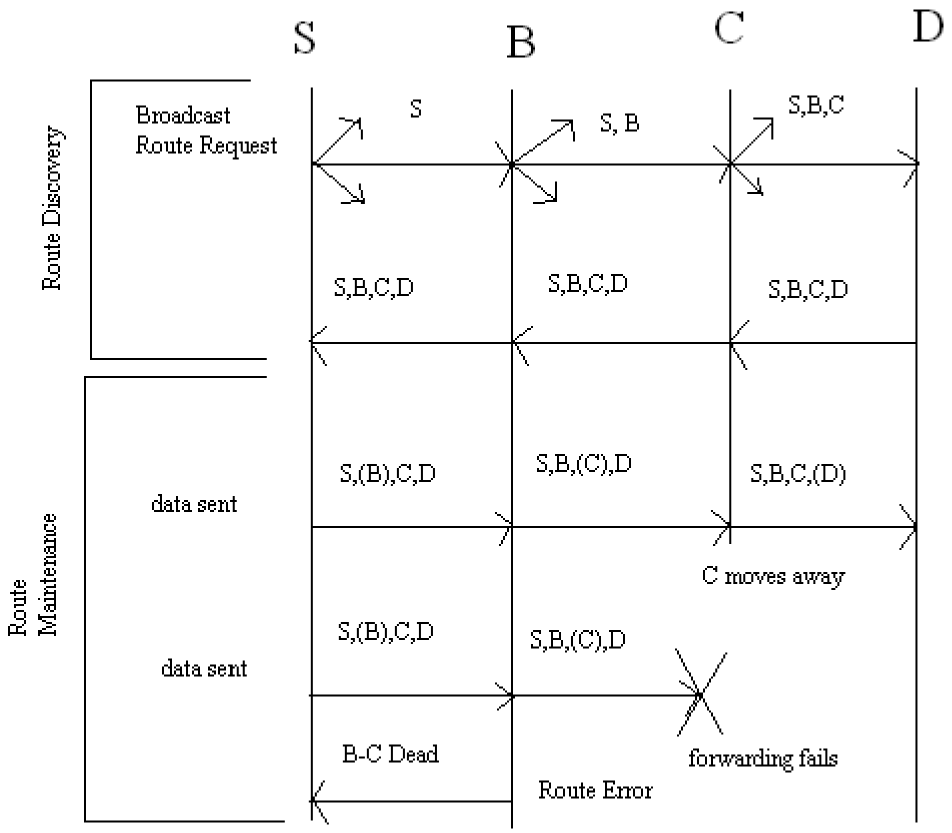



Figure 4: DSR Route discovery and maintenance [39]

# CHAPTER 4 NETWORK SIMULATION:

There are many simulation environments/network simulators available for simulation of a network. There are some network simulators that require commands or scripts while other simulators are GUI driven. In network simulation the behavior of network models is extracted from information provided by network entities (packets, data links, and routers) by using some calculations. In order to assess the behavior of a network under different conditions different parameters of the simulator (environment) are modified.

## 4.1 NETWORK SIMULATOR:

### 4.1.1 OPNET Tool:

The process of designing of different networks, applications, devices and protocols is accelerated by OPNET. The simulated networks can be analyzed for different technological impact designs on end-to-end behavior. OPNET enables designing of different networks and technologies in a development environment that includes TCP, MPLS, IPV6 and several others. The simulator has the key features involving discrete event simulation engine, hierarchical modeling environment, object-oriented modeling, integrated, GUI-based debugging and analysis and others [35].

### 4.1.2 Network Design:

To perform this simulation the network designed is wireless local area network (WLAN) consisting of basic network entities as sensor nodes (mobile) and base station. To configure the application and for mobility of nodes profile configuration, application configuration, and mobility configuration objects are included as shown in figure according to scenario. IN the first scenario there are then sensor nodes and the parameter end-to-end delay and throughput for both the routing protocols AODV and DSR are analyzed. In the second scenario the number of nodes is increased to twenty and again the behavior of the protocols with the same performance metrics is analyzed. Finally there are thirty five sensor nodes and the two protocols are evaluated in order to determine which one works the best under the required circumstances. All the networks are modeled on area of 500X500 under high network load. The simulation time is set for 1800 secs. The entity base station in the network communicates with nodes in the network and the outer world. The nodes communicate with each other on demand basis relying on the type of application. The type of application that will run on base station and nodes is FTP.

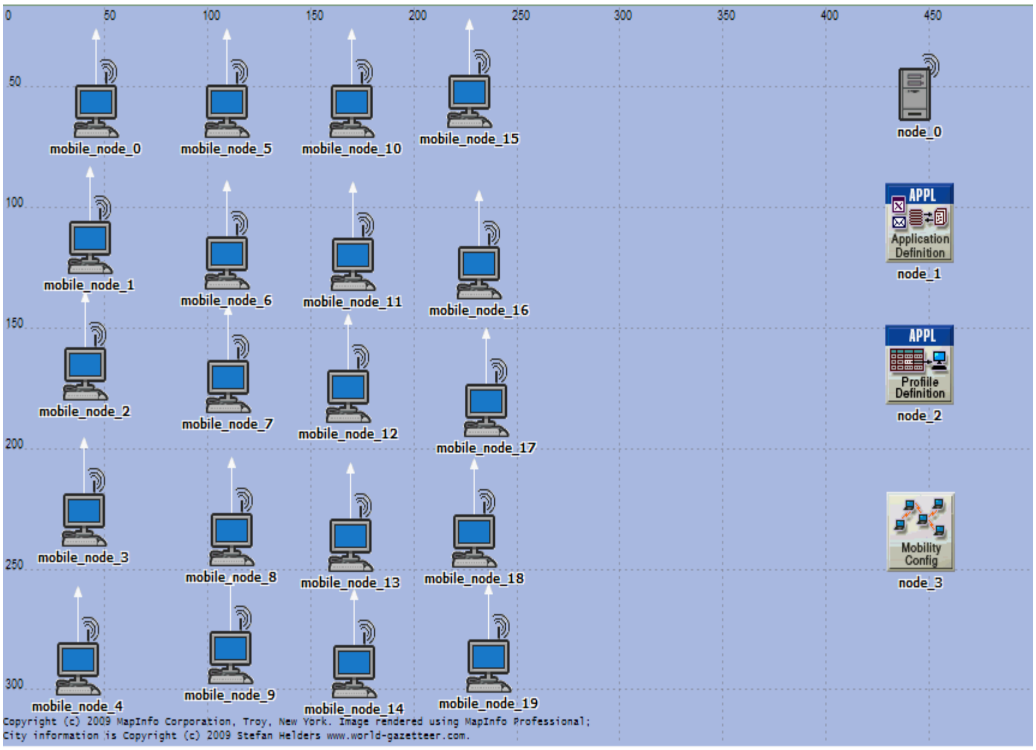



Figure 5: Wireless Sensor Network

## 4.2 SIMULATION PARAMETERS:

The network designed consists of basic network entities with the simulation parameters presented in table 3.

| SIMULATION PARAMETERS | |
|---|---|
| Examined Protocols | DSR and AODV |
| Simulation Time | 1800 seconds |
| Simulation Area (m x m) | 500 x 500 |
| Nodes in all scenarios | 10, 20 and 35 |
| Traffic Type | FTP |
| Performance Parameters | Throughput and Delay |
| Type of Nodes | Mobile |
| Mobility (m/s) | 10 meter/second |
| Packet size | 512 byte |

Table 3: Simulation Parameters

# CHAPTER 5: ANALYSIS AND RESULTS:

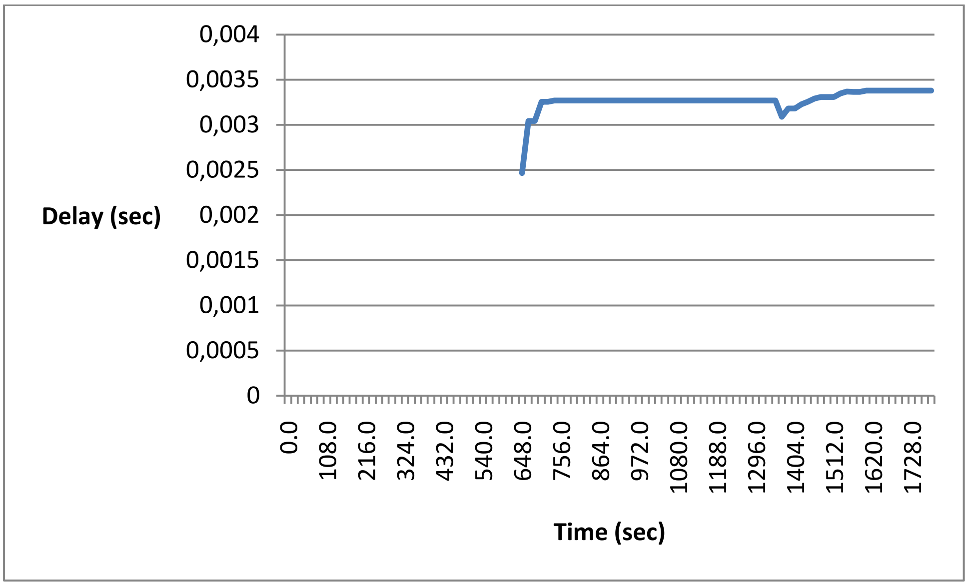
The results of our simulations are analyzed and discussed in this chapter. The results are analyzed and discussed in different scenarios having networks of ten, twenty and thirty five mobile nodes for monitoring applications. These different networks having mobile nodes represent monitoring applications in WSN. In the first scenario, a network with ten sensor nodes, the performance evaluation of the AODV and DSR routing protocols with the performance parameter of end-to-end delay is compared. After performing this simulation then the two protocols are analyzed in different scenarios by increasing the number of nodes from ten to twenty and then to thirty five making the network more complex and then comparison of the two protocols with the help of same performance parameter of end-to-end delay is analyzed. The same procedure is repeated for the other parameter throughput.

## 5.1 Parameters:

All the three scenarios are aimed for the monitoring of critical conditions. The participating nodes in all the three scenarios were considered as mobile and submitting nodes communicating to sink at regular intervals. In the first scenario the number of sensor nodes deployed was ten having an environment size of 500x500. For all scenarios the application used was FTP with packet size 512 bytes with packet rate of four packets/sec. The scenario is simulated for 1800 seconds (30 minutes).In second scenario the network is scaled by increasing the number of nodes to twenty and performance of the protocols is again analyzed. In the final scenario the network is made more complex by scaling the network with sensor nodes up to thirty five. In these scenarios the parameter end-to-end delay of the two protocols DSR and AODV is analyzed for the designed network.

## 5.2 End-to-End Delay:

The term end-to-end delay refers to the time taken by a packet to be transmitted across a network from source node to destination node that includes all possible delays caused during route discovery latency, retransmission delays at the MAC, propagation and transfer times. The protocol which shows higher end-to-end delay it means the performance of the protocol is not good due to network congestion.



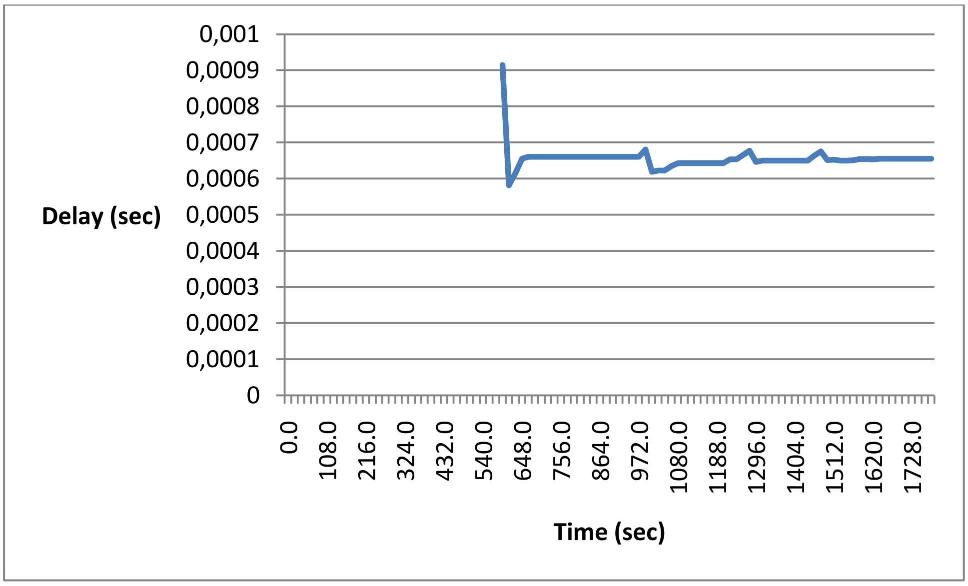
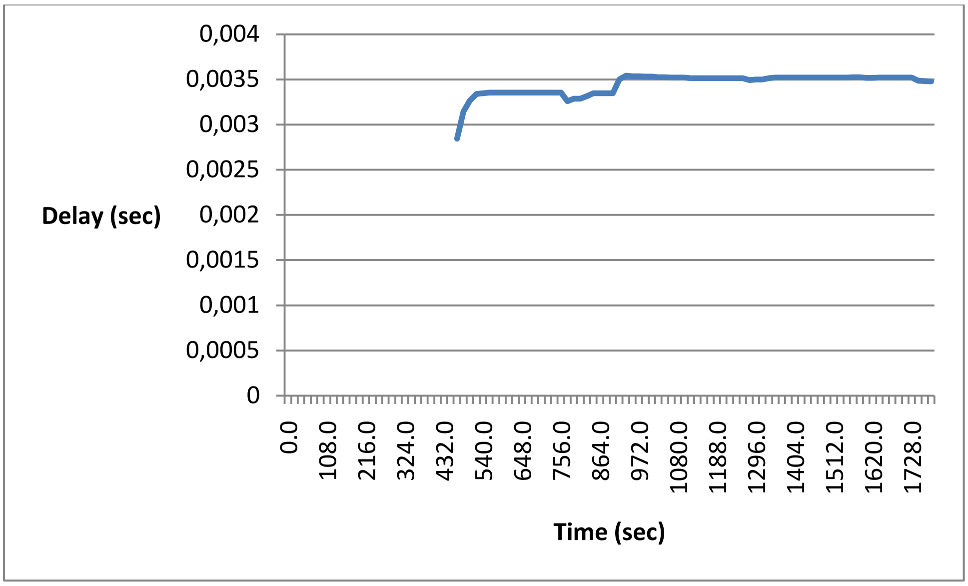




Figure 6: End-to-End Delay of DSR vs. AODV for 10 nodes



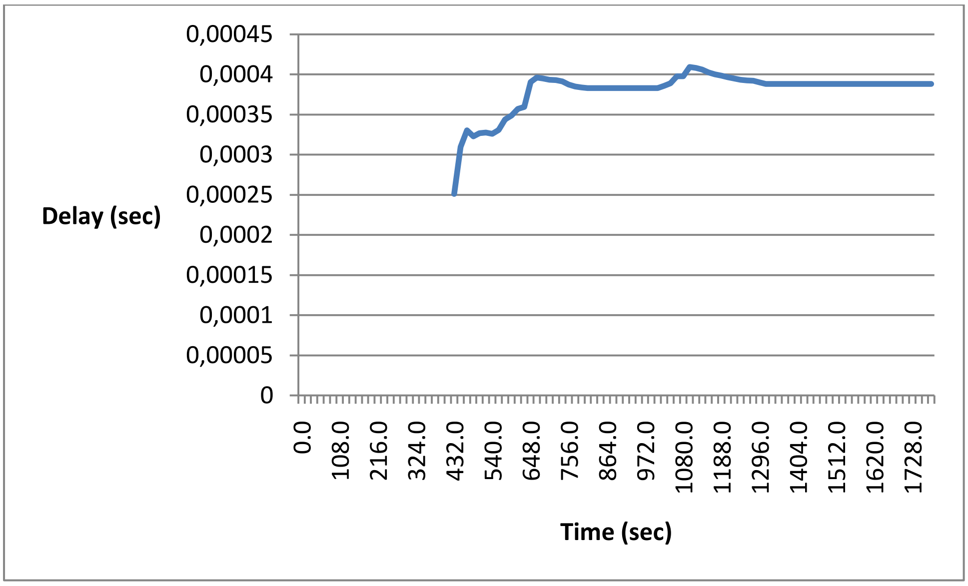
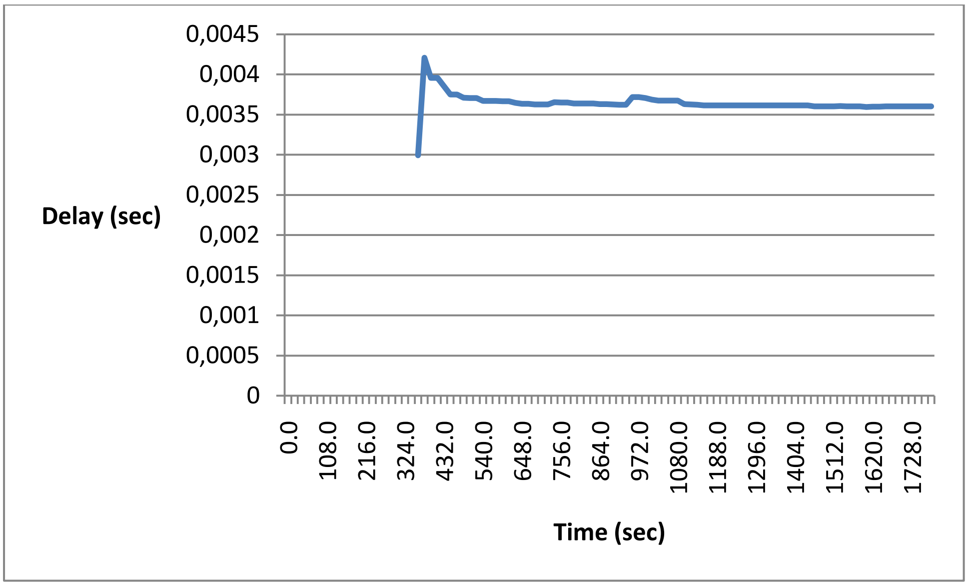




Figure 7: End-to-End delay of DSR vs. AODV for 20 nodes



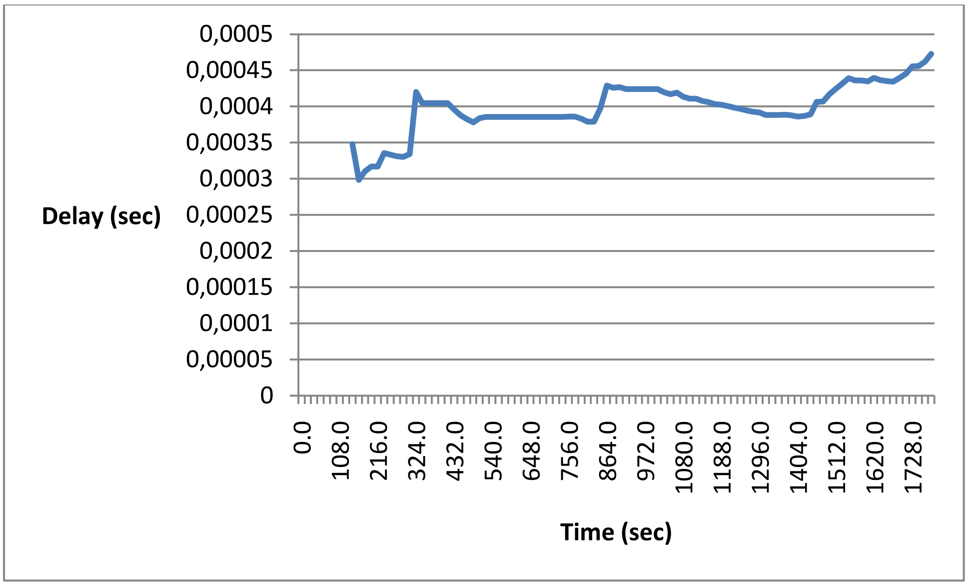
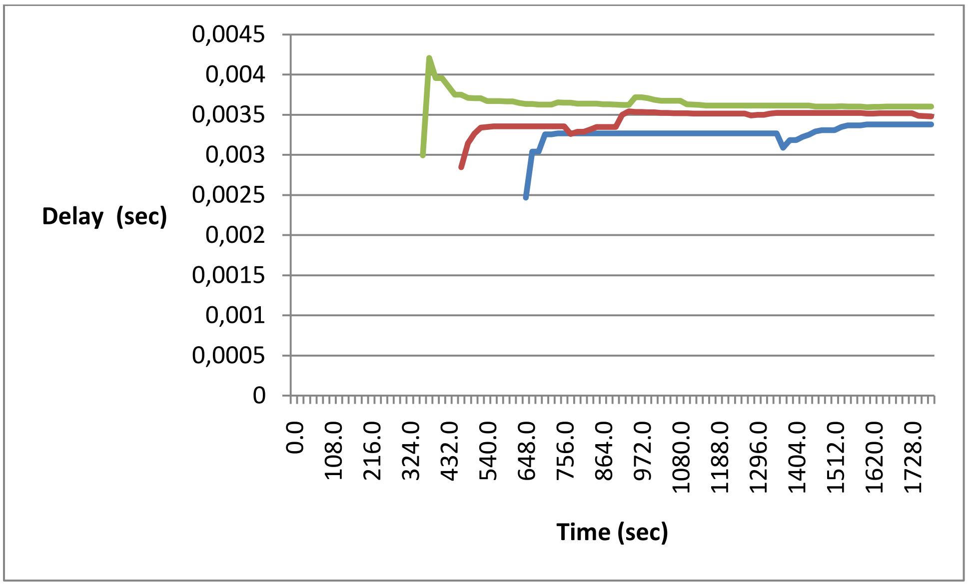




Figure 8: End-to-End Delay of DSR vs. AODV for 35 nodes



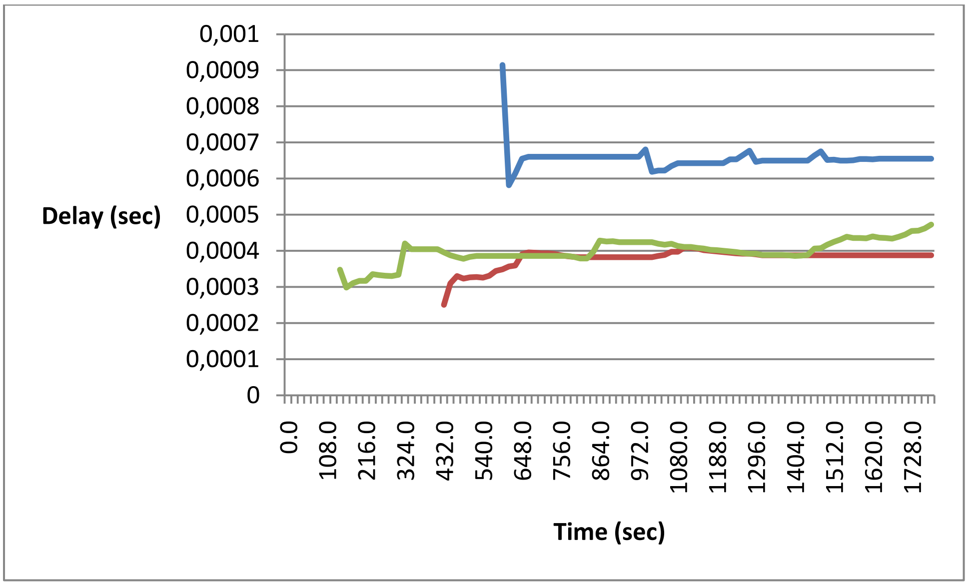




Figure 9: End-to-End Delay of DSR vs. AODV

### 5.2.1 End-to-End Delay in small, large and very large network:

The end-to-end delay characteristics of the two protocols are shown in figure 6, 7, 8 and in figure 9, a comparison of all the three scenarios is shown. In AODV routing protocol a route is established only when required by the source node for transmission of data packets. To identify the most recent path it employs destination sequence numbers. A major difference between DSR and AODV stems out from the fact that in AODV, the source node and the intermediate nodes store the next-hop information corresponding to each flow for data packet transmission; however DSR uses source routing in which a data packet carries the complete path to be traversed. The source node floods the Route Request packet in an on-demand routing protocol when a route is not available for the desired destination but in other on-demand routing protocols and AODV a major difference is that it uses a destination sequence number (DestSeqNum) to determine an up-to-date path to destination. So, in AODV the route is established on demand and destination sequence numbers are used to find the latest route to the destination and connection setup delay is lower. Refer to figure [6], figure [7] and figure [8].

As AODV and DSR are both reactive routing protocols which in the beginning take some time to establish route from source to destination so the delay starts at different times in all the three scenarios, once the route is established. In small network of ten sensor nodes the end-to-end delay in AODV is less and varying than DSR which shows a consistent and higher end-to-end delay. In the beginning the delay in AODV falls down a certain level after which it increases for some time and then remains between two levels with minor spikes in the middle. When the network is scaled by increasing the number of nodes to twenty and then to thirty five, the performance of AODV improves and show low end-to-end delay while the delay in DSR increases. DSR suffers a significant degradation in its end-to-end delay. The reason of degradation in the end-to-end delay of DSR at large number of nodes is attributed to its route discovery process. As AODV replies to the first arrived RREQ packet and discards other RREQs which arrive later from other sources which automatically favors the least congested route instead of the shortest path. While DSR replies to all the RREQs that arrived and it will be difficult for the protocol to select the least congested path which results in increasing delay of packets. In AODV hop-by-hop initiation helps in reduction of end-to-end delay.

The end-to-end delay response of the DSR is more consistent and larger than AODV with the growth of the network. The routing protocol DSR uses cached routes and more often, sending of traffic onto stale routes, causes retransmissions and leads to excessive delays. In networks with high traffic sources the increased number of cached routes worsens the delay. DSR tries to minimize the effect of stale routes by use of multiple paths.

As in the case of small network of ten nodes the delay in DSR starts at 0.0025 seconds and then increases till 0.0032 seconds and remain constant for 10 minutes. After 10 minutes it shows a minor spike and varies with a little increase for the rest of the time. Whereas with the increase of the nodes density the delay in DSR increases and starts at 0.0028 seconds which after increasing to 0.0035 seconds remains constant for few minutes and then a minor spike occurs after which it remains constant for the rest of the time. The delay pattern for 20 nodes in DSR is similar to the delay pattern for 10 nodes. When the network is made more complex by increasing the nodes to 35, a jump in the delay from 0.0030 seconds to 0.0042 seconds in the beginning occurs, which shows a consistent nature after a decrease close to 0.0036 seconds with a minor spike in the middle. However in case of AODV, all the three scenarios show a varying nature and improvement in delay with the increase in nodes density. In case of networks having nodes 20 and 35 the delay at few stages compete with each other but the delay in case of 35 nodes still remains slightly higher than the delay in network of 20 nodes.

In this subsection we have observed that AODV had an improved end-to-end delay as the network grew whereas DSR had a consistent end-to-end delay and suffered more delay as the network grew larger at higher loads due to increase in route discovery requests.

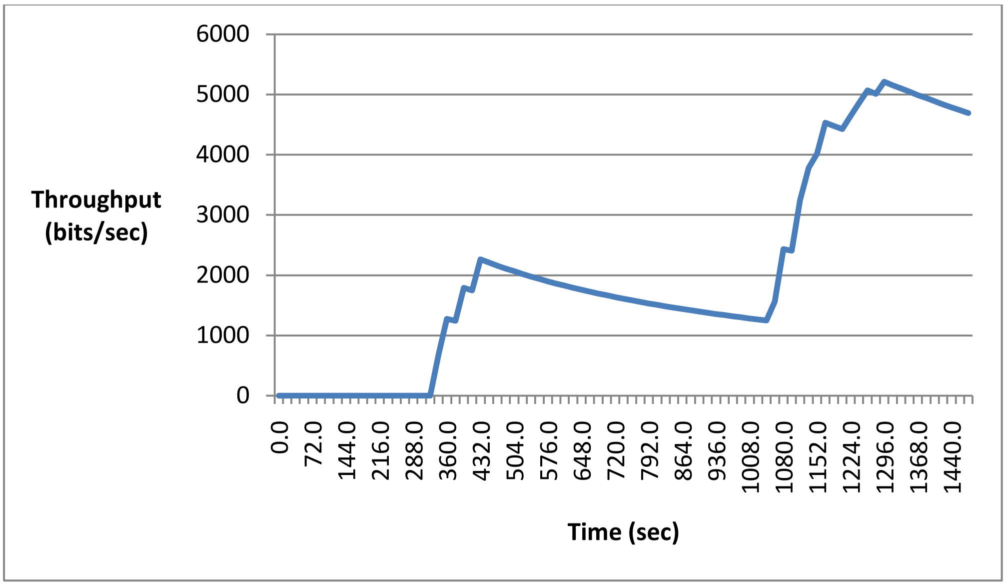
## 5.3 THROUGHPUT:

Throughput is the ratio of the total amount of data that a receiver receives from a sender to a time it takes for receiver to get the last packet. A low delay in the network translates into higher throughput. Delay is one of the factors effecting throughput, other factors are routing overhead, area and bandwidth which is not the scope of our thesis. Throughput gives the fraction of the channel capacity used for useful transmission and is one of the dimensional parameters of the network.

### 5.3.1 Throughput in small, large and very large network:

The performance of the routing protocols of the parameter throughput is shown in the figures 10, 11, 12 and 13. From the figures we observe that AODV by far outperforms DSR in all the three scenarios considered. In small network AODV marginally performs better than DSR. With the increase in the number of traffic sources, problems of congestion, hidden terminal and network degradation come more into effect. The protocols start to react differently due to these problems to the varying conditions and delay becomes an important factor in determining the network throughput. Refer to figure [11] and [12]. From the figures we observe that the performance of the AODV improves and is better than DSR as the network grows. From the observations it is concluded that AODV performs better and had a higher throughput in networks with relatively higher number of traffic sources and higher mobility.

For small network of ten sensor nodes, as the delay in AODV is less so its throughput rate reaches up to the peak of 6,500 bits/sec with passage of time while DSR gives the throughput rate which is above than 5,000 bits/sec with a decrease in throughput in the middle. As the delay in AODV improves (becomes less) with the increase in network, the throughput should also be increased and a clear difference in the throughput rate of DSR and AODV can be seen from the figure when the network is scaled up to the nodes of 35 and the throughput in AODV is 98,000 bits/sec whereas the throughput peak in DSR is just above 16,000 bits/sec and then decreases.



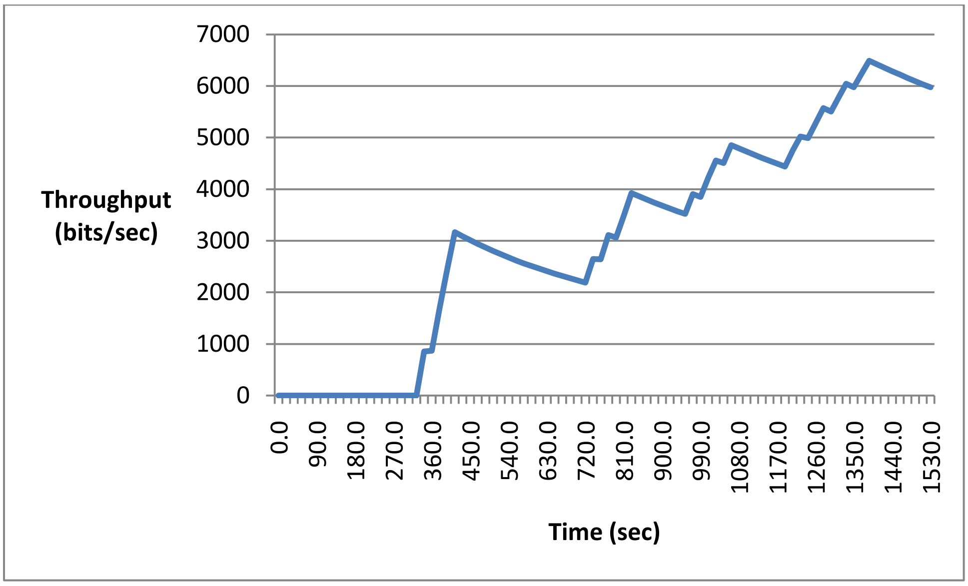
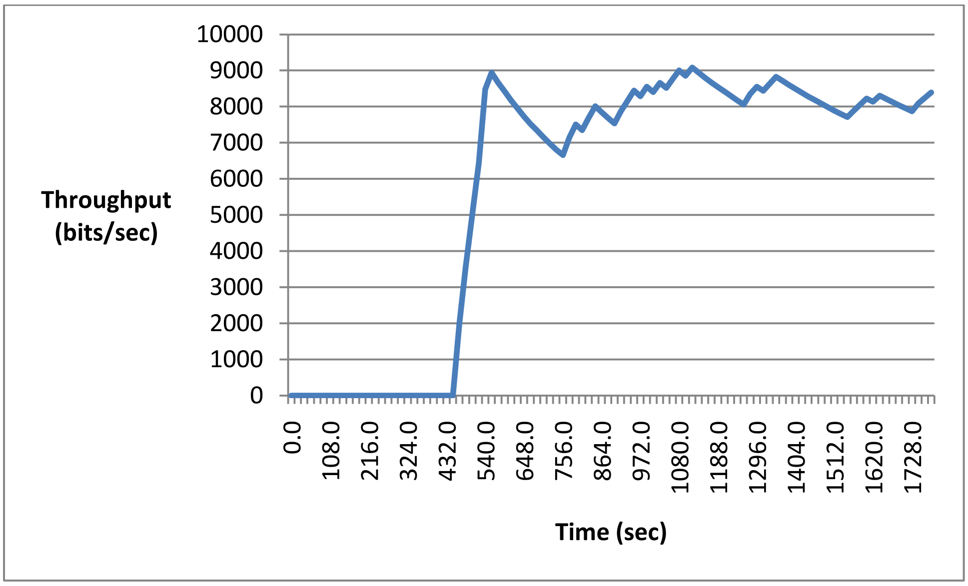




Figure 10: Throughput of DSR vs. AODV for 10 nodes



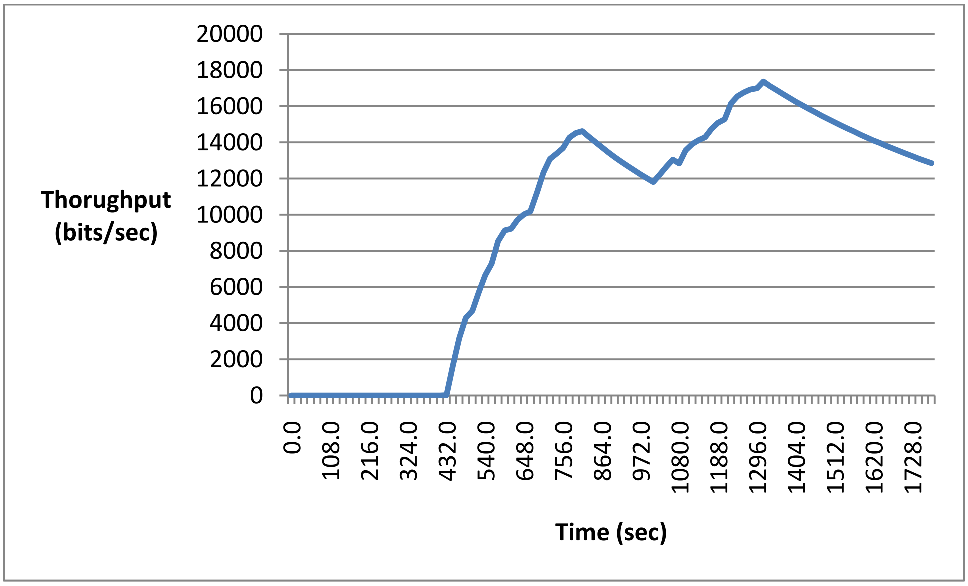
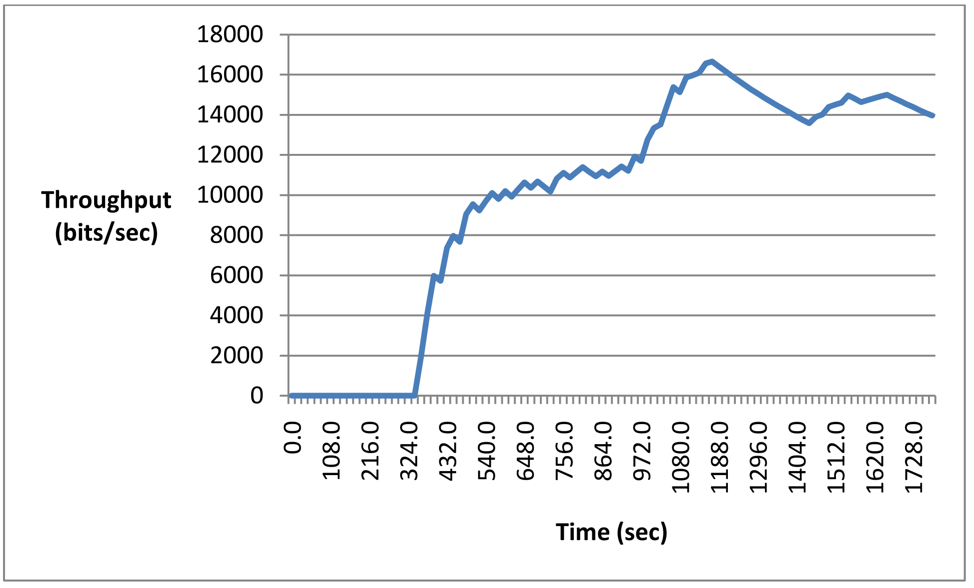




Figure 11: Throughput of DSR vs. AODV for 20 nodes



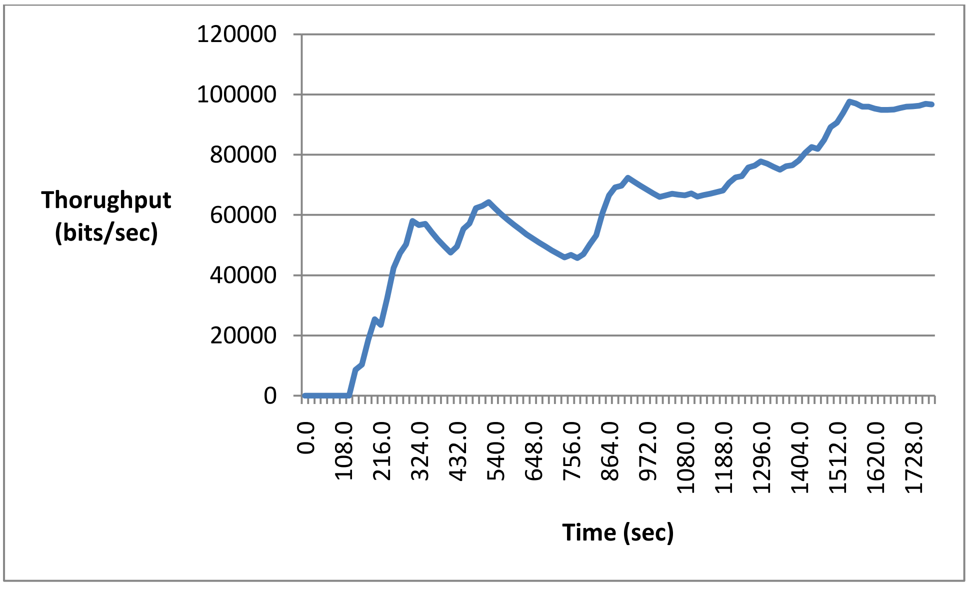
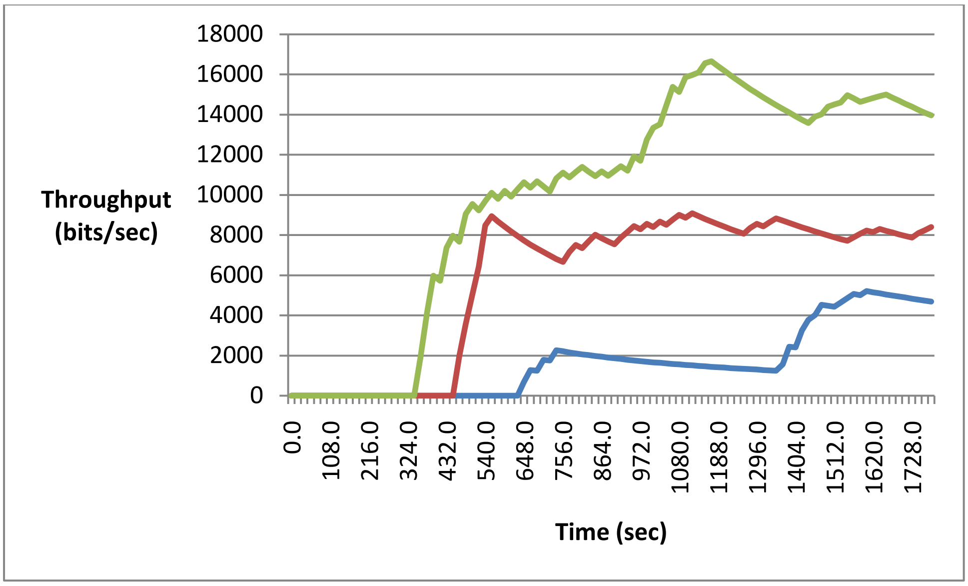




Figure 12: Throughput of DSR vs. AODV for 35 nodes



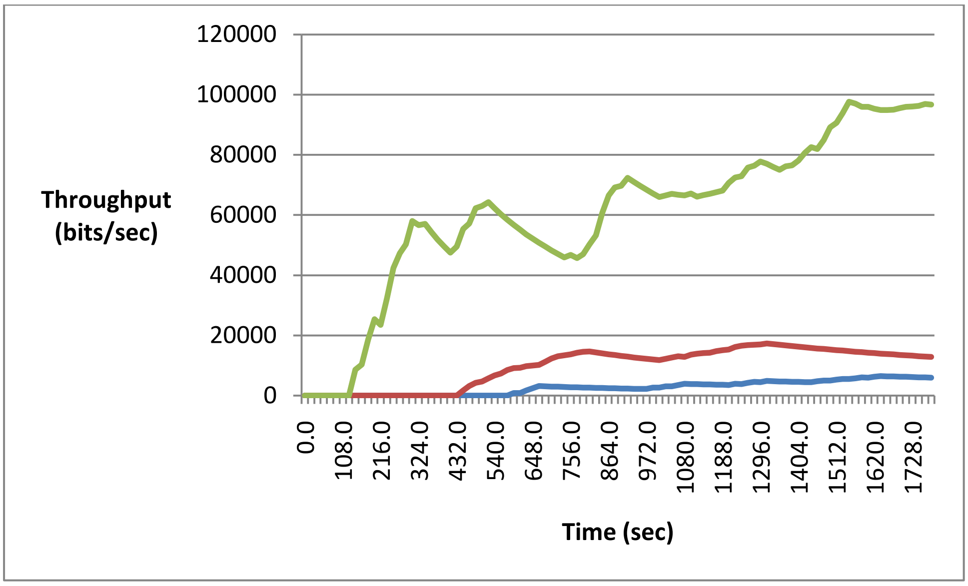




Figure 13: Throughput of DSR vs. AODV

The throughput in all the scenarios of AODV improves more than DSR with the passage of time. The delay in all the three scenarios of AODV improves with the increase in node density. In case of ten sensor nodes the delay in the beginning of figure [6] shows a big difference by falling from 0.0009 to 0.0006 so there is a rise in throughput as well, from figure [13] but the delay then shows a varying nature (increase and decrease) between 0.0006 and 0.0007 due to which throughput also shows a varying nature.

## 5.4 SUMMARY/OBSERVATION:

The simulated results are analyzed and discussed in this chapter. The different metrics of wireless sensor networks in different topologies and complexities have been discussed and simulated. The main metrics that are considered in this chapter are throughput and end-to-end delay. Mobile node network scenarios with scalability have been taken and simulated for a certain period of time. For the simulation purposes we have set certain parameters and simulated results are shown. The two different routing protocols AODV and DSR were implemented in each scenario in order to evaluate their performance for the designed network in the presence of scalability. The results based on graphs and tabulated values of each protocol according to the scenario wise observations are given below.

| Protocol | Metric | Small Network | Large Network | Verylarge network |
|---|---|---|---|---|
| DSR | Delay (sec) | 0.0033 | 0.0035 | 0.0042 |
| | Throughput (bit/sec) | 5,000 | 9,000 | 16,200 |
| AODV | Delay (sec) | 0.0009 | 0.0004 | 0.00047 |
| | Throughput (bits/sec) | 6,500 | 17,500 | 98,000 |

Table 4: Comparison of DSR and AODV

Our observations on the basis of tabulated results of each protocol for different metrics in both scenarios are as follows:

- In all the three scenarios of small, large and very large networks AODV gives considerably less delay as compared to DSR. AODV outperforms DSR with prominent difference in delay. In terms of delay the network size has an impact on both AODV and DSR performance.

- The throughput rate of AODV in small and large networks exceeds with a little margin than the throughput rate of DSR but in case of large networks the difference is prominent and AODV by far performs better than DSR.

## CONCLUSION and FUTURE WORK:

Our study in this thesis is the evaluation of the two routing protocols for their responses to network scalability with respect to their packet end-to-end delay and throughput as their performance metrics in cases of critical conditions monitoring applications such as military, leakage of toxic gases and liquids in industrial plants etc. In terms of reliability and efficient use of network resources for mobile sensor nodes networks the selected performance metrics were subjected to identify protocols effectiveness and suitability. This is because in any network the demand in the demand for protocol reliability and effectiveness is vital.

DSR and AODV implemented in three different scenarios having small, large and very large number of executing nodes in mobile nodes networks. In each scenario all the nodes were used as source nodes of sending data to a common base station. On the basis of results in this study we analyzed and proved that AODV is more reliable protocol in terms of delay and throughput than DSR. AODV is more superior to DSR in terms of delay in all the three scenarios. Network size has no considerable effect on AODV performance with respect to delay but it does affect DSR.

With respect to throughput AODV outperforms DSR in all the three scenarios of mobile nodes networks. The network size does not have a considerable effect on the throughput of DSR but in case of AODV it has considerable effect. In mobile nodes networks AODV is a good choice in all the three scenarios of small, large and very large network for minimal delay and higher throughput.

On selected protocols, from the conducted study we conclude that in overall performance one protocol is superior to other protocol. One protocol may be far better in performance than other protocol in terms of delay and throughput. The size of the networks also matters for the performance of the protocol. DSR has its own effectiveness in terms of consistency so selection of a particular routing protocol will depend on application type and intended use of network. The focus in our thesis was on mobile sensor nodes and the same protocols can be analyzed in a fixed scenario especially in case if sensors are burnt due to fire and damaged due to climatic changes then it will be interesting to observe the behavior of the routing protocols in case of some failure of nodes and then checking the delay and throughput in both routing protocols.

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