Chapter 5

PROTOCOLS BASED ON POWER SAVING SCHEMES IN WIRELESS SENSOR NETWORK

This chapter gives an Investigations and optimization of power saving schemes based protocols in Wireless Sensor Network. The brief overview of the contents of chapters is described below.

5.1 INTRODUCTION

MANETs [175] consists of mobile nodes that communicate with each other through either direct link or multi-hop wireless links in the absence of fixed infrastructure. The nodes of these networks have several constraints such as limited bandwidth, transmission range and processing capability due to which the network working has to be fully decentralized i.e. message processing or message passing must be done by nodes themselves using certain routing protocols [176-177].

Several power aware routing protocols that are used for to extending the battery lifetime these are Minimum Total Power Routing Protocol (MTPR), Minimum Battery Cost Routing Protocol (MBCR), Power-Aware Source Routing Protocol, Localized Energy Aware Protocol, Online Power Routing Protocol, Power Aware Localized Routing Protocol and Power Aware Routing Protocol. All of above routing protocols are used to extending battery life and also increase the lifetime of the mobile nodes in desired network [178].

There are number of power routing protocols that are used for to extending the battery lifetime, these are Minimum Battery Cost Routing Protocol [MBCR], Minimum Total Power Routing Protocol (MTPR), Power Aware Source Routing Protocol [PASR], Localized Energy Aware Protocol [LEAR]. All of above routing protocols are used to extending battery life of the mobile nodes [180, 182].

In power aware routing, the protocol doesn’t prioritize short routes anymore, but rather it tries to select those routes which will optimize battery using up to network. If a route contains nodes with low down the battery levels, a longer route is chosen if available. The Minimum Total Transmission Power Routing (MTPR) protocol for instance, chooses routes either with more or shorter hops rather than fewer hops & longer transmission ranges [180-181].
Each node in MANET utilizes its limited residual battery power for its network operations. There are some basic problems related to battery power like difficulties in replacing the batteries in the field, recharging of the batteries, selection of optimal transmission power etc. Due to all these problems power management [182] is an important issue in MANET. Efficient utilization of battery power increases the network lifetime hence is critical in enhancing the network capacity [182].

Power conservation in Wireless Sensor Network and Mobile Ad hoc Network (WANET) is a major challenge even today for researchers. To conserve it various power aware routing protocols have been proposed. These protocols do not take into consideration the residual power left in nodes. To ensure the success of WANET in such scenarios designed in QualNet simulator software in last chapters, it is necessary that the routes be established between every possible pair of nodes at any instant of time irrespective of the shape of the area and the mobility pattern of the nodes. Such an idealistic situation can be created by high density of nodes, high transmission range and very high battery powers [183]. This chapter presents some of our own experimental work performed on the MATLAB tool to study the impact of various parameters on path optimality, throughput and hop count were recorded in presence and absence of power scarce node.

**Need for a new energy saving routing protocol**

A comparative study of existing power routing protocols indicate that these Protocols suffer from the following drawbacks:

- Unwanted wastage of power when no transmission and receiving process is done.
- All the existing power routing protocols select a gateway which is not done in an intelligent way.
- Most of the power aware routing protocols are not conserving power.
- In all of the existing routing protocols congestion is high.

**Assumptions for new energy saving routing protocol**

Energy saving routing protocol makes three basic assumptions, which are as follows:

- All nodes are located with in the maximum transmission rage of each other.
• Radios are capable of dynamically adjusting their transmission power on a per-packet basis.

• Energy aware routing protocol (EAR) comprises of two core algorithms that support overhearing and redirecting

5.2 LITERATURE SURVEY ON ENERGY SAVING SCHEMES

<table>
<thead>
<tr>
<th>Authors</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Azimet.al</td>
<td>“Proposed power efficient routing protocol for sensor networks. Here, scheme consists of short range and non distance communication between the sensor nodes. Here the author did not focus on the outside of the transmission region. The node occupies high power consumption with limited distance” [186].</td>
</tr>
<tr>
<td>Ouadoudi.et al</td>
<td>“The author explored a power efficient clustering protocol based on decentralized clustering algorithm. Here, the power is distributed to all sensor nodes in the network in order to prolong the network life time. In case if the un-authenticated node is entering in to a cluster, the retransmission of packet will occur which leads to the high power consumption. So the network connectivity may be damaged. Here they have focused only on increasing the network life time. But due to clustering the network vulnerability may be induced” [187].</td>
</tr>
<tr>
<td>Sujatha.et al</td>
<td>“The author developed a load balancing mechanism for improving energy efficiency based on traffic interference between the neighboring nodes. Here, the energy efficiency of the protocol is evaluated using energy metrics average energy consumed variance and network lifetime” [188].</td>
</tr>
<tr>
<td>Li et.al</td>
<td>“The author explored a distributed protocol to construct a minimum power topology and also developed an algorithm to find the shortest path. The length of the path is measured in term of energy consumption. This proposed algorithm used only local information between the neighboring nodes” [189].</td>
</tr>
</tbody>
</table>
5.3 ROUTING PROTOCOLS BASED ON ENERGY SAVING SCHEMES

This process continues at each and every intermediate nodes till the packet reaches to a destination node. The diagram of routing protocol and path matrix is given below [179,180]

![Diagram of routing protocol]

Fig. 5.1 Diagram of routing protocol

The destination node receives RREQs from various nodes but selects the path with minimum total transmission power. It should be noted here that the total transmission power scales with transmitted distance as $d^2$ to $d^4$ depending on environmental conditions. This routing approach will in most cases tend to select routes with more hops than others [182,188].

The above protocol can made clearer with the help of an example network as shown in Fig. 5.2. The distances between various pairs of nodes are shown in path matrix (see Table- 5.1). Let us suppose 1 as the source and 7 as the destination. The paths selected from source to destination may be as follows:

- The path (1-2-3-4-6-7) has total transmission loss = $k (15 \times 15 + 10 \times 10 + 10 \times 5 + 5 \times 5 + 10 \times 10) = 550k$ units (Here total transmission loss is taken as $kd^2$).
- The paths (1-3-4-6-7) has total transmission loss = $k (20 \times 20 + 10 \times 10 + 5 \times 5 + 10 \times 10) = 625k$.
- Similarly total transmission power loss in path (1-4-6-7) = $k (25 \times 25 + 5 \times 5 + 10 \times 10) = 750k$.
- The path (1-2-3-4-6-7) has minimum total transmission power loss. Therefore the same is selected as shown in Fig. 5.2. The limitations of this approach can be summarized as under:
1. The network will be congested as the packets has to routed from multiple nodes
2. More number of nodes has to participate in forming a routing path
3. It will always select its nearest neighboring node.

![Diagram showing packet movement from source node 1 to destination node 7 using MTPR]

**Path Matrix**

Table 5.1 Show the path matrix of source node to destination nodes with distance between them

<table>
<thead>
<tr>
<th>Node</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
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<tr>
<td>1</td>
<td>0</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>0</td>
<td>10</td>
<td>20</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>3</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>10</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>4</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>5</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>6</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
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</tr>
</tbody>
</table>

Distance between Nodes
5.4 PERFORMANCE ANALYSIS OF MINIMUM TOTAL TRANSMISSION POWER ROUTING (MTPR) PROTOCOL IN POWER DEFICIENT NODE

5.4.1 Introduction

This work is based on the performance analysis of low bandwidth and power constraints of nodes, being used in the mobile ad hoc network and design its basic structure and evaluates the outcome of same; minimum hop path, minimum transmitted energy path, residual energy, bandwidth, throughput and power to be adequate so that a reliable and trustful connection between participating nodes is maintained.

This chapter considers MTPR routing protocol and tries to avoid those nodes whose residual power is too low. In addition to this chapter compares the performance of both these protocols on various performance metrics such as throughput, hop count etc. The result shows a significant improvement when nodes with residual energy are avoided from path [183].

We conducted two experimental investigations to study the impact of various parameters such as path optimality, throughput and hop count, shape of the network, size of the network, mobility of nodes, minimum hop path, minimum transmitted energy path, residual energy, bandwidth, throughput and power and other aspects related to MANET performance.

5.4.2 Simulator Design Setup

To perform this experiment, an area of the size 1500 sq. units was chosen and N number of nodes were uniformly distributed using randint() function. Each node was assigned a transmission range. There after routes from all source nodes to all destination nodes were explored using Dijkstra’s shortest path algorithm.

5.4.3 Simulation Set up Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routing Protocol used</td>
<td>MTPR</td>
</tr>
<tr>
<td>Transmission Range</td>
<td>320 units</td>
</tr>
<tr>
<td>Number of Nodes</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 5.2: Simulation set up parameters
<table>
<thead>
<tr>
<th>Nodes Placement Strategy</th>
<th>Random</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of iteration</td>
<td>25</td>
</tr>
<tr>
<td>Percentage of nodes</td>
<td>0 to 100% step size of 10 %</td>
</tr>
</tbody>
</table>

One routing strategy named as Minimum Total Power Routing (MTPR) was implemented using Dijkstra’s shortest path algorithm. Table 5.2 provides the simulation parameters.

### 5.4.3.1 Proposed Metrics

The metric used for the performance evaluation are as follows:

**MTPR_Hop Count:** It is defined as number of at the instance of path formation by route from source to destination for successful transmissions.

**MTPR_Throughput:** It is defined as number successful data packets received at receiver to the total no of data packets sent by transmitter. Higher value of the throughput indicates higher stability of the route.

**MTPR_Path Optimality:** It is defined as ratio of path length under presence realistic environment and absence idealistic environment.

### 5.4.4 Snapshot of Simulator

The figures 5.3 to 5.6 show the snapshot of simulation process. Fig 5.4 shows that the yellow line in the figures shows the path created by using MTPR routing algorithms. The path measure the impact of variable transmission range on the network performance, the energy consumed for a route is calculated by taking fixed and variable transmission range of nodes.

Shortest path when no node is selfish and the black lines shows the shortest path after the avoidance of selfish nodes. At low concentration of selfish nodes it is more likely yellow and black lines will be same and as the concentration increases they are likely to be different. Thus at 0% concentration of selfish nodes the route found between a pair of source and destination is shortest and at k% concentration the route found is shortest as if no selfish nodes were present. Thus with the increase in concentration of selfish nodes.
Nodes distribute in an area of 1500*1500 sq units randomly

Input Enter the length (TR)

No of Nodes (N)

Input Transmission Range (M)

For Power scarce (PS) = 0 to 100

For iteration = 1 to K

Select Source (S) and Destination (D) Randomly

Apply shortest path Routing Algorithm

Calculate MTPR_Hop Count, MTPR_Throughput, MTPR_Path

Next iteration

Calculate Average MTPR_Hop Count, Average MTPR_Throughput, Average MTPR_Path Optimality for all iteration

Next SL

stop

Fig. 5.3 Flow chart of design simulator

Fig. 5.4 Snapshot to study the effect of MTPR_Path Optimality

Fig. 5.5 Snapshot to study the effect of MTPR_Throughput

Fig. 5.6 Snapshot to study the effect of MTPR_Hop Count
5.4.5 Simulation Results

5.4.5.1 MTPR_Throughput

Throughput [15] is the ratio of number of data packets received by the destination upon the total number of data packets delivered by source. Throughput is shown in Fig 5.7 the throughput rate maximum value when 40% then decrease from 40% proportionate to decreasing percentage level 0 with 90%. packets dropped.

![Fig. 5.7 MPTR_Throughput v/s with or without Power scarce](image)

5.4.5.2 MTPR_Hop Count

Fig 5.8 shows the impact of increase in hop count as the concentration of power scarce nodes increases. The average hop count is almost same when the selfish nodes are up to 10% of the total number of nodes. The maximum hop count occurs at 50%. The average hop count slightly decreases up to 70% and 0 when it reaches 100%. If the route formation does not occur, then in that the maximum hop count (16) was taken.

![Fig. 5.8 MPTR_Hop Count v/s with or without power scarce](image)
5.4.5.3 MTPR_Path Optimality

Fig. 5.9 shows the impact of simulation of path optimality of selfish nodes path length on the percentage of packets dropped. There is no remarkable change in the percentage packet dropped when the selfish node concentration is up to 15%. It reaches to a maximum value of nearly 45% then the selfish node decreasing percentage level 0 with 100% packet dropped.

![MPTR_Path Optimality](image)

Fig. 5.9 MPTR_Path Optimality v/s with or without Power scarce

5.4.6 Conclusion

The problem of power scarce nodes is very common in ad hoc networks. The major reason for it is cooperation among nodes in routing data packets. As the time passes away the nodes loose their battery power. The effect of environment is also pronounced. The following inference can be made from above results as follows:

- There is almost 45% decrease in values of hop count, throughput, and path optimality in the presence and absence of power scarce nodes.
- Nearly 10%, power scarce nodes do not have any negative effect on the network activities.
- The network never comes to halt position where as the power scarce node reaches to nearly 100%.

The average hop count reaches to a maximum 3.4 times, Probability of percentage of power scarce nodes and throughput comes down to nearly 45% at its peak and percentage of packet drop goes up to nearly 55% at the most.
5.5 ANALYSIS OF MANET WITH LOW BANDWIDTH ESTIMATION

A Mobile Ad-hoc network (MANET) is a self organizing and adaptive in environment. A MANET consists of a set of mobile nodes that have to collaborate, interact and communicate to complete an assigned operation. These applications have need of Quality of Service (QoS) parameters such as: minimum hop path, minimum transmitted energy path, residual energy, bandwidth, throughput and power to be adequate so that a reliable and trustful connection between participating nodes is maintained. The proposed work on the performance analysis of low bandwidth and power constraints of nodes, being used in the mobile ad hoc network and design its basic structure and evaluates the outcome of same; on a designed simulator in MATLAB -7.0 and studies its performance on various inputs, like as number of nodes, transmission range, transmission radius of each node throughput and number of iterations. Simulation results show that the number of hop-counts decreases as we increase the percentage of low down bandwidth nodes in the network, it was also concluded that the throughput rate decreases as we increase the number of low down bandwidth nodes in the network.

5.5.1 Introduction

The bandwidth estimation is a basic function that is required to provide QoS in Mobile Ad-hoc Networks [179]. It is a way to determine the data rate accessible on a network path. It is of curiosity to users wishing to optimize end-to-end transport performance, overlay network routing, and peer-to-peer file distribution [190].

Techniques for accurate bandwidth estimation are also necessary for traffic engineering and capacity development support. Because of an Ad-Hoc network is a collection of wireless mobile hosts forming a temporary network without aid of any centralized administration. Mobile Ad- Hoc Networks has a new structure in the field of wireless Communication network. They do not require any fixed infrastructure for instance a base station to work. The nodes themselves address topology changes due to the mobility, the entrance or the exits of nodes. These networks use a radio medium. The technology gives the user a freedom to move freely any were in the communication range and it has become independent of its infrastructure [189]. This freedom from existing infrastructure has made Mobile Ad-Hoc Networks more flexible, affordable and easily deployable in all environments including military and
rescue operations. There are two types of mobile network namely Mobile IP and MANET [190].

MANET consists of nodes that are capable to communicate wirelessly among them. MANETs consist of a group of wireless mobile nodes which dynamically exchange data among themselves without the reliance on a fixed base station or a wired backbone network [191].

MANET nodes are typically differentiated by their limited power, processing, and memory resources as well as high degree of mobility. In MANETs, the wireless mobile nodes may dynamically enter in the network as well as leave the network. Because of the limited transmission range, minimum hop path, minimum transmitted energy path, minimum normalized residual energy used, minimum absolute residual energy used, bandwidth, throughput, hop-count and power to be adequate so that a reliable and trustful connection between participating nodes is maintained of wireless network nodes, multiple hops are generally required for a node to exchange information with any other node in the network [79]. Multi-path routing permits the formation of multiple paths between one source node and one destination node. We have used the means of simulation using MATLAB (7.0), a simulator is being designed in MATLAB 7.0. It gathers data about number of hop-count (number of nodes between source and destination for successful routes) and throughput rate (total number of packets received by the destination to the total number of packets send by source). The simulator uses dijkstra algorithm to implement shortest path routing. To evaluate the effectiveness of MANET for nodes having lower bandwidth, the nodes were made unreachable by assigning low bandwidth to a group of some specified percentage nodes in the network [191].

5.5.2 Related Work

Earlier works on throughput constrained routing for MANETs [189-192] has already considered many of the aspects of the problem by estimating achievable throughput. Some of the researchers shared knowledge in the techniques on MTPR proposed and given below;

| Abdullah       | “Proposed a technique implemented in a sniffing based tool (called wimeter) which captures and analyzes on real-time the frames sent in a preconfigured WLAN. The analysis of captured frames consists on determining the |

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portion of time when the channel is free and then to estimate the available bandwidth in function of the packet size of expected frames to be transmitted and the link-layer rate of the sender and the receiver stations. They went ahead to implement a Call Admission Control Framework that uses the wimeter as a basis for bandwidth estimation” [193].

CheikhSarr and Heinzelman

“Modified the hello messages in the AODV routing protocol so that it carried bandwidth information of each node and its immediate neighbors. This information was then used to calculate the residual bandwidth due to second hop neighborhood interference” [192].

C-K. Tohet al

“Implemented a load balancing technique based on a probing available bandwidth measuring technique” [194].

Xiang-Yang Liet al

“Proposed an admission control method they called Perceptive Admission Control (PAC). In the method the used a bandwidth estimation method based on listening for the idle time for channel and calculated the available bandwidth as a ratio of idle time to total time multiplied by the channel capacity” [189].

Sujatha P Terdal, et al.

“Proposed a MAC layer based estimation method. It is based on the bandwidth of a link in discrete time intervals by averaging the throughputs of the recent packets in the past time window and use it to estimate the bandwidth in the current time window. Obviously, this estimation may not be accurate because the channel condition may have changed. Greedy Perimeter State-less Routing (GPSR) is used to discover a route to the destination of a new flow. This is a location based protocol which is characterized by their scalability and efficient bandwidth utilization as they do not flood the net-work to find the destination” [188].

QuadoudiZytouneet

“Proposed a new approach based on Multipath Routing
al. Backbone (MRB) for supporting enhanced QoS in MANETS. It improves throughput and minimizes overall end-to-end delay. This protocol is designed for highly dynamic ad hoc networks where link failures and route breaks occur frequently. This protocol finds multiple disjoint paths from source to destination where each path satisfies the conditions for QoS. Many other methods have been proposed varying from numerical calculations to probing methods” [189].

| C.R. Lin | “Based Backup Routing Protocol considers both route length and link lifetime to achieve high route stability. Primary route for forwarding data packets is formed primarily based on greedy forwarding mechanism, whereas local backup path is established according to link lifetime” [197]. |
| Deepak Vidhateet al. | “Proposed a Multipath Optimized Link State Routing (MP-OLSR) which is a multipath routing protocol. This protocol gives great flexibility by employing different route metrics and cost functions. A modified route recovery and loop detection mechanisms are also implemented in MP-OLSR in order to improve QoS” [198]. |
| R.D. Haanet al. | “Proposed that the discovery of the route operation for path reconstruction should be done from the source itself. It has also given a new mechanism to determine multiple disjoint paths for forwarding the packets from source to destination” [199]. |

5.5.3 Bandwidth

5.5.3.1 Limited Network Capacity (Bandwidth)

Unlike wired networks with abundant bandwidth, MANETs are limited in radio bandwidths therefore data transfer rates are less than those of wired networks. This
raised the need for a routing protocol to optimally use the bandwidth. Furthermore, limited bandwidth results in less stored topology information. Complete topology information is required for an efficient routing protocol, however this cannot to be the case in MANET routing protocol as this will cause an increase in node control messages and overheads which wastes more bandwidth. Control message are messages send over the network enabling nodes to establish connections before packet messages are transfer. An efficient routing protocol is required for a balanced usage of the limited bandwidth [188, 195].

5.5.4 Bandwidth Constraints

The purpose of the MANET is to homogenize IP routing protocol functionality is appropriate for the wireless routing application within both dynamic and static topologies with raised dynamics because of node motion and other factors [192, 200]:

- **Dynamicity**: Every host can randomly change position. The topology is generally unpredictable, and the network position is inaccurate.
- **Non-centralization**: There is no centralized organization in the network and, therefore, network possessions cannot be assigned in a predetermined approach.
- **Radio properties**: The wireless channel can suffer from multi-path effects, fading and time variation, etc.

5.5.4.1 Bandwidth Estimation Methods

Estimating precise available bandwidth allows a node to make optimal decision before transmitting a packet in networks. It is therefore clear that the available bandwidth estimation enhances the QoS in wired and wireless Networks [201]. Measuring available bandwidth in ad hoc networks is challenging issue in MANET and calculating the residual bandwidth using the IEEE 802.11 MAC is still a challenging problem, because the bandwidth is shared among neighboring hosts, and an individual host has no knowledge about other neighboring hosts’ traffic status and battery power. Two methods for estimating bandwidth are used below [201]:

*Intrusive Bandwidth Estimation Method*

The intrusive approaches techniques are based on end-to-end probe packets to estimate the available bandwidth along the length of a path [201].
**Passive Bandwidth Estimation Method**

The passive approaches techniques uses local information on the used bandwidth and that may exchange this information via neighborhood broadcast [197].

### 5.5.5 Bandwidth Allocation Algorithm for MANET

Bandwidth estimation in a cross-layer design of the routing and MAC layers and the available bandwidth is estimated in the MAC layer and is sent to the routing layer for admission control. Therefore, bandwidth estimation can be carried out in various network layers [198].

All the information of MANET which include the History of ad hoc, wireless ad hoc, wireless mobile approaches and types of MANETs, and then they present more than 13 types of the routing Ad Hoc Networks protocols were proposed. They give description of routing protocols, analysis of individual characteristics and advantage and disadvantages to collect and compare, and present all the applications or the Possible Service of Ad Hoc Networks [199].

Present bandwidth estimation tools measure more than three related metrics: capacity, available bandwidth, hop count, throughput, and bulk transfer capacity etc. Currently available bandwidth estimation tools utilize a various strategies to measure these metrics. These issues of multipath routing in MANETs were particularly examined. They also discuss the application of multipath routing to support application constraints such as reliability, load-balancing, energy-conservation and QoS [196].

An improved mechanism was proposed to estimate the available bandwidth in IEEE 802.11-based ad hoc networks. In 802.11-based ad hoc networks, few works deal with solutions for bandwidth estimation.

The hitch is present in bandwidth estimation was reorganized by IEEE 802.11 based ad hoc networks. According to them estimation accuracy is increased by improving the calculation accuracy of the prospect for two adjacent nodes idle period to overlap [195].

In a scattered ad hoc network, a host’s available bandwidth cannot decided only by the unprocessed channel bandwidth, but also by its neighbour’s bandwidth usage and interference caused by other sources, each of which reduces a host’s available bandwidth for transmitting data. Therefore, applications cannot properly
optimize their coding rate without awareness of the status of the entire network. The problem in available bandwidth estimation was reorganize in IEEE 802.11 based ad hoc networks [202]. According to them estimation precision is increased by improving the calculation accuracy of the prospect for two neighboring nodes inactive period to overlap.

5.5.6 Experimental Setup and Design Simulator

5.5.6.1 Simulation Model

We have used a comprehensive simulation model based on MATLAB 7.0, for system protocol modeling. MATLAB is a high-performance language for technological computing. It integrates computation, visualization, and programming in an easy-to-use environment, where problems and solutions are expressed in familiar mathematical notation. Typical uses include math and computation algorithm development data acquisition modeling etc.

5.5.6.2 Simulation Design Parameters

We have primarily selected the design parameters

- Number of hop-count
- Throughput
- Number of nodes between source to destination
- Total number of packets received by the source to destination

5.5.6.3 Simulation Setup Parameters

Table 5.3 Simulation set up parameters for impact on Low bandwidth consideration

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>1500*1500</td>
</tr>
<tr>
<td>Number of Nodes</td>
<td>50</td>
</tr>
<tr>
<td>Transmission Range (TR)</td>
<td>300m</td>
</tr>
<tr>
<td>Battery status</td>
<td>High</td>
</tr>
<tr>
<td>Nodes Placement Strategy</td>
<td>Random</td>
</tr>
<tr>
<td>Number of iteration</td>
<td>25</td>
</tr>
</tbody>
</table>
### 5.5.6.4 Flow Chart for Design Simulator

- **Start**
  - Nodes distribute in an area of 1500*1500 sq units randomly
  - Input Enter the length (TR)
  - No of Nodes (N)
  - Input Transmission
  - For Bandwidth scarce (BS) = 0
    - For iteration = 1 to
      - Select Source (S) and Destination (D) Randomly
      - Apply shortest path Routing Algorithm (dijkstra)
      - Calculate Hop Count, Throughput, Path Optimality
      - Next
      - Calculate Average Hop Count, Average Throughput, Average Path Optimality for all iteration
  - Next SL

Fig. 5.10 Flow chart for design simulator

| Percentage of nodes having low bandwidth | Varies from 0 to 100 percentage (with a interval of 10) |
5.5.7 Snapshots

The figures mentioned below are the variety of outcomes which came during the simulation running process.

![Snapshots of simulator producing input data](image1)

Fig. 5.11 Snapshots of simulator producing input data.

![Number of minimum hop in a shortest path](image2)

Fig. 5.12 Number of minimum hop in a shortest path
Fig. 5.13 Snapshots of simulator producing output data.

Fig. 5.14 Hop-count in the shortest path

Fig. 5.15 Number of maximum hop in a shortest path
5.5.8 Simulation Results

5.5.8.1 Impact of Low Bandwidth on Hop-Count

The Fig. 5.16 shows that as we gradually increases the percentage of low bandwidth nodes form 10 to 40 number of nodes and then on going up to 100, then hop-count decreases; It shows that the routes which required more intermediate nodes are not forming in the network. Simply longer routes were not being established with the growth of low bandwidth nodes.

Fig. 5.16 Bandwidth V/s Hop-Counts

5.5.8.2 Low Bandwidth on Throughput

Throughput is the ratio of number of packets received by the destination upon the total number of packets delivered by the source. The outcome shown in Fig 5.17.

Fig. 5.17 Throughput V/s Number of hop-counts in a shortest path

The throughput rate is going to decrease from level of 50 nodes to the level 100 in proportionate to increasing percentage of low bandwidth nodes in the network and it reaches to level 0 to 100% for low bandwidth estimated nodes.
5.5.8.3 Impact of Low Bandwidth on Path Optimality

![Path Optimality Vs number of nodes](image)

Fig. 5.18 Path Optimality V/s Number of hop-counts in a shortest path

Fig. 5.18 shows the impact of simulation of path optimality of nodes path length on the percentage of packets dropped. There is no remarkable change in the percentage packet dropped in between 0 to 50, when the node concentration is up to 30. It reaches to a maximum value of nearly 60 nodes then the bandwidth decreased.

5.5.9 Conclusion

MANET consists of autonomous, self-organizing and self-operating nodes. It is characterized by links with less bandwidth, nodes with energy constraints, nodes with less memory and processing power and more flat to security intimidation than the fixed networks. However, it has many advantages and different application areas, different assumptions such as location information availability and transmission power control. In this paper, we designed a simulator which is intended in MATLAB-7.0. The simulator uses dijkstra algorithm to implement shortest path routing. To evaluate the effectiveness of MANET for nodes having lower bandwidth, the nodes were made unreachable by assigning a distinct bandwidth to divergent nodes. We conclude performance of three QoS factors (hop count throughput and path optimality) on the basis of varying percentage of low bandwidth nodes in the network. The simulator designed in MATLAB 7.0 gathers data about number of hop-count (number of nodes between source and destination for successful routes). There is almost 45% decrease in values of hop count, throughput, and path optimality in the varying number of nodes.
Two papers are produced out of research work carried in this section of thesis.
