Load Balancing Adaptive Scheduling with Minimum Packet Loss in Wireless Mesh Networks

Thesis submitted in partial fulfilment of the requirements for the award of degree of

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in
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Certificate

I hereby certify that the work which is being presented in the thesis entitled, "*Load Balancing Adaptive Scheduling with Minimum Packet Loss in Wireless Mesh Networks*", in partial fulfilment of the requirements for the award of degree of Master of Engineering in *Information Security* submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of *Dr. Neeraj Kumar* and refers other researcher's work which are duly listed in the reference section.

The matter presented in the thesis has not been submitted for award of any other degree of this or any other University.

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This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

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Abstract

With the enhancement in the wireless technology, the accessing quantity of mobile Internet has increased exponentially. According to the usage quantity of the mobile Internet, the demand of Quality of Service (QoS) is also increased. These types of applications requires high data rate. Wireless Mesh Networks (WMNs) is one of the networks that support these types of services. WMNs is the combination of Mesh Routers (MR), Mesh Clients (MC). The nodes can communicate with each other through the MR. The network consists of mobile nodes as well as static nodes having properties of self-forming, self-configured and self-healing.

This thesis provides solution to overcome the problem of QoS. For QoS in the WMNs Load Balancing Adaptive Scheduling with Minimum Packet Loss (LBASMPL) algorithm is proposed. It minimizes the loss of the packets and sends them in the priority manners. The Variable Load Index (VLI), Total Capacity (TC), Estimation of Delay (ED) are also calculated. The traffic is schedule according to Time Division Multiple Access (TDMA). Lower and Upper bound of the link on TC is also calculated. The traffic is load on the link according to priority. For scheduling this traffic matrix is generated. This proposed algorithm is used to minimize the packet loss at the routers and gateway.

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List of Abbreviation

ARC	Adaptive Rate Control
AODV	Ad-hoc on Demand Distance Vector
AWT	Average Waiting Time
BA	Bacteriological Algorithm
BLC	Bottleneck Link Capacity
CARS	Capacity Aware Route Selection
CSC	Channel-Switching Cost
CGSR	Cluster-head Gateway Switching Routing
CEF	Cost Evaluation Function
Diffserv	Differentiated service
DCF	Distributed Coordination Function
DSDV	Distance Vector Routing Protocol
DSR	Dynamic Source Routing Protocol
EBT	Expected Busy Time
ED	Estimation Delay
EDR	Expected Data Rate
ETX	Expected Transmission Count
ETOP	Expected Transmission on a Path
ENT	Expected Number of Transmission
ETT	Expected Transmission Time

INX	Interference Neighbour Count
Intserv	Integrated service
IVCS	Inter-Vehicular Communication System
LARS	Load-Aware Route Selection
LB	Lower Bound
LBAS	Load Balancing Adaptive Scheduling
LBASMPL	Load Balancing Adaptive Scheduling with Minimum Packet Loss
LQSR	Link Quality Source Routing
LQCA	Link Quality and Congestion Aware
MC	Mesh Clients
MR	Mesh Routers
MG	Mesh Gateway
MIC	Metric of Interference and channel switching
NAM	Network Animator
NAV	Network Allocation Vector
NIC	Network Interface Card
NS-2	Network Simulator version 2
OTcl	Object oriented Tool command language
OLSR	Optimized Link State Routing Protocol
PD	Propagation Delay
PPD	Packet Pair Delay

QoS	Quality of Service
RoR	Rate of Requests
RTT	Round Trip Time
TC	Total Capacity
TCD	Transmission Contention
TDMA	Time Division Multiple Access
TF	Traffic Flow
TORA	Temporally Order Routing Protocol
TS	Total Time taken by System
UB	Upper Bound
VLI	Variable Load Index
VoIP	Voice over IP
WCETT	Weighted Cumulative ETT
WMNs	Wireless Mesh Networks
WLAN	Wireless Local Area Network
WMNs	Wireless Mesh Networks
ZRP	Zone Routing Protocol

Chapter 1

Introduction

1.1 Background

In 1970s, the wireless networks grow rapidly. In 1971, the University of Hawaii first introduced the radio communication and computer networks and gives the name of it as ALOHANET.

The first Wireless Local Area Network (WLAN) gives star topology that was based on the bidirectional communication [1]. In 80s, the technology is improved drastically and as the time goes in 90s, the technology took a new look and reached at the peak due to the exponentially growth of the internet.

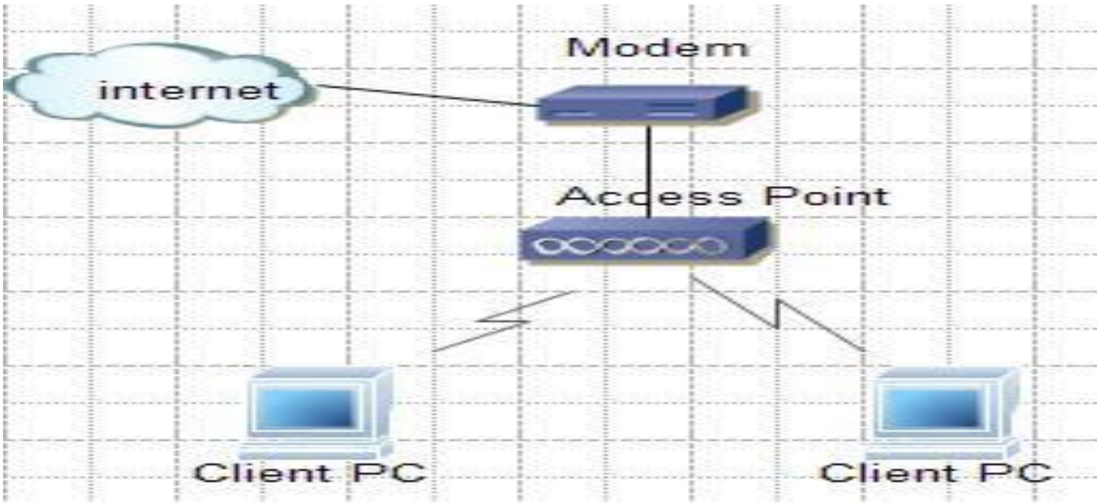

Figure 1.1: Simple WLAN

In the recent time, Internet technology has been increased exponentially. Video streaming, Voice over IP (VoIP) are some examples of the Internet technology. As various wireless networks emerged; Wireless Mesh Networks (WMNs) is one of the examples. WMNs are the combination of Mesh Gateway (MG), Mesh Routers (MR) and Mesh Clients (MC) [2]. These nodes are not only act as host but router as well.

Whenever one node want to communicate with another nodes and they are not directly connected to each other then, these nodes act as a router and pass the packet according to destinations. So, these nodes are also known as relay node. WMNs have low up-front costs, easily maintenance, reliable in nature because of the self-organized and self-configured feature of WMNs.

Nodes that do not have the Wireless Network Interface Card (NICs) can directly connect to the routers through the Ethernet. The nodes that have NICs can connect through it, e.g., desktop, PDA, phones etc. The MR can have more than one network interfaces. But the MC can have only one interface.

1.2 Network Architecture

WMNs consist of two types of nodes: MC, MR. These MR also contains the additional functionality i.e. gateway as well as repeater for further communication. MR can have more than one interface. MC can have only one interface but it has all the functionality for mesh networking. These nodes can sometimes act as the router to forward the packets. But the functionality of gateway as well repeater does not exist in MC. MC can be laptop, PDA, phones etc.

The network architecture of the WMNs is classified into three categories:

- Infrastructure/ Backbone WMNs

  The network architecture is shown in Figure 1.2, the solid line shows the direct connection and the other lines show the wireless connection in between. In this type of architecture MR form the infrastructure for clients that are connected to them. The various radio technologies is used to build the infrastructure, e.g., IEEE 802.11. The architecture is connected to the internet through the gateway. This architecture also provides the backbone to the MC. This architecture is most commonly used. The MR mainly used the two types of radios i.e. for backbone communication and for the user communication.

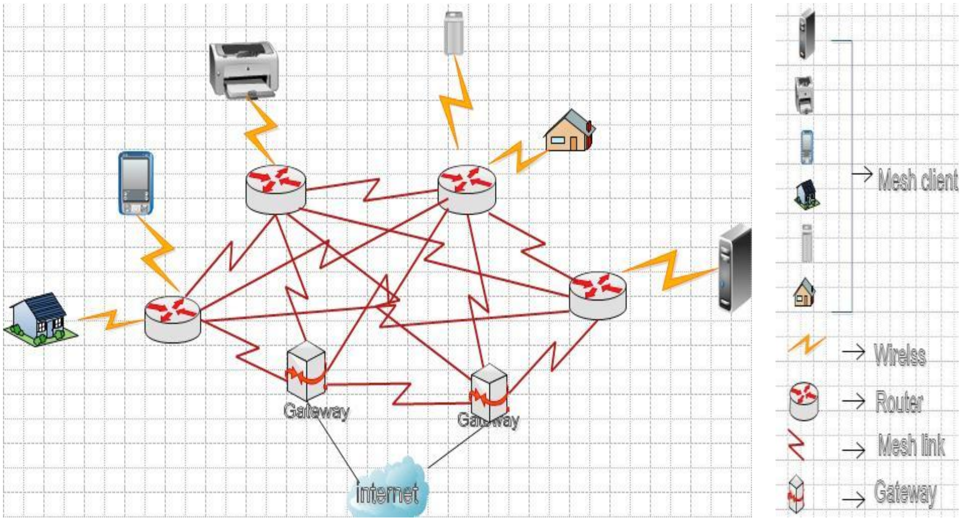

Figure 1.2: Architecture of Infrastructure/Backbone WMNs

- Client WMNs

  Client WMNs meshing provides the peer-to-peer networks. In this architecture client nodes act as routers as well as repeater. These nodes can actually perform the routing. These nodes also provide the configuration functionalities. This architecture does not require the MR. figure 1.3 shows the architecture of client WMNs.

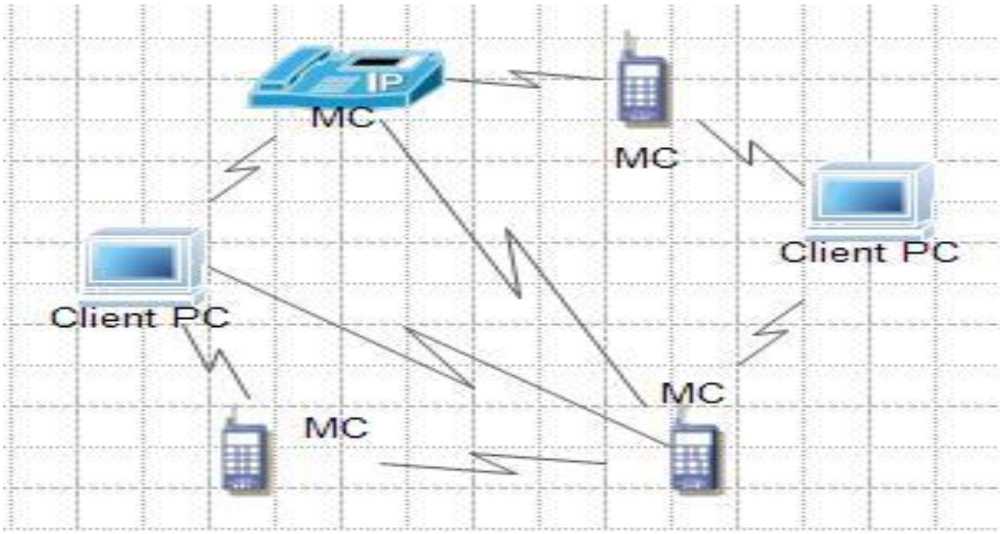

Figure 1.3: Client WMNs

In this architecture, if one node wants to communicate to another node, it sends its packet to one client and that client pass the packet to the destination. It has only one type radio. In this architecture, the end users have to do additional functionality such as routing as well as self-configuration.

- Hybrid WMNs

  This architecture is the combination of the infrastructure and client WMNs. Figure 1.4 shows the architecture of the hybrid WMNs. MC can communicate through the MR as well directly through clients. We can connect to the other network through the internet. This architecture is the most applicable.

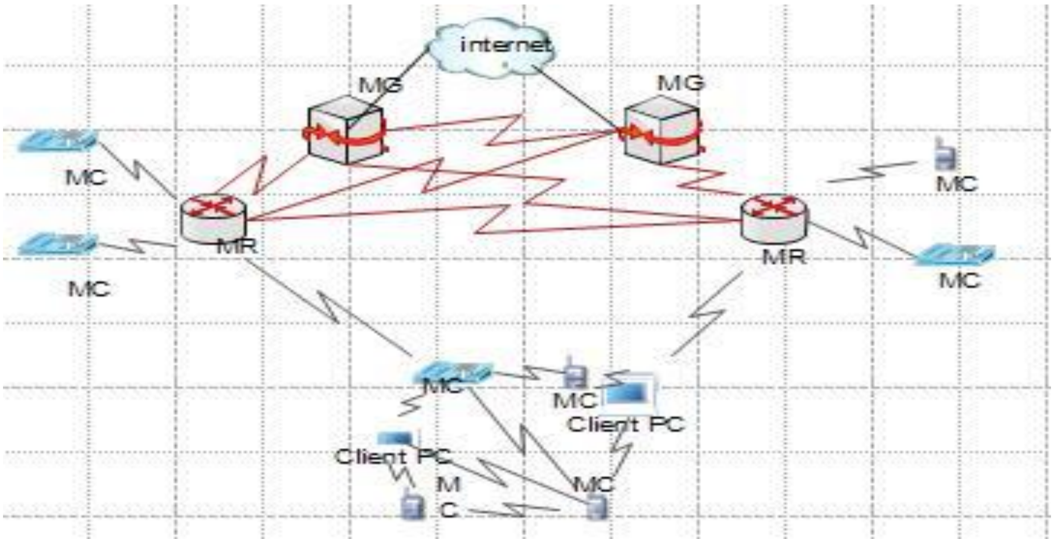

Figure 1.4: Architecture of Hybrid WMNs

1.3 Characteristics of WMNs

- Multi-hop wireless networks:

  One of the main issues in all network models is capacity, but WMNs is one of the networks that help to reduce this problem. It increases the coverage range of the network. It also provides throughput [3], less interferences in the nodes and high frequency is used in between all nodes.
- Various feature such as self forming, self-healing and self-organization.
- Mobility of nodes depends on its type:

As MR are stationary in nature and the MC are mobile in nature. It depends on the nature of the nodes.

- Support multiple type of network access:
  According to the architecture it can support both the backhaul as well as the peer-to-peer network [4]. But this type of facility is not present in the ad-hoc network.
- Power-consumed on the basis of type of nodes:
  Power-consumed on the basis of type of nodes, e.g., MR do not require high power but the MC are depends on the power they consume [5].
- Compatibility with the other networks:
  WMNs are compatible with the other networks, e.g., it is compatible with the other 802.11 standard.

1.4 Advantages of WMNs

- Wireless infrastructure/ backbone:
  Due to the architecture of WMNs, it provides better coverage area, connectivity and robustness in the network. But in case of ad-hoc networks reliability is depends on the end users.
- Integration of the networks:
  In WMNs the MC can communicate within its own area as well they also have the facility of integration with the other network, e.g., they can communicate to other network also.
- Efficient configuration and the dedicated routing:
  In case of ad-hoc networks, routing and other functionality is done by the nodes. It increases the load on the nodes. But in WMNs the MR are used that helps to do routing and it carries all the network traffic that decreases the traffic on the nodes. It also consumes the low energy. The requirement of the end-user decreases and which reduces the cost of the network.
- Multiple Radios:
  WMNs can work with the multiple radios. MR can have more than one interface so one radio can work for the routing and configuration of the traffic and the other can be used for carrying network packets. MR and MC can use

different radios at a single time. This concept improves the capacity of the networks.

- Mobility: In ad-hoc networks the routing is depends on the clients, because the connectivity between the networks depends on the movement of the nodes. In case of WMNs routing is depends on the infrastructure. It increases the coverage area and the throughput of the network is increased.
- Compatibility with the other networks:
  WMNs is compatible with all IEEE 802.11 standard.

1.5 Basic Design Factors

- Multiple radio techniques
- Scalable in nature
- Broadband and Quality of Services (QoS)
- Compatibility with other networks
- Security
- Ease of use
- Mesh connectivity

1.6 Applications of WMNs

The following are some basic application where WMNs is used:

- Broadband networks
- Enterprise as well as community network
- Transportation network
- Surveillance systems

1.7 Routing in WMNs

Routing is the action of moving packets across the network from one node to destination node. This process is taken place into different steps: first find out the best routing path and next is to pass the traffic from that best path for passing or choosing the best path the routing algorithm is used. This algorithm decides from where to pass the packet and which node will act as intermediate node. Routing protocol use different routing metrics for passing the traffic from source to destination.

For doing this process, the routing algorithm determines and routing tables are maintained. This routing table contain the route information. This information varies according to the routing algorithm used. Through the routing algorithm the table is filled and it contain the information such as hop – count, source to destination physical as well as logical address etc. Basically hop – count is used to tell the count the number of hops in between the source to destination.

1.7.1 WMNs protocols desirable properties

The following are some property required for routing protocol

- Operations should be distributed: The WMNs protocol should be distributed in nature, so that the load on the network will be reduce
- Security: The protocol should be secure in nature so, that it should not be vulnerable for attacks
- Free from loop: It should be free from loops, so that it improve the overall performance. It will reduce the wastage of channel bandwidth and utilization of resources consumption
- Less Power consumption: It Should be like MC should consumes less power
- QoS: The WMNs should be sup-portative of QoS. Some QoS are: Throughput, Capacity, delay, load etc.

1.7.2 Classification of WMNs routing protocols

Basically classification is done on the basis of network topology and the routing protocol. The routing protocol can be static as well as dynamic in nature. There are many limitations and attributes of WMNs such as bandwidth, load, capacity, high error rate etc. Moreover, in WMNs MC are mobile and MR are static in nature.

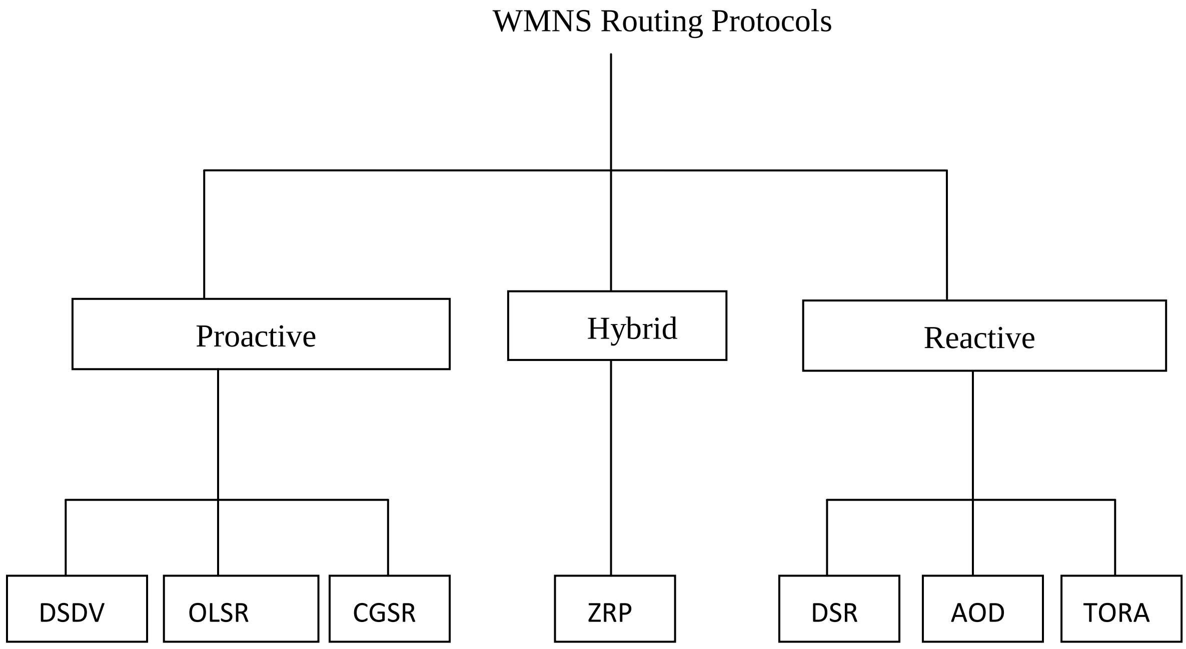

Figure 1.5: Classification of WMNs Routing Protocols [6]

- **Proactive Routing Protocol**

  In this protocol, the routing path is established between the two nodes before the traffic is initiated in between them. Each node maintains their own routing table itself and the information in between these tables periodically updated. When there is any change occurs in the network topology the routing table periodically updated for the reliable routing table. Every node has information of the network topology. When the information is updated periodically there is the overhead of bandwidth. One of another drawback its own information is updated periodically; there is a chance of redundant route entries for a specific destination come in the routing table.

  Some of proactive routing protocols are Destination Sequenced Distance Vector Routing Protocol (DSDV), Optimized Link State Routing Protocol (OLSR), Cluster Head- Gateway Switch Routing Protocol (CGSR).

- **Reactive Routing Protocol**

  This protocol starts and set the routing path after the traffic occurs in between two nodes. Reactive Routing Protocol [7] is the on demand routing Protocol. When one node wants to sends packet to the destination node, the destination route is first check into the route cache. If destination route found into the cache then the packet is send directly. But if the route does not found into the cache then the route request packet is propagated to the neighbour nodes, when neighbour nodes get the packet request and they forward the packet to immediate neighbour until the destination is not found. After receiving the packet, the destination node replies the source node with the shortest path. Major advantage of reactive routing is it saves bandwidth overhead problem.

Some of examples of Reactive Routing Protocols are Ad-hoc on-Demand Distance Vector Routing (AODV), Dynamic Source Routing Protocol (DSR), Temporally Order Routing Protocol (TORA), Link Quality Source Routing (LQSR).

1.7.3 Performance Parameters

The main goal of a routing Protocol is to find out the best routing path from source to destination. The following are the performance parameters:

- Per – flow parameters:- It includes QoS parameters such as Delay, Cost, Packet loss and other parameter are hop – count, per – flow throughput
- Per – node parameters:- It includes computation complexity and power efficiency
- Per – link parameters:- It includes link quality, utilization of channel, transmission rate
- Inter – flow parameters:- It includes inter – flow interference and fairness
- Network – wide parameters: - It includes QoS, overall network performance, throughput of a network.

1.7.4 Routing metrics

The routing metrics are used to capture the performance parameter of the networks.

- Hop-count: It is very simple routing metric. This metric is only used to find the link exists or not. It does not give any helpful information such as loss of packets, quality of link etc. It has only one performance parameter.
- Per-hop Round Trip Time (RTT): It is calculated by sending packets to nodes and calculates the average time spend by the packet while acknowledgment.

It is used to calculate the packet loss and to find out the load on the network [8].

- Per-hop Packet Pair Delay (PPD): It is calculated by sending two packets to the neighbour node. One packet should be large in number and second should be small in number. After receiving these packets the delay is calculated and sends this information to the sending node. This method is used to calculate the packet loss and transmission delay in the packets.
- Expected Transmission Count (ETX): It is used to calculate the expected number of transmission for successful deliver of packets for a particular link. For calculating the route all the ETXs are sum up. It is used to calculate the loss of packets. It uses the per- link performance and per-flow performance parameters [9].
- Expected Transmission on a Path (ETOP): ETOP solve the problem that is come at the time of ETX, e.g., when the best routing path is selected through ETX, it does not consider the position of the link. Only cumulative ETX values are selected while choosing best routing path. To overcome this problem ETOP is chosen. Because in case one link has to do retransmission again and again and second link does not have to retransmit again and again. If we do comparison between these two links and if the ETX value is same for both link than it might be the case that it give worst performance. ETOP solve the problem by taking the relative position of the link and calculate the cost of the link [10].
- Expected Transmission Time (ETT) and Weighted Cumulative ETT (WCETT): it is the extended version of the ETX. It does not take only transmission count but also take the packet size as well as quality of the link. For calculating the best routing path the ETT of the network is calculated by sum up the all ETT of the links of the network. But if in case of WMNs the multiple radios is using by some nodes it does not calculate the channel diversity. So, this method does not consider as good. WCETT is proposed to solve this metrics. It calculated the trade off but the routing delay and channel diversity utilization. It is basically use bandwidth of the network and size of packets [11].

- Effected Number of Transmission (ENT): ENT is proposed [12] to find out the mean loss ratio and the variance of the link in the particular network. For providing QoS ENT defined two parameters link upper bound of the network. It provided the accuracy in link capacity. It is basically worked on the parameters loss of packets.
- Metric of Interference and Channel-Switching (MIC): MIC is proposed for calculating the both inter-flow ad intra-flow interference in the network [13]. The author proposed the Channel- Switching Cost (CSC) algorithm to find out the intra-flow interference. But there are some problems. It does not give the accuracy in the intra-flow interference. It does not capture the link-quality. It does not calculate the actual channel-switching time.
- Bottleneck Link Capacity (BLC): this is proposed to calculate the expected busy time (EBT) of the link by transmitting the packets. EBT is calculated by taking the loss rate of the packets and transmission mechanism. It is used for balancing the load on the network. It does not consider the self- interference for calculating the capacity.
- Expected Data Rate (EDR): EDR is the combination of the ETX and the expected transmission contention (TCD). TCD is taken as the time taken to resend or retransmission of the non-acknowledgement packets. This metrics have number of problems such as it does not consider the interference range of the link, it does not take multiple rates taken by the nodes etc.
- Low Overhead Routing Metrics: Some metrics creates the overhead on the network such as while sending the probing message and collecting the information of the neighbours. To overcome the problem of overhead this metrics is generated [14]. These metrics are Link Quality and Congestion Aware (LQCA) and the Network Allocation Vector (NAV). This algorithm took the parameters such as Hop count, RTS and ACK failure count.
- Airtime Cost Routing Metrics: this metrics is proposed for identify the radio-aware path among the entire network [15]. This metrics is worked on the IEEE 802.11s standard by default. It calculates how much channel resources consumed at a particular link while transmitting a packet on the link. The best path is considered as the sum of smallest airtime cost of the link.

- Interference Neighbour Count (INX): INX metrics is proposed to find out the inter-flow as well as intra-flow interference in the network. This metrics is the extended version of ETX and the ETT. This metrics gave better results with the low load at the network [16].

Classification of WMNs Routing Protocols and their Metrics

Table 1.1: Classification of WMNs Routing Protocol and their Metrics

Protocol	Class	Metrics
LQSR HR-LQSR LOLS	Ad-hoc based	ETX WCETT ETX or ETT
MHRP OLSR AODV-ST	Controlled flooding	Doesn't specified yet HOP, ETX, ETT, ML, ETX or ETT
ROMER	Opportunistic	Hop & Delay
Renewal and Chillan's	Traffic Aware	Hop or Load balancing

Classification of different routing Protocols:

Table 1.2: Table of different routing metrics

Routing metrics	Performance layer	Performance parameters
hop – count	Network	Number of hops

Per – hop RTT [8]	Network	Loss of packets, load one network, quieting delay
Per – hop PPD	Network	Loss of packets, delay in transmission
ETX [9]	Network	Loss of packets, Retransmission
ETOP [10]	Network	End- to – End attempts, link retransmission
ETT WCETT [11]	Network	Bandwidth of link and size of packet
ENT [12]	Network link	Loss of packets, end –to – end packet loss
MIC [13]	Network	Interference such as inter flow and intra – flow
LQCA [14]	Network link	Hop count, RTS and ACK failure count
NAVC [14]	Link	Average count of NAV
Airtime cost [15]	Link	Utilization of resources by a packet on a link
INX [16]	Network	Extends the ETX metric and work for interference

1.8 QoS issues in WMNs

QoS defines the overall performance of the network. It is very much important during the transmission of the traffic. It is affected by various factors; it might be degrade by human knowledge or it might be degrade by technically, e.g., stability of service, delay in delivering packet, reliability, throughput, effectiveness etc.

The following are some factors that affect QoS

- Throughput: QoS of the network is affected if throughput is low. This occurs most of the time when the bit rate provided to the network become low.
- Delay: QoS of the network is affected if the delay in the network increases. When network takes much time to deliver the packets to the destination.
- Packet drop: when the traffic is passes from source to destination and the router is intermediate; if the buffer of the router is full than buffer will drop the packets. At the destination end retransmission of the packet is done. It will cause the delay in the delivery.
- Error: some time traffic get corrupted and the bits of the packets get corrupted it also affect the QoS.
- Latency: some time the packets have to wait in the queue. It takes long time to reach its destination. If the latency of the packet increases it will render some of the applications
- Jitter: because of long queue as well as buffer at router some time delay in the packet delivery occur and it various from packets to packets. This is called jitter. This is also affects the QoS of multimedia network.

As in infrastructure/backbone networks, QoS is required in its access network in the WMNs. To provide QoS to each end-to-end user is very hard task. The following are some protocols that are used to provide QoS [17-22]

- Integrated Servie (Intserv): It provides the QoS and guaranteed per-flow. Most of the router uses Intserv
- Differentiated Service (Diffserv): It provides QoS and guaranteed per-flow class. But some of the routers implement it.
- Frame Relay: Basically used in the wide area network. Mostly packet switching techniques uses frame relay concept.

1.9 Motivation

QoS is the main issue in any network. In WMNs to provide QoS to each end-to end user is very difficult task. Delay in packet delivery, loss of packets, low throughout, load and the capacity degradations are the main issues of degradation of QoS. To overcome the problem of load on the network; Load Balancing Adaptive Scheduling with Minimum Packet Loss (LBASMPL) algorithm is proposed.

To implement LBASMPL algorithm queues are used at MC as well as at MR. The dropping of packets at queue is done according to the Time Division Multiple Access (TDMA) manner. This whole scenario is simulated and evaluates its effects in the network. For simulation, Network Simulator – 2 (NS-2) is used. NS-2 is the collection of all network protocols for simulation of the network topologies.

While simulating the LBASMPL algorithm, this new algorithm is compared with the previous Load Balancing Adaptive Scheduling (LBAS) algorithm [23]. The comparison between Rate of Request (RoR) and load is also done. To overcome the problem of load on the network LBASMPL algorithm is simulated at NS-2 and analyses the results.

1.10 Thesis Outline

This thesis consists of 7 Chapters and they are organised as follows:

Chapter 1 explains the introduction about WMNs, Routing protocol, routing protocol metrics and QoS approaches. Chapter 2 describes the survey on various load balancing techniques, channel assignment techniques and queuing approach. Chapter 3 introduces the problem statement and objective. Chapter 4 introduces the assumed network model and problem formulation. Chapter 5 introduces the implementation part and simulation study. Chapter 6 shows the result of simulation and finally, in Chapter 7 the thesis is concluded and future scope is given.

Chapter 2

Literature Review

2.1 Literature survey

Numerous studies have been done in past to overcome the problem of load on the network and provide QoS to the network. Many load awareness scheme have been proposed to balancing the load on the network.

The issues of balancing the load were hugely come under few years back. Cardellini *et al*. [24] had worked on web server systems that are distributed in nature and reviewed the state of the system in load balancing concept. They developed the need for web server architectures that is distributed in nature and it meet the end-users requests to meet the dynamic changing and available requirements. They also worked on the load balancing and review the state of the system and find the requirements and the disadvantages of the technique.

Bryhni *et al.* [25] had described the comparison of the load balancing methods for web servers; they worked on the different technique of load balancing and do comparison between their performances. This comparison was done on the basis of trace-driven and did the simulation on the traces from the service provider. This method was used to balance the load on the network and find out different load balancing techniques that were basically based on the redirection of the requests and redirection of mapping into the DNS, e.g., mapping in between canonical name and the IP address.

Schroeder *et al.* [26] had given the overview on the clustering technique. They worked on the web server cluster. They broadly classified the transparent web server into three categories. The authors had worked on the products and the sample of the commercial networks. Farshid *et al.* [27] had worked on the IEEE 802.11 Distributed Coordination Function (DCF) throughput model for MAC protocol. This model was optimistic for the protocol parameters and for the hop-to-hop ad hoc networks.

Mustafa *et al.* [28] had designed the M/M/MGI/K queuing model. This model was worked for the IEEE 802.11. These queuing were helping to find the contention conditions such as contention window size variations. The analysis was on the basis of probability in collision, probability in transmission and contention window size.

Tickko *et al.* [29] had designed the model that was evaluated the queuing delays and the access time of the channel in the IEEE 802.11 model. The service time provided to each queue is calculated by accounting number of factors, such as channel access delay, impact of collision in the packet and the distribution of the packet size. The authors proposed a model that worked on the arrival pattern of the networks, the distribution size of the packet and the number of nodes present in the network to find out the delay and the characteristics of the queues. For calculating the service time for queue it was calculated by the number of factor such as delay in channel access, impact of packets while collision and by calculating the back-off time.

Bisnik *et al.* [30] had worked on the G/G/I queuing network and find out the maximum end-to-end delay and the throughput of the network achieved maximum. They developed a structure that takes input as the number of nodes, arrival process of random packets, the traffic locality, back-off and the mechanisms of collision avoidance. It used the diffusion approximation to evaluate close to the expression for finding the end-to-end users delay.

Bruno *et al.* [31] proposed the network model that accurately defined the capacity of the network in the mesh networks and that was basely based on the queuing model. They developed a new algorithm, i.e., Load-Aware Route Selection (LARS),that helped in the improvement of the network capacity. They proposed a new multi-class queuing network that finds the throughput allocation in the mesh networks. They proposed the new Capacity-Aware Route Selection (CARS) algorithm that gave the direction upstream and downstream the flow of the internet packet for better utilization of the network. By doing this, the utilization of the resources increased such as gateway and the internet connection.

Ancillotti *et al.* [32] had worked on the load balancing problem and the capacity of the network and calculate the capacity and proposed the new queuing network model that defined the unused capacity of the path taken by the network. They developed a load-aware route selection algorithm that gave 240 % improvement in throughput over the existing model. Mo *et al.* [33] had given brief on the window based congestion control protocol. It worked on the packet-switched network combine with the First-come-first-served based routers. The developed algorithm used only the information that is present at the end user only.

Paganini *et al.* [34] had given brief on the congestion control system that helped to find the capacity of the network. It provided the high utilization of the resources, low queuing delay. They used the packet marking technique to find the congestion from link to sources. The proposed algorithm provided the fairness among the end user. Zhao *et al.* [35] proposed a novel gateway load balancing aware multicasting mesh network. They took the load balancing with respect to the multicast traffic flow on the gateways.

Sathappan *et al.* [36] had work on the issues in the task scheduling in the distributed system. The main goal was worked on maximize the throughput and reliability and decreasing the make span. The algorithm that was developed is the combination of the Bacteriological Algorithm (BA) and the generic algorithm. The developed algorithm worked on the real time applications and compared the results with the existing algorithm.

Quan *et al.* [37] had designed a data rate allocation algorithm that depends on utility-based and it provided the more quality mobile video-streaming. They designed the algorithm that helped to find out the data rates for maximizing the utilities. Surasee *et al.* [38] had developed an algorithm for the Inter-Vehicular Communication System (IVCS) that provided the QoS to the network it used the adaptive balancing of load concept. It adjusted to traffic according to the priority. In the multi-medium voice was set as high and the video were set as medium and the data was set as the lowest priority. The authors developed the algorithm that is the extension of the Adaptive Rate Control (ARC) and namely as PTM. They took video and data as lowest priority and evaluated their results on different -different scenario.

Yang *et al.* [39-41] had worked on the location-dependent contention CATT. Ma e*t al.* [42-43] had worked on the load-dependent cost and on the flow admitted on each-flow. Chamy *et al.* [44] had given a brief on the end- to-end window based control. It described the fairness level of the spectrum which was varying from zero to infinity.

Neeraj *et al.* [23] proposed an algorithm Load Balancing and Adaptive Scheduling (LBAS) that found the load index and available capacity of the links; they created a queue model at MR for scheduling the traffic according to the priority. They also calculated the lower and the upper bound of the link. According to the bounds the traffic was forwarded to the same link otherwise dynamically pass to another link. But the main issue of queue at MR was that if the number of traffic increases, the chance of packet loss occurs. The performance of the network got degraded.

Low and lapsley [45] had developed a concept for the control of the flow. The main objective of this approach was to maximize the resource utilization over the transmission. In this approach the source node selected their own transmission rate for their benefit, which decreased the cost of the bandwidth. All the links adjusted their bandwidth according to the source decisions.

Shenker [46] had classified the traffic types and their flows in WMNs as elastic as well as real system. In the real system time flow, he found the strict latency in the network, e.g., VOIP, video streaming. Elastic flow adapted the flow according to the transmission rate, e.g., email, file transfer etc. Kryvinska *et al.* [47] had proposed a tool for network management. For the management of signal they had proposed queues on the application layer in the network. They had evaluated the performance of steady state such as waiting time and provide the numerical results. Hwang *et al.* [48] had given a new control policy that differentiates clearly the combination of voice with the data traffic. They proposed an algorithm which maintained a queue and the queue contains the traffic related to data that required more bandwidth instead of rejecting those packets; the packets were passed to network when all the resources were free.

Khurram *et al.* [49] had developed an algorithm for multimedia traffic. For storing the multimedia data they used redundant buffer and store the multimedia data in transmit mode. Bahl *et al.* [50] worked on the switching channels; channels were switched synchronously in a pseudorandom sequence so that neighbor node could communicate at the common node. Shacham [51] worked on the switching channels nodes first listen the traffic at the links and for the transmission of packets the sender nodes switched to receivers channels.

Mishra *et al.* [52] worked on the non-orthogonal channels for the purpose of the communication. They had worked on the model and assumed that the first-switching was not capable for radio interface. Wv *et al.* [53] had taken two radios: one radio work for the signal packet such as control packets other was used for the data packets. When one node wanted to send the packet at a channel was based on the signal packets. Gong *et al.* [54] worked on the channel assignment approach and they used the routing protocol for assignment of the channel. They used the control channels for the transmission of the data. Raniwala [55] worked on the tree-based structure network for easily used of channel assignment. Tang et al. [56] worked on the network for the preservation of k-connectivity for minimizing the interference in between the channels. Raniwala *et al.* [57] proposed an algorithm for channel assignment. This channel assignment algorithm was based on centralized load aware.

Ramachandran *et al.* [58] had proposed a measurable-approach for the assignment of the channel at radios. For the preservation of the original topology, one common radio was created at each node for a common channel. But if there were only few interfaces, then this technique was wasteful. And the channel assignment at radio was not a useful technique for a transmission link. Rad *et al.* [59] had proposed a linear optimized model for the assignment of the channel at the interface. Then the neighbors were assigning to these channels. Now, the neighbors that had common channel can communicate. Marina *et al.* [60] had proposed an approach for the assignment of the channel at the communication link in a network having multiple radios per nodes. For minimizing the interference they proposed a centralized approach.

2.2 Load Balancing

Load Balancing is a technique that is used to enhance the resource utilization, the throughput of the network and increase the response time of the network [61]. The objectives for load balancing are to minimize the decision time. The another method of load balancing is Job migration, but it is efficient only when it guarantee that job are submitted reliably and efficiently in case of process failure, system failure, network failure, node crash, degradation and system performance delay in communication and resource failure [62].

Load balancing technique is broadly classified as [63]

- Centralized or decentralized
- Dynamic or static
- Periodic or non periodic

The load balancing methods are designed to increase the resource utilization. It is done by spreading a complete load to the whole resources and utilization of resources increases. This method also minimizes the execution time. There are different type of policies, categories and techniques that give different-different results to the users in different environment.

2.2.1 Categories of load balancing

Load balancing algorithm is classified into two categories:-

- Static
- Dynamic

a) **Static Algorithm:** In this algorithm, tasks are allocated to the network by checking the load; it means how much load is allocated at a time to a node or by checking average load on the network.

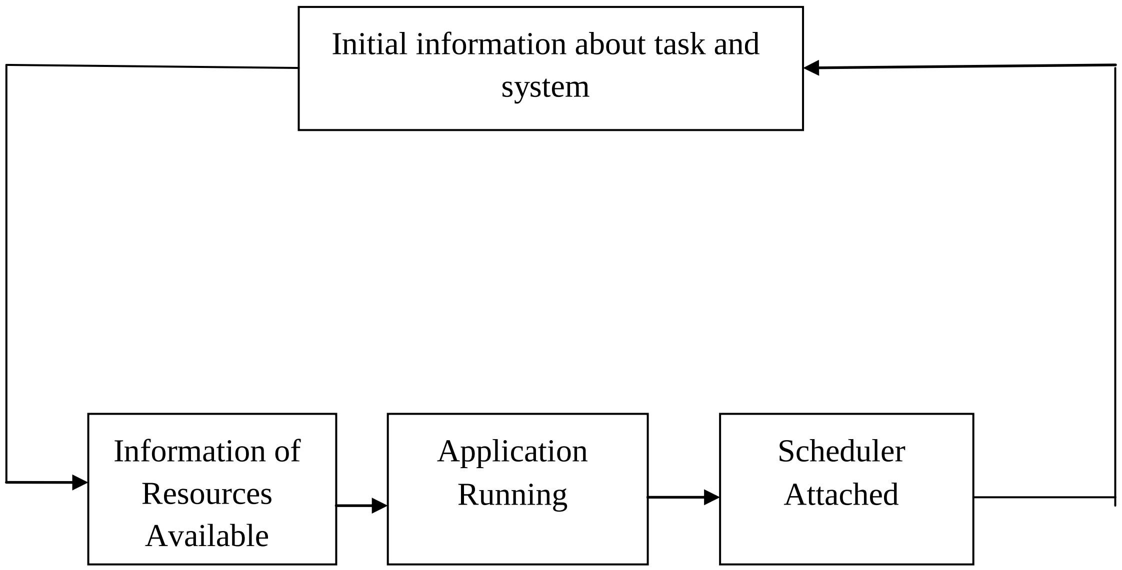

Figure 2.1: Static Load Balancing

The decision is taken at compile time about the load balancing. At compile time requirement of resources are estimated. The main advantage of this algorithm: it is simple in both cases such as implementation as well as overhead. In this algorithm there is no need to watch or monitor the network, traffic and their performance.

The main drawback it work well only in case of there is no variation in the load at a network. Static algorithm is not so good for the WMNs because there is a chance of variation in load at a network. The following are some load balancing techniques are [64].

- Round Robin algorithm: In this algorithm tasks are assigned in the sequential order, the task is assigned according to round robin manner.
- Randomized algorithm: In this process are allocated randomly.
- Simulated Annealing or genetic algorithm: It is the mixture allocation algorithm. It includes optimization techniques.

Drawbacks of static load balancing algorithms

- It is very difficult to find out the execution time of the various part of the program before the execution.
- It might be possible for the occurrence of communication delay.

b) **Dynamic Algorithm:** According to the name, the decision is taken place at the run time. It uses recent and current load information for taking decision.

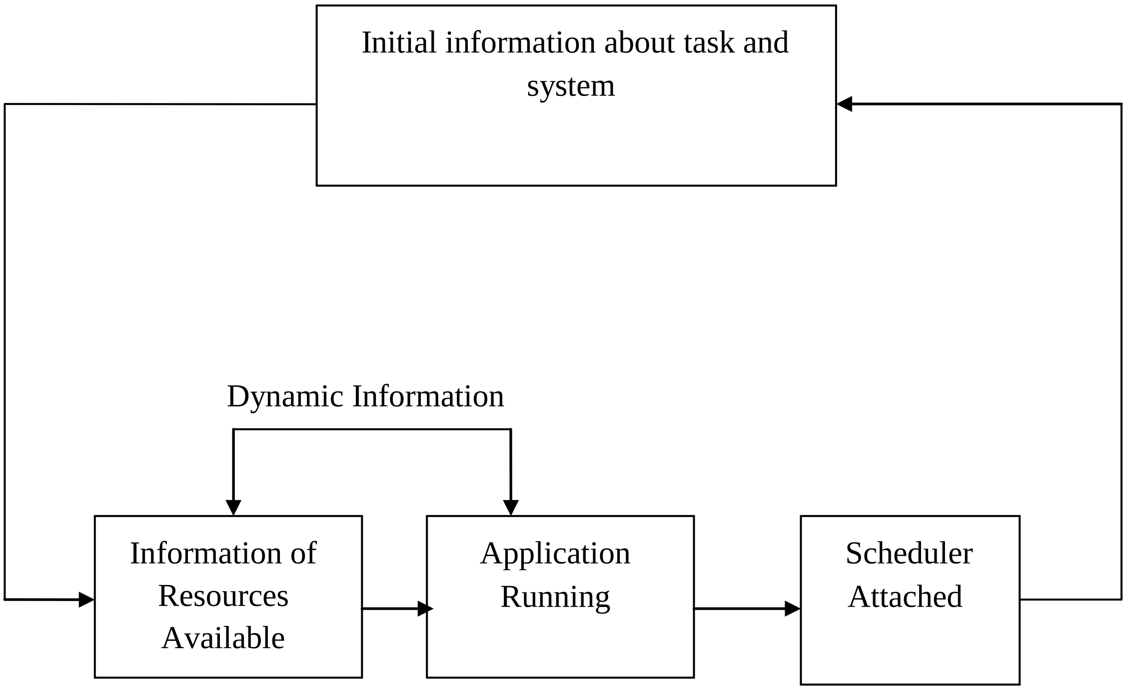

Figure 2.2: Dynamic Load balancing

Dynamic load balancing technique provides better performance than the static load balancing. But the cost required for getting information is high [65].

2.2.2 Load Balancing techniques [66]

Some load balancing techniques are discussed below:

a. Sender v/s Receiver –Initiated techniques: In sender techniques, the congested node tries to move its load to lightly loaded nodes. In receiver-initiated technique, light-weight nodes look for the heavily loaded nodes.

b. Global v/s local techniques: This technique is helped to make a decision of load-balancing in global level. The choice of the global or local technique depends only on the application. In local techniques, network is divided into groups and the main benefit is the information is passed according to group-wise. In global techniques, load balancer is faster than the local techniques.

c. Centralized v/s De-centralized techniques: In case of centralized techniques, the load balancer algorithm is placed at the central node and it takes all decisions.

d. Co-operative v/s non-cooperative: As the name co-operative, the load is balanced co-operatively by the other nodes. If co-operation of the nodes does not taken place then it is called non-cooperative and they can take their own decisions.

e. Adaptive v/s non-adaptive: As a name, this technology adapts the previous predefined decision, system information that affects the previous decision and environment and in case of non-adaptive the parameters remain same unless the past behavior.

f. One time assignment v/s Dynamic assignment: In case of one time assignment the task is assigns only one time to the node until the communication is finished. But in case of dynamic assignment the task is assign to all nodes dynamically until it completes.

Main features of centralized techniques are:

- In the centralized technique master/main node is the main node which collects all the tasks and it has all further information about the task.
- It selects the node according to the task.
- After execution of one task another task is executed.

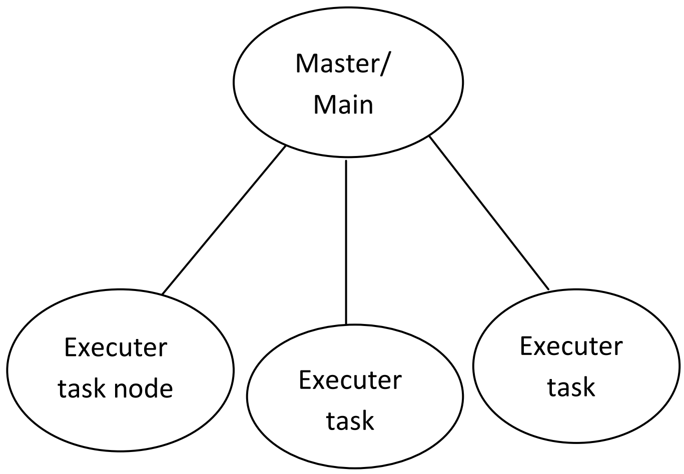

Fig 2.3: Centralized technique [67]

In centralized techniques, it is less scalable then the decentralized. The decentralized techniques help to solve this problem. It is scalable in nature. Centralized technique requires "one-to-all" exchange information which is not scalable in nature. But decentralized technique does not require "one-to-all" exchange information [68].

Decentralized technique: In de-centralize scheme, the load-balancer is present at all the nodes. For the selection of job different algorithms are used, e.g., round robin, random polling etc[69].

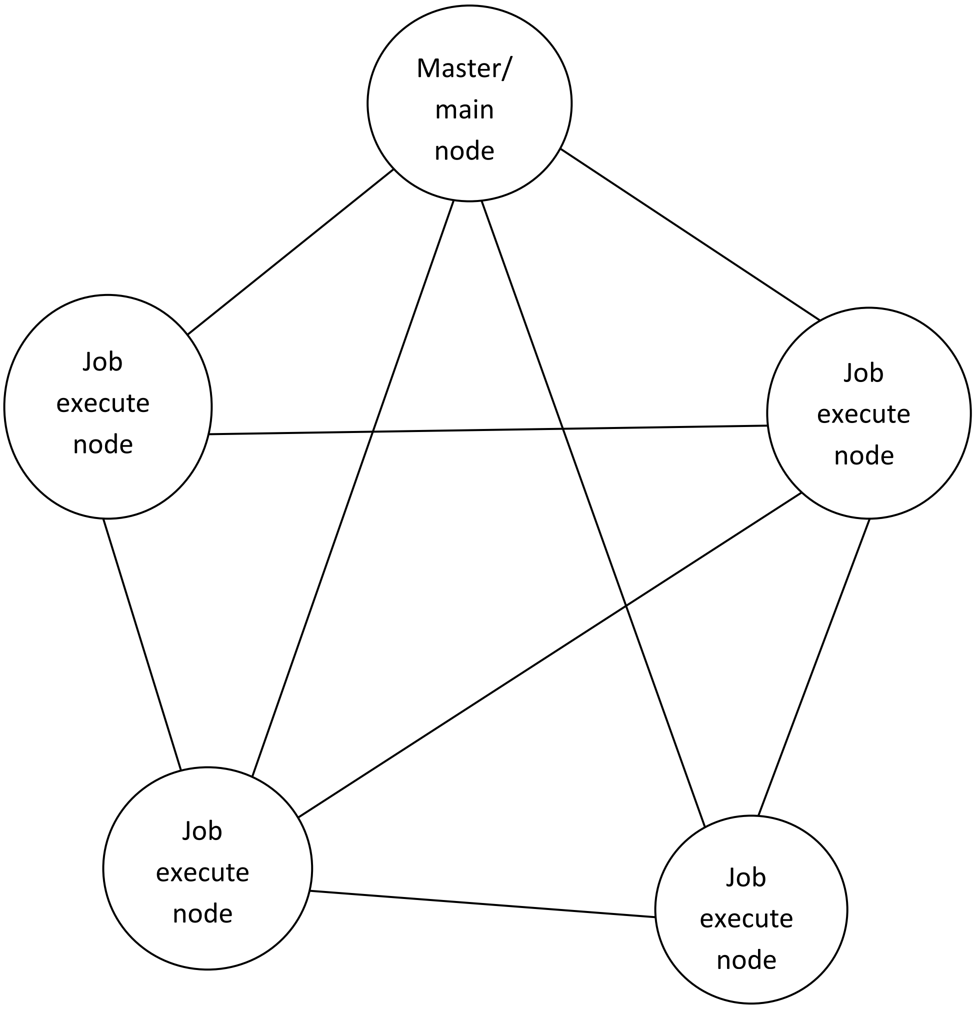

Figure 2.4: Decentralized technique

2.3 Queue Management

The main issue in the network is congestion which affects the entire performance of the network. For the stability in the network congestion control algorithm uses the queue mechanism. These queues are maintained at the routers. Queue Management is proposed by the IETF at the routers for the detection of congestion inside the network. The main effect of the congestion; large amount of packet drops, delay in packet delivery. These causes are done because the overflow of queue.

2.3.1 Drop Tail

It is one of the simple queue methods that is used by routers when there are large number of packets in the network and the packets have to drop down. When the number of packets entered into the queue and there is no capacity in the queue. Then the queue drops the packets. This cause the slow start problem for the sender and the size of the congestion window become high. The queue uses the FIFO mechanism.

2.4 Queuing theory

It is the mathematical study of the queues. Basically queuing theory is used for the predication of the waiting time and length of the queues. Queuing theory does not use to predict the next event. The main application of the queuing theory is telecommunication, for examine the traffic etc.

2.4.1 Queuing Model

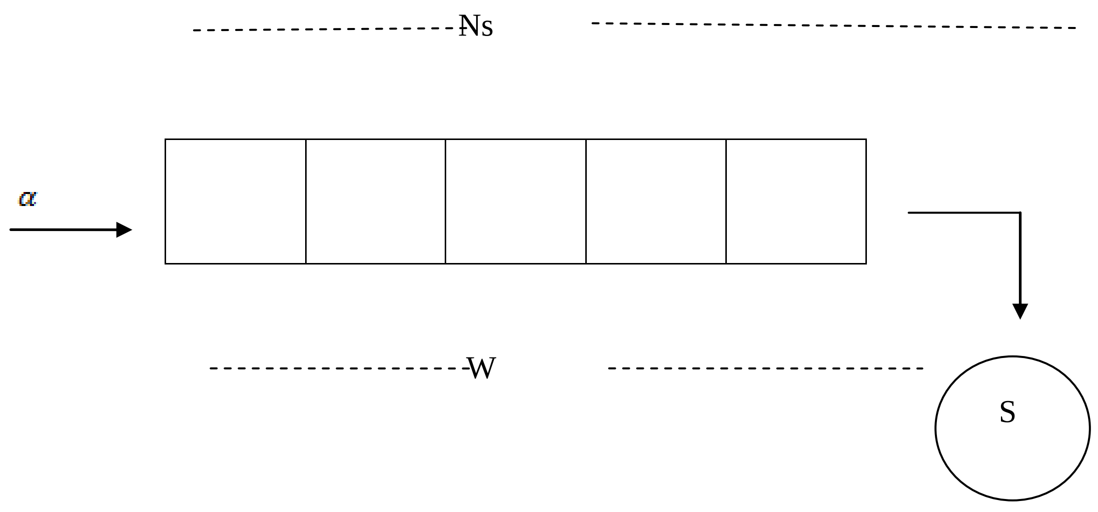

Figure 2.5: Queuing Model

Where α is taken as arrival rate.

Ns is taken as number of system.

S is the service time.

W is waiting time.

α is arrival rate, the time at which packet arrive in the system. Average Waiting Time (AWT) is the average time taken by the packets in a queue before processing. Total time taken by the System (TS) is the time spent by the packet in the system. It might be waiting as well as processing time.

$$TS= AWT + S$$

2.4.2 Queuing model for M/M/1

In this model the arrival and the service time both are exponentially distributed. This model have single server.

Table 2.1 shows the different model of the queuing theory.

Table 2.1: Queuing models

Models	Description
M/M/1	Single-server model, arrival rate is based on the poisson distributed and service time is exponentially distributed.
M/M/n	Multiple-servers model; arrival rate and service distribution both are exponentially distributed.
M/D/1	In this model arrival time is exponentially distributed and the service rate is fixed.
G/M/1	In this process arrival rate is generally taken as 1 and the service time is exponentially distributed.
G/G/1	Single-server model; arrival and service time is generally distributed and it severs the entire request in first-cum-first service based.

G/G/m	Multiple-server model; arrival and service time is generally distributed.
M/G/m/m	This queue model is of finite capacity. All the states are probably distributed in this model.

Chapter 3

Problem Statement and Objective

In chapter 2, the detailed survey about the load balancing has been discussed. Chapter 3, discuss about the objective as well as discussion on the problem statement.

3.1 Problem Statement

Thesis carried out the detailed survey of the load balancing with minimum packet loss and their counter measures for the balancing of load and minimizing the loss of packets. The work discuss about the issue related to the QoS of the WMNs. When the number of packets have to dropped due to reason of load on the network. In this thesis, how to overcome this problem is discussed.

3.2 Objective

Objective of the thesis is to implement LBASMPL algorithm in WMNs. This algorithm includes three phases. These phases are discussed as follows:

- Pass the traffic through TDMA basis.
- Calculation of Total Capacity (TC) of the links.
- Assign the load to the link according to the capacity.

Chapter 4

Network Model and Problem Formulation

4.1 Network Model

The WMNs architecture is shown in the Figure 4.1, as we know that WMNs is the combination of the stationary as well mobile nodes.

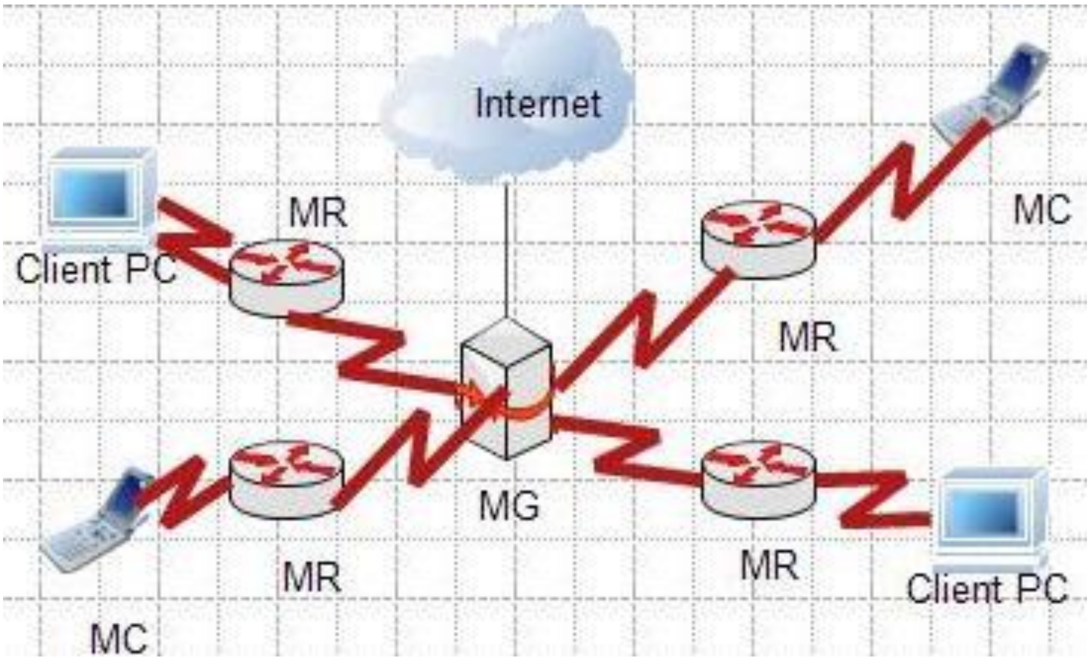

Figure 4.1: Architecture of WMNs

4.1.1 Mesh Client

MC is stationary in nature. Mobile phone, laptops, desktop etc are the example of the MC. The packets requests from MC are going to MG through the MR. For overcome the problem of packet loss, queues are generated at the MC and these queues are work through TDMA manners. The size of the frame is taken same as the number of MC due to overcome the problem of starvation. The packets in the queues are arranged in the priority wise. The high priority packet is pass in TDMA manners to the MR. When any MC have turn to send the packet, it send its packet, these packets are arranged in the priority queue. The next TDMA frame slot goes to the next MC for collecting their packets. This process helps to reduce the packet loss. By doing this, not all the packets are sent together but some packets that are in TDMA frame will drop at MR.

4.1.2 Mesh Router

The packets requests from MC are going to MG through MR. Queues are generated at the MR and when the packets requests comes from MC, these packets are passed through the MR to MG. if the number of packets are more than the size of queue buffers than these packets are dropped. For overcome the problem of loss of packets queues at MC send their packets in priority and TDMA manner. Now the MR has less number of packets rather than before. This reduces the flooding at the MG.

4.1.3 Mesh Gateway

It is the interface between the two clients. When one MC want to communicate to another MC, and these clients are not directly connected to each other then the packet request of one client is pass to another through MR and MR pass these packets to MC through MG, e.g., if a network have 10 nodes and they have 100 packets to send if all the nodes send their packets at a time then there is chance of flooding at MG. To overcome flooding at MG; MR sends the packets in priority wise and it resolve the packets priority wise.

4.1.4 Queue

The queues used at MC and MR are drop tail in nature. Priority scheduler is attached with these queues. Drop tail queue is a queue when we add packets in it, if there is no capacity in the queue then queue will drop the packets. When priority scheduler is attached to the drop tail queue, it will take the packets in the priority wise. The packets that have high priority are entered into the queue before the other packets.

The proposed model for LBASMPL algorithm shown in Figure 4.2, queues are generated at the MC and MR. The queues at MC are passed through TDMA manner to MR.

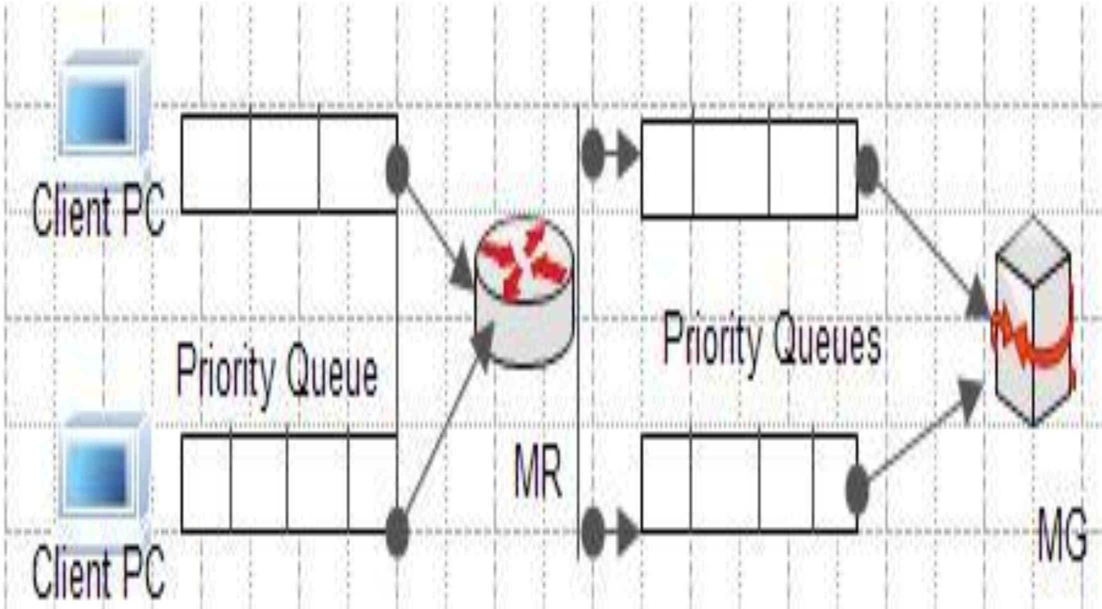

Figure 4.2: Architecture of proposed system

Let suppose WMNs is represented as as G = (V, E), where V is the set of vertices. i.e. V= $\{v_1,v_2,\ldots\ldots..,v_n\}$ and edges i.e. E = $\{e_1, e_2,\ldots\ldots, e_{n}\}$ in the architecture. Let the set of Traffic Flow (TF), the set of Priority be P = $\{p_1, p_2, \ldots\ldots\ldots,p_n\}$. Scheduling is done through priority basis. Each flow is defines as {0, 1} form. When the value of flow is 1 it means flow is passing through the link, otherwise its value is 0. Estimation of Delay (ED) is also associated with the flow, Ln be the set of links. We have calculated the Propagation Delay (PD) for the calculation of the Cost Evaluation Function (CEF). Variable Load Index (VLI) is calculated before allocating the load to the link. VLI is calculates by using FS, equation 4.2, λ, α_i and p_i to find out the load on the link at a particular time interval i.e.

$$\text{VLI} = (p_i * \alpha_i * \frac{FS}{\lambda} * b_{ij}) \quad (4.1)$$

Where $1 \le i \le n$, α_i is the request arrival rate from the MC. λ is the bandwidth of the link.

Frame Size (FS),

$$b_{ij} = \begin{Bmatrix} 1 & | & uplink \\ -1 & | & dpwnlink \end{Bmatrix} \qquad (4.2)$$

Service time and the mean load of the link is calculated a

$$E(\mu) = m \qquad (4.3)$$

$$\beta = \left(\alpha * m * \frac{FS}{\lambda} \right) \qquad (4.4)$$

Where μ is the service time and the m is the service rate. The ED is calculated by the time required for job submission to the total time in processing that job. Each link has the bounds such as upper bound and the lower bound on TC. This upper bound and the lower bound is used to find the threshold on the link capacity. When the load on the link is crosses the upper bound than the load is automatically transferred to another link dynamically at run time. This process is called the load shifting dynamically.

The CEF is calculated by using the equation 4.5, PD, Ln, TF, TC, throughput for a link is defines as:

$$CEF = \frac{\sum_L VLI * PD}{Ln * \sum TF + \sum_L TC + throughput} \qquad (4.5)$$

.

The main objective is to minimize the CEF.

Chapter 5

Implementation

As shown in Figure 4.1, MC packet requests are sent to MG through MR, to overcome the problem of packet loss; when there is large number of packets come from MC to MR, LBASMPL algorithm is proposed. VLI is calculated before passing the traffic to the link.

5.1 Phases of proposed algorithm

There are three phases in the proposed algorithm:

- Pass the traffic through TDMA basis.
- Calculation of TC of the links.
- Assign the load to the link according to the capacity.

A. Pass the traffic through TDMA basis.

For prevention of packet loss at MR, priority queues are created at MC. These queues are generally drop-tail; priority scheduler is attached to the queues. The priority of the packets is set from 1 to p. 1 is set as maximum priority and p is set as minimum priority. The assignment of the priority is done by the client itself.

Now, the processing of these packets is done according to the TDMA basis. The size of the frame is generally taken as the number of clients otherwise there would be chance of starvation. After taking the round trip from the entire MC, the TDMA frame drops the packets to the MR.

B. Calculation of TC of the links.

Before assigning the packet load to a particular link, the capacity of the link is calculated. This is done for the load balancing. For calculation of the load on the particular link, we generally use the M/M/1 queue. This queue is applicable for this type of model. Let α be the arrival rate and the distribution of the packet is done according to the Poisson distribution and let X be the number of arrival rate then

$$P\{X=n\} = \frac{\left(e^{\alpha}T\right)\left(\alpha T\right)}{n!} \qquad (4.6)$$

The inter-arrival time is independent of the service time. The value of TC is calculated by dividing the VLI with the flow of packets.

C. *Assign the load to the link according to the TC*

Once the TC of the link is calculated, the traffic has to be load according to the capacity of the link. The priority is assigned to the traffic so, the higher prioritized traffic load on a particular link before the other. This process is done by creating the matrix. The higher priority load is getting the first position in the matrix. According to the priority the position is set in the matrix. The higher prioritized traffic is assigned to the link which has high TC and low ED.

In the initial step the priority queues are assigned to the MC. Packets are assign to the TDMA frame for the further processing. After the placing of packets to TDMA frame these TDMA frame are assign to the MR. Before allocating the flow to any particular link the TC of the link is calculated as well the upper bound and lower bound of the link is calculated. After calculation of the TC the load is assign to any particular link, the high priority traffic is assign to the link which has low CEF.

Algorithm LBASMPL

Inputs: G (V,E), CEF of the link

Outputs: load balancing with minimum packet loss.

1: initialization of priority queue at MC

2: *for (i=1,2,3...., n)do*

3: Assign the packets in the frame according to TDMA

4: *endfor*

5: Repeat

6: Accept the TDMA frame from MC

7: Define the arrival and inter-arrival time of the packet.

8: Calculate the TC of the link by dividing it with VLI.

9: Calculate the CEF for each link from eq. 4.5

10: Calculate the Upper (UB) and Lower (LB) Bound of the link

11: $if\ (VLI > threshold\ \ value) then$

12: Find the link having minimum CEF

13: Assign the traffic to link having minimum CEF

14: *elseif (CEF > 1)*

15: Make the entry of the flow in the load matrix

16: Place the flow in matrix until step 11

17: *else*

18: Discard traffic

19**:** End if

20: until

5.2 Network Simulator (NS-2)

In this section, the Network Simulator (NS-2) is described in brief [70] In both the wired and wireless networks for knowing the dynamic features of the congestion and flow control mechanisms it has been supposed as the variant of the real network simulator. NS-2 has developed around 1989 and is being supported by various societies and institutions to carry out their simulation works. NS-2 is used basically in network related research works and is an event driven simulator. With the help of it several protocols, algorithms, traffic sources, etc. can be implemented. NS-2 offers or also supports for the simulation of TCP, multipath protocols and routing over both the wireless and wired networks.

For the purpose of simulation NS-2 uses the programming language Object Oriented Tool command language (OTcl) at the simulating layer for transcripting the simulation scripts given by the users [71]. OTcl programming language is an objected oriented extended version of the Tcl Language only. The Tcl programming language is compatible with the C++ programming language. Thus NS is basically used for interpreting the user Tcl scripts.

During interpretation of the OTcl script two files are generated in the NS in which the analysis or results are present. These two files are the trace file and the Network Animator (NAM) file. In the NAM file the visual animation of the whole simulation is being shown. On the other hand, in the trace file the output of all the objects created in the simulation is shown.

Various packages such as ns, NAM, tcl and tcl etc, comes along with the NS project. The package is then named as all-in-one package. But these all utilities can be even separately downloaded and installed. In this work, the stable version 2.34 of ns all-in-one package is utilized which is installed in the Ubuntu environment. In this, the work is in the .tcl files which are to be written in the hex editor and then correspondingly the output is analysed in the .tr files in which the traces of the output values of each object are stored.

5.2.1 Mobility Model

The mobility model is used for generating the detailed scenario of the motion of nodes in the area of simulation. In most of the simulations the Random Waypoint mobility model is employed. In this particular model the nodes move from one waypoint to the next with a randomly chosen speed. In each transition a specific speed and duration is chosen. After the stipulated transition time ends the node may stops for a certain time before starting its transition towards the next waypoint. The nodes in the simulation set up move randomly according to the model which is known as the random waypoint model that selects the rectangular field.

5.3 Simulation Set up

The network model is formed taking mesh network having 20 nodes to large scale (up to 400 nodes) mesh nodes. In simulation the mesh nodes have packets to send and implement the User Datagram Protocol and Internet Protocol as the transport and the network layer protocols. The packet losses at the network layer have taken in this simulation setup. But on the other hand, the packet losses at the media access control are still assumed. The packet size is taken here to be 512 byte. Each node is wireless communication card with the transmission range of 100 metres operating in the 2.4 GHz radio frequency band. In order to analyse the scalability property the number of nodes taken for simulation are varied from 20 to 400 nodes and the simulation time taken for which the nodes keep in motion is taken to be around 50 seconds. As the numbers of packets are increased for determining the simulation considerably the area of simulation is also increased. At the same time the density of the whole areas is kept constant. The density of the area is kept constant so that the issues such as contention and collision over the wireless sharing channel.

The simulation is set up over such an environment in which the nodes can move freely without any collision in a square type two-dimensional flat area. The motions of nodes are depended upon the mobility model described above in section 4.8. While simulation the nodes choose unusual speed upto 1 to 3 m/s. The simulation parameters taken are given in Table 5.1.

Table 5.1: Simulation Parameters

Interface	Wireless
MAC Protocol	IEEE 802.11b
Network Protocol	IP

Transport Protocol	UDP
Packet size	512 byte
Mobility Model	Random waypoint
Simulation Area	1000 * 1000
Simulation Time	50 second
Number of Nodes	20 to 400
Node speed	1 to 3m/s
Transmission Range	100 m
Radio Frequency	2.4 GHz
Traffic Model	CBR
Protocol	AODV
Queue length	Equal to Number of nodes
Bandwidth	2 mbps

Chapter 6

Results and Discussions

In this chapter, the performance of the LBASMPL algorithm is analysed and using an underlying ad hoc routing protocol compare it to the LBAS algorithm [23]. The underlying protocol used for the basic simulations is AODV routing algorithm because of its on-demand property and popularity. AODV is on-demand protocol in which when a node need route to destination it initiate a route discovery process.

6.1 Performance metrics

For calculating the performance of the network different metrics are used. Some of the metrics of the network is discussed here. In this chapter results are discussed that are based on the different parameters.

- Throughput

  This parameter defines the successive ratio of the delivery packet to the network. It describes how fast the packet is delivers to the network.
- Response Time

  This parameter defines the total time taken by a network to response the particular packet request. It describes when the network responses to the packet request.
- Packet Loss Rate

  This parameter defines the rate of packet loss in the network. It means it defines how much packets falls to reach at its own destination. In the video streaming and multimedia packets this causes the jitter effect.
- Load on a Network

This parameter defines the total load on the link. If the load on the link increases then the loss of packet is also increases. The main motive of this parameter is to decrease the load on the link and increases the response time of the network.

- Link Capacity

  This parameter defines the capacity of the link. When the packet has to send at a particular link, the capacity of the link is calculated. For allocation of the load to a particular link AC and LI is calculated for a link then the packets are delivers to link according to the CEF.

- Rate of Requests

  Rate of Requests is defined as the number of total packets sent by the node. The packets sent include very packet sent from node such as the routing layer packet and the upper layer packet such as data and data requests packets. In this criterion the uni-cast and broadcast packets both are treated as single packet. Generally this parameter helps to calculate the message overhead involved in solving data lookup problem with or without replication.

6.2 Results and Analysis

Figure 6.1 shows the throughput comparison in between LBAS and LBASMPL w.r.t RoR.

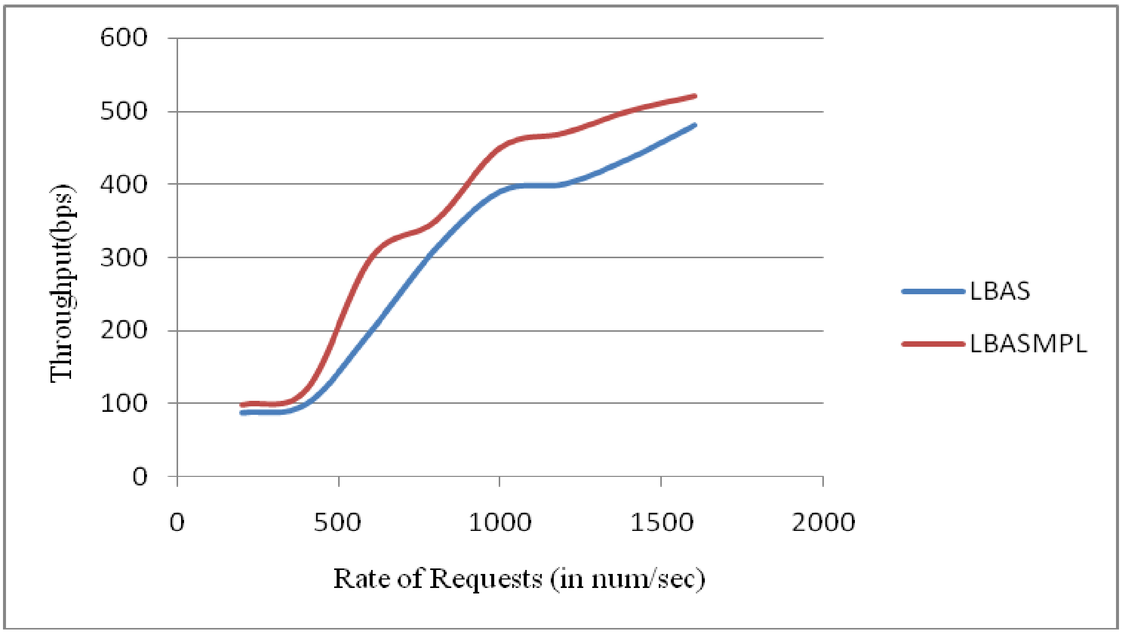

Figure 6.1: Throughput comparison in between LBAS and LBASMPL

RoR is calculated with the help of equation 4.6, As per the figure 6.1 that the throughput of the proposed LBASMPL is higher than the previous algorithm LBAS. The main reason for this is scheduling the traffic according to priority and creating queues at MC. All the traffic at MC is also come across according to priority manner and these queues take the packet according to the TDMA manner. One of the main reasons is also that all the traffic is assign to the link according to the CEF. The link that has minimum CEF, the traffic is passes to that link, along the CEF, TC is also calculated. Based on these factor our proposed algorithm have higher throughput than the previous algorithm LBAS.

Figure 6.2, shows the comparison in between proposed algorithm LBASMPL and previous algorithm LBAS w.r.t to response time and the number of requests from the MC.

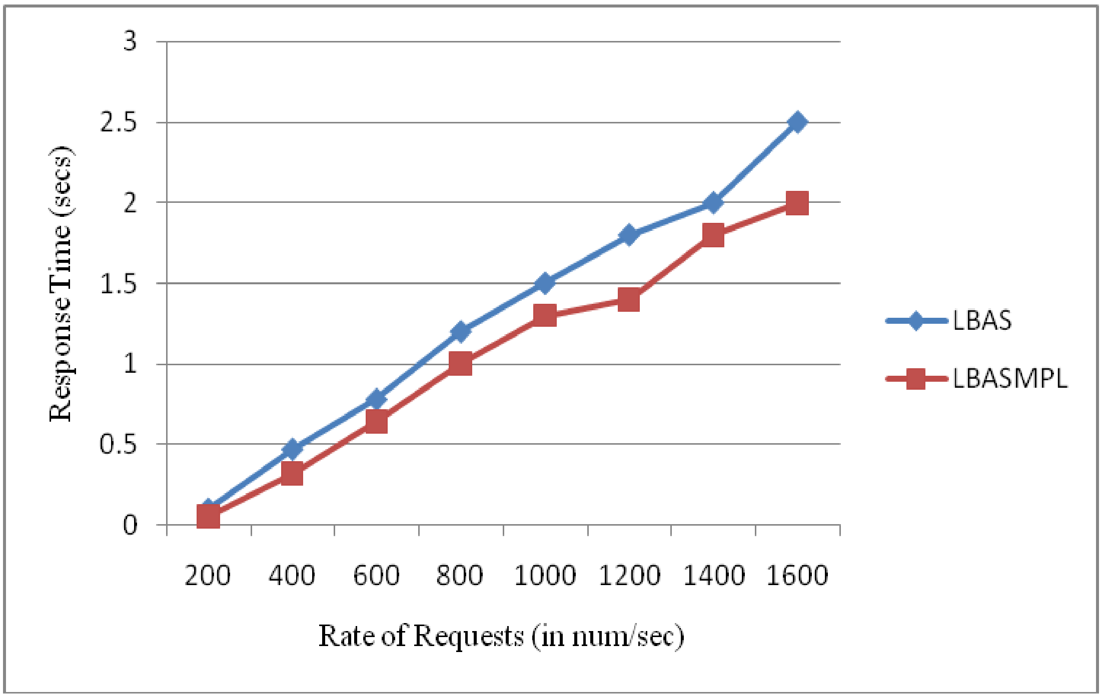

Figure 6.2: Comparison of response time w.r.t RoR between LBASMPL and LBAS.

The response time is increases as the RoR increases. But according to the figure 6.2, it shows that the response time of proposed LBASMPL algorithm is less than the previous LBAS algorithm. The main reason is that of using queues at MC and the queues work according to the TDMA manner .Other MC has to wait for the packet to send until they have their own turn to send the packet and the queue that is used by the MC have frames equal to number of MC. If one MC has to send packets more than one then, MC has to wait until its own turn. Because of these factors the response time of the proposed LBASMPL algorithm has less than the previous LBAS algorithm.

Figure 6.3, shows the comparison in between proposed LBASMPL algorithm and previous LBAS algorithm w.r.t to link capacity and the rate of packet loss.

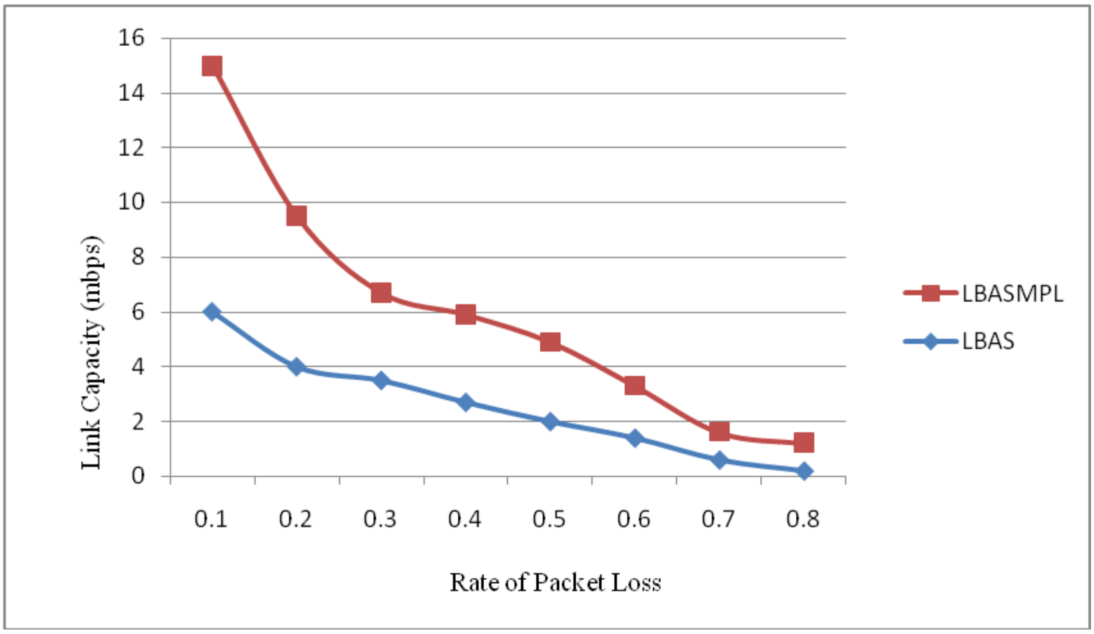

Figure 6.3: Comparison of link capacity w.r.t rate of packet loss between LBASMPL and LBAS

In this figure 6.3, its shows that the capacity of the link increases in the proposed LBASMPL algorithm. When MC has packets to send, the packets are arranged in the priority based. After arranging the packets in the queue according to the priority; the TC of the link is checked and traffic is passed to the link according CEF. The link that has minimum CEF the traffic is passed to that link. In this scenario packet loss rate is taken as same. If there is less packet loss than the capacity of the link automatically increases. If there is packet loss then the retransmission will require bandwidth and the capacity of the link will get decreases and the performance of the network system will get degraded. From the figure 6.3, it shows that the link capacity of the proposed LBASMPL algorithm is high than the previous LBAS algorithm, because the MC sends their packet in priority wise and in TDMA manner and calculate the TC of the link.

Figure 6.4, shows, the success ratio w.r.t RoR in between the proposed LBASMPL algorithm and previous LBAS algorithm

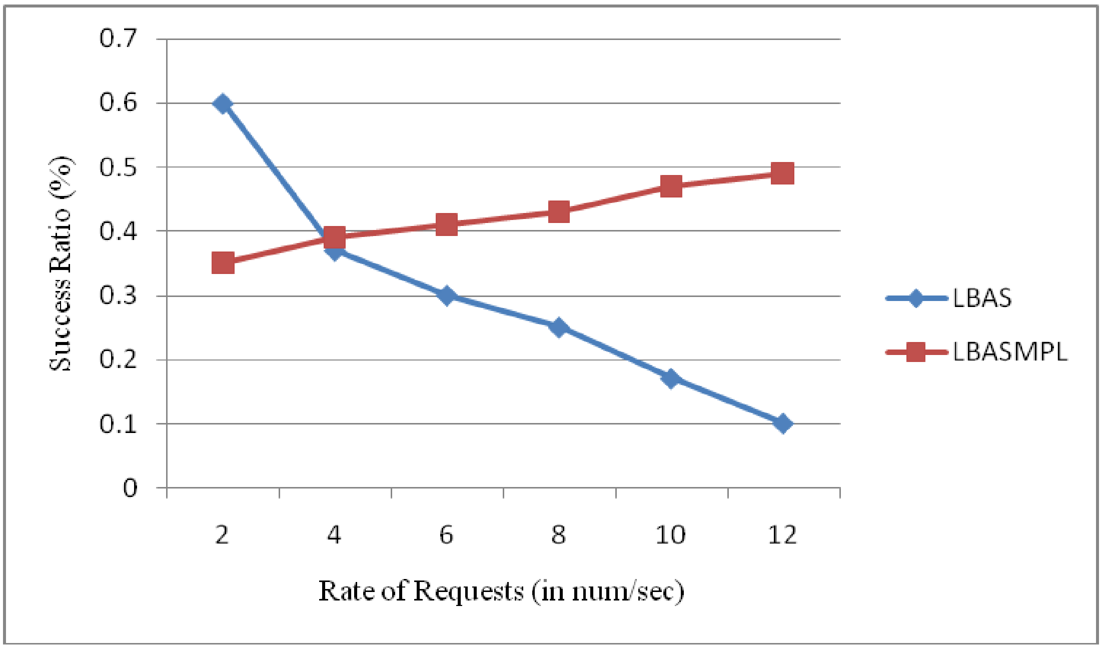

Figure 6.4: Success Ratio w.r.t RoR between LBASMPL and the LBAS.

In this figure 6.4, it shows that the success ratio of the previous LBAS algorithm is high at one point. When the request rate increases the success ratio of the previous LBAS algorithm get decreases and the success ratio of proposed LBASMPL algorithm is higher when the number of request rate increases. From the figure 5.4, it found that the performance of the proposed LBASMPL algorithm is higher than the previous LBAS algorithm.

Figure 6.5, shows the general information of load w.r.t RoR.

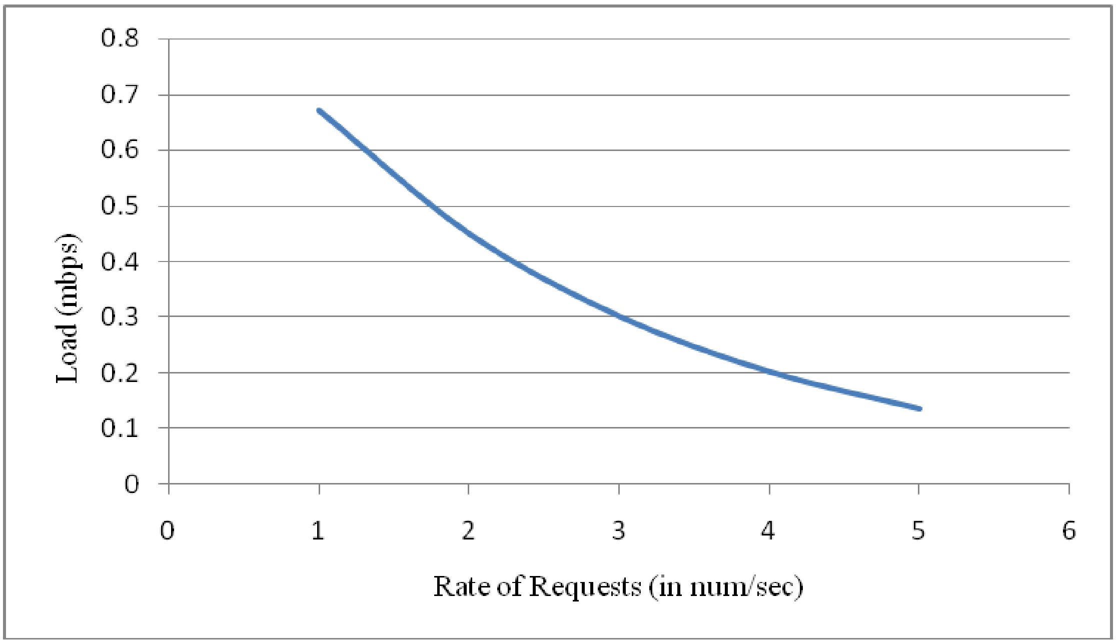

Figure 6.5: Average load w.r.t RoR

From figure 6.5, it shows the load on the network w.r.t RoR. When number of request send by the node increases, the load on the network decreases. In our proposed LBASMPL algorithm when MC has packet to send. They have to wait for their turn on the queue and all the packets are sent according to the priority wise. When packet has to send at network; TC of the ink is calculated and according to CEF the packets are passing to the link. All these concepts reduce the load on the network as the chance of packet loss decreases and network will not require extra bandwidth.

Chapter 7
Conclusion and Future Scope

7.1 Conclusion

Minimum packet loss, load balancing and scheduling are the main issues for maintaining QoS in WMNs. The traffic should be passed from source to destination using minimum packet loss, high throughput, minimum congestion, delay etc. In this thesis, LBASMPL algorithm have been discussed and analysed. This algorithm helps to minimize the packet loss in the network and provide the QoS in the network for minimizing the packet loss at routers. TC and the VLI is calculated for each link and all the traffic is assigned to the MR according to the priority and TDMA manner. We have calculated the CEF for each link. We also find the ED. The proposed algorithm is used basically for minimize the packet loss.

7.2 Future Scope

LBASMPL algorithm is successful for minimizing the packet loss. As TDMA approach has taken for passing the packets into the frames, all the MC can pass the packets according to their slot. If there are two MC, one has normal data to send and second have multimedia data to send. So, multimedia MC requires more frames rather than other. All this work requires dynamically allotment of frames. Dynamically allotment will provide better functionality and it will be done in future.

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List of Publications

1. Tanu Goyal, Neeraj Kumar, "TDMA based Minimized Conflict Resolution Channel Assignment in Wireless Mesh Network", *International Journal of Research in Advent Technology*, Vol.2, No.2, February 2014.

2. Tanu Goyal, Neeraj Kumar, "LBASMPL: Load Balancing Adaptive Scheduling with Minimum Packet Loss" IEEE International Conference on Advanced Communications Control and Computing Technologies (ICACCCT), Syed Ammal Engineering College, Ramanathapuram, Tamilnadu, India, 2014. **[accepted and presented]**