CHAPTER 1

INTRODUCTION

1.1 AD HOC NETWORKS

An Ad hoc network is a wireless network in which the hosts are connected with other hosts dynamically in radio range. The resulting multi hop topologies present many challenges for Media Access Control (MAC) and reliable transport protocol designers, with the potential for dynamically changing routes to a destination, and continuously varying radio characteristics between prospective hosts. This challenge is amplified by allowing multi hop ad hoc networks in that a single wireless network link is not enough to the data transfer.

The transport protocol presents the poor performance over a number of different MAC protocols and this is a major problem in all ad hoc wireless networks. The performance of the MAC protocol such as fairness and delay is the important to the transport protocol. For wireless, and other shared media, one characteristic of poor MAC performance is 'channel capture'. A capture state arises when a given host is able to monopolies the channel resource at the expense of contending connections. With ad hoc networks, channel capture has also been identified as a significant problem, particularly in the presence of hidden terminals (Christopher et al, 2000). The wireless multi-hop ad hoc network provides quick and easy networking in some situations where the temporary network services are needed or when cabling is complex. The IEEE 802.11 Distributed Co-ordination Function (DCF), based on Carrier
Sense Multiple Access with Collision Avoidance (CSMA/CA), is the most popular MAC protocol used in wireless ad hoc networks.

In wireless networks, interferences are location-dependent. For a traffic flow from a source node to a destination node in a multi-hop network, the nodes in the middle of the path have to contend with more nodes when forwarding the traffic of the flow. Experiencing lighter contention, the source node may inject more traffic into the path than can be forwarded by the later nodes. This may result in excessive packet losses and re-routing instability. When there are multiple flows, unfairness may also arise when some flows experience higher contention than other flows. To devise schemes to achieve high throughput and fairness in multi-hop networks, it is important to be able to analyze the contention experienced by a node as a function of the network topology and traffic flows in a quantitative manner. Such an analysis is currently lacking in the literature, possibly due to the fact that the analysis is complicated by the existence of hidden-node and signal-capturing effects.

In a multi-hop ad hoc network, sources may inject more traffic into the network than can be supported. This may result in two problems (Ping Chung Ng and Soung Chang Liew 2007).

- High packet loss rate, and
- Re-routing instability.

The Mobile Adhoc Network has a set of mobile hosts which are operated without the support of established infrastructure of centralized administration such as base stations or access points. In this network, the nodes communicate via wireless links with other mobile hosts by their antennas. Due to concerns such as radio power limitation and channel utilization, a mobile host may not be able to communicate directly with other
hosts in a single-hop fashion. In this case, a multi-hop scenario occurs, where the packets sent by the source host must be relayed by several intermediate hosts before reaching the destination host. The applications of the MANET are getting more and more important, especially in the emergency, military, entertainment, and outdoor business environments, in which instant fixed infrastructure or centralized administration is difficult or too expensive to install (Hih-Lin Wu et al., 2005).

**Advantages**

- Mobile users can access the real-time information even when they are anywhere in the world.
- Network can be extended to places which cannot be wired.
- Wireless networks provide more flexibility and adapt easily with the alteration of network configuration.

**Disadvantages**

- Interference may occur due to weather, other radio frequency devices, or obstructions like walls.
- The existing multiple connections affect the total throughput.
- In Wireless network there is no guarantee of data to reach at destination (Jain et al, 2012).

In order to design good protocols for Ad hoc networks, the essential features of these networks must be studied.
- **Dynamicity:** All the nodes are free to move and hence the topology is generally random. The network status is indefinite.

- **Non-centralization:** This network has decentralized control so that network resources cannot be fixed previously.

- **Radio properties:** Since the channel is wireless, it will be suffered by fading, multipath effects, time variation, etc.

With these limitations, Hard QoS for example guaranteed constant bit rate and delay, is difficult to achieve. The reasons are as follows (Lei Chen and Heinzelman 2005).

- The exact knowledge of the global status of the network is needed in end host to support QoS. Due to the dynamic nature of MANETs, it is difficult for hosts determining the information about their local neighborhood, much less the global status of the network.

- It is hard to establish cooperation between neighboring hosts to determine a transmit schedule for guaranteed packet delivery in decentralized control. The same physical channel is shared by all nodes in MANETs, and the transmissions of each node will interfere among the transmissions of neighboring nodes. Due to this unpredictability, successful transmissions are difficult to guarantee.

- Fading and interference causes unreliability and this is the main deficiency of wireless channel.
1.2 THE IEEE 802.11 STANDARD

IEEE 802.11 was developed for a single access point scenario but now it has become the standard for Wireless LAN’s both in infrastructure and in ad hoc mode (Sylvia Van den Heuvel et al., 2005). Probably this causes many problems and limitations in a pure wireless multi-hop network, where the nodes are not within the transmission range of one another and everyone has to contend for the access to the radio channel. But in wireless terminals, the energy is provided by batteries which have limited amount of energy and limited transmission power. In ad hoc networks, the network topology is determined by power levels so that the energy consumption is an essential factor. The power saving mechanism preserves the energy supported by the standard. Another approach is power control scheme, in which the energy consumption is reduced by varying the transmit power.

The IEEE 802.11 (Wi-Fi) standard is assumed as the basic wireless technology by most of the actual works on ad hoc networking. This standard offers an ad hoc mode and permits the node to communicate directly without any base station. Since radio communication range is limited, a real ad hoc network is operated by a distributed routing protocol which ensures the communication between out-of-range peers is possible. The first task of the ad hoc networking community has been to design such a routing protocol. Many protocols have been and still are proposed through the MANET IETF working group. This field is now mature and new perspectives are tackled, for instance designing more suited MAC protocols, enforcing security or addressing or quality of service. But, the resources available in the network must be estimated by the nodes before providing guarantees on delay, bandwidth or any other metric. Most of the actual propositions rely on the assumption that the nodes are able to perform this evaluation.
When the routing is performed in the network, the remaining bandwidth estimation is needed before completing admission control, flows management, congestion control or routing based on bandwidth constraints. Surprisingly few methods have been proposed so far to estimate the available bandwidth or the radio channel occupancy in ad hoc networks. This task is fundamentally different from its counterpart in wired networks as the link notion differs drastically. The radio medium is persistent and the available bandwidth of every node is influenced by a frame emission from a node. Due to mobility, radio propagation phenomena such as interferences and the distributed nature of these networks makes this task even more difficult (Sarr et al., 2005).

1.3 **IEEE 802.11 MAC**

The Distributed Coordination Function (DCF) of the IEEE 802.11 standard is the most dominant MAC protocol for ad hoc networks. This Alaa Muqattash and Marwan Krunz (2004) protocol generally pursues the CSMA/CA paradigm and in addition RTS/CTS handshake packets are exchanged between the source and the destination. These control packets can be used to reserve a transmission floor for the successive data packets. The control and data packets are transmitted by the nodes at a common maximum power level and the all potentially interfering nodes are avoided to start their own transmissions. Any node that hears the RTS or the CTS message defers its transmission until the ongoing transmission is over.

The four-way handshake procedure such as RTS/CTS/DATA/ACK is used to deal with the hidden terminal problem. Before a node begins to transmit, it should first sense the channel to determine whether there is any ongoing transmission. If the channel is busy, the node is suspended until the channel become idle for a period of DIFS. Then the node randomly chooses a backoff period according to the contention window and starts a backoff timer
to back off. The back off timer decreases by 1 after the channel is idle for the duration of a slot. If the channel is sensed busy during any slot in the back off interval, the back off timer will be suspended. It can be resumed only after the channel is idle for a period of DIFS again. After the back off timer reduces to 0, the sender transmits a RTS omnidirectional. After correctly receiving the RTS, the receiver responds with a CTS after a period of SIFS. Similarly, after correctly receiving the CTS, the sender begins to transmit the data after a period of SIFS later. This transmission ends after the receiver correctly receives the data and responds with an ACK. All four kinds of frames contain an estimated duration of the rest time of the transmission. Other nodes that receive these frames update their NAVs (Network Allocation Vector) with the duration. Every NAV decreases by 1 after a time slot. Those nodes are only allowed to transmit after they sense the channel idle for a period of DIFS after their NAVs expire. (Pan Li et al., 2009) Although this scheme prevents the hidden node problem, it negatively impacts the channel utilization since the parallel transmissions are not performed over the reserved floor.

![Figure 1.1: Scenarios to show (a) The hidden-terminal problem and (b) The exposed-terminal problem](image)

In a MANET, a MAC protocol has to contend with the hidden terminal and the exposed-terminal problems. To see the first problem, consider the scenario of three mobile hosts in Figure 1.1(a). Hosts A and B
are within each other’s transmission range, and so do hosts B and C. However, A and C cannot hear each other. When A is transmitting to B, since host C cannot sense A’s transmission, it may falsely conclude that the medium is free and transmit, thus destroying A’s ongoing packets. The problem that a station cannot detect a potential competitor because the competitor is too far away is called the hidden-terminal problem. In Figure 1.1(b), when B is transmitting to A, host C can sense the medium and thus will conclude that it cannot transmit. However, if C’s intended recipient is D, then such transmission can actually be granted. Such inefficiency in channel use is called the exposed-terminal problem.

To overcome these problems, many protocols have been proposed in which protocols RTS (request to send) and CTS (clear to send) packets are transmitted before the data transmission. When a node wishes to transmit a packet to neighbor, it first transmits an RTS packet. The receiver then consents to the communication by replying a CTS packet. On hearing the CTS, the sender can go on transmitting its data packet. The hidden-terminal problem in Figure 1.1(a) will be eliminated when C hears the CTS packet, and the exposed-terminal problem in Figure 1.1(b) will be eliminated if C is granted to transmit if it can hear B’s RTS but not A’s CTS. Such an approach has been accepted by the IEEE 802.11 standard (Shih-Lin Wu et al 2005).

### 1.4 CHANNEL ALLOCATION FOR AD-HOC NETWORKS

In ad hoc networks, designing the network protocols is a difficult problem. The Medium Access Control (MAC) protocol is a solution and it provides a guaranteed Quality of Service (QoS) since ensuring a fair and maximum allocated channel bandwidth to each subscriber. Due to the lack of the centralized control, each user with data to send should compete with the others for accessing the channel. An exponential back-off scheme is used by most of the MAC protocols for the random access channel allocation strategy.
But, random access channel allocation schemes cannot guarantee to provide
same opportunity for all users to obtain the channel (Yan Ming et al., 2001).

1.5 QUALITY OF SERVICE METRICS

When a packet stream is transferred from a source to its destination,
the network has to meet a set of service requirements which is known as QoS.
The network is expected to guarantee a set of measurable pre-specified
service attributes to users in terms of end-to-end performance, such as delay,
bandwidth, probability of packet loss, and delay variance (jitter). Other QoS
attributes particular to MANETs are power consumption and service coverage
area. QoS metrics may be concave or additive. Bandwidth is concave and the
end-to-end bandwidth is the minimum of all the links along the path. Delay
and delay jitter are additive and the end-to-end delay (jitter) is the
accumulation of all delays (jitters) of the links along the path. Furthermore,
QoS metrics could be defined in terms of one of the parameters or a set of
parameters in varied proportions. Multiple QoS metrics is optimized by multi-
constraint QoS when the network resources are provided and it is a difficult
issue.

The following performance metrics has been considered in MAC
protocol evaluation for wireless mobile ad hoc network.

- **Throughput**: It is the measure of successfully transmitted
  radio link level frames per unit time.

- **Transmission delay**: The time interval among the frame
  arrival time at the transmitter’s MAC layer and the time at
  which the transmitter recognizes that the transmitted frame is
  received by the receiver successfully is refered to as
  transmission delay.
- **Fairness**: It represents the way by which the channel is allocated among the flows in various mobile nodes. The two major factors are influences the fairness are node mobility and unreliability of radio channels.

- **Energy efficiency**: It is the ratio of useful energy consumption to the total energy expenditure.

- **Packet error rate**: The packet error rate is generally calculated by the Bit Error Rate (BER) and the packet length. The receiver estimates the SNR for the RTS packet and gets the BER with a transmission rate by the equations derived from an analytical model (Pillai et al., 2010).

1.5.1 **Issues and Difficulties with QoS Support in MANETs**

Unlike traditional wired Internet infrastructures, mobile multi hop wireless networks have unique issues and difficulties for supporting QoS. Unpredictable link properties, node mobility, and limited battery life are the examples for features of the issues and hidden and exposed terminal problems, route maintenance, and security are characterized as consequences of the issues. These issues are detailed as follows.

- **Unpredictable link properties**: Wireless media is very unpredictable. Packet collision is intrinsic to wireless network. Signal propagation faces difficulties such as signal fading, interference, and multipath cancellation. All these properties make measures such as bandwidth and delay of a wireless link unpredictable.
- **Node mobility**: Mobility of the nodes creates a dynamic network topology. Links will be dynamically formed when two nodes come into the transmission range of each other and are torn down when they move out of range.

- **Limited battery life**: Mobile devices generally depend on finite battery sources. Resource allocation for QoS provisioning must consider residual battery power and rate of battery consumption corresponding to resource utilization. Thus, all the techniques for QoS provisioning should be power-aware and power-efficient.

- **Hidden and Exposed Terminal Problems**: In a MAC layer with the traditional Carrier Sense Multiple Access (CSMA) protocol, multi hop packet relaying introduces the “hidden terminal” and “exposed terminal” problems. The hidden terminal problem happens when signals of two nodes, say A and B, that are out of each other’s transmission ranges collide at a common receiver, say node C. With the same nodal configuration, an exposed terminal problem will result from a scenario where node B attempts to transmit data (to someone other than A or C) while node C is transmitting to node A. In such a case, node B is exposed to the transmission range of node C and thus defers its transmission even though it would not interfere with the reception at node A.

- **Route maintenance**: The dynamic nature of the network topology and the changing behavior of the communication medium make the precise maintenance of network state information very difficult. Thus, the routing algorithms in
MANETs have to operate with inherently imprecise information. Furthermore, in ad hoc networking environments, nodes can join or leave at any time. The established routing paths may be broken even during the process of data transfer. Thus, the need arises for maintenance and reconstruction of routing paths with minimal overhead and delay. QoS-aware routing would require reservation of resources at the routers (intermediate nodes). However, with the changes in topology the intermediate nodes also change, and new paths are created. Thus, reservation maintenance with updates in the routing path becomes cumbersome.

- **Security**: Security can be considered a QoS attribute. Without adequate security, unauthorized access and usage may violate QoS negotiations. The nature of broadcasts in wireless networks potentially results in more security exposure. The physical medium of communication is inherently insecure, so security-aware routing algorithms are needed to design for MANETs (Mohapatra Li and Gui 2003).

Algorithms must have the following features to provide QoS support in MANETs:

- Accurate measurement of bandwidth availability in the shared wireless channel and accurate measurement of effective end-to-end delay in an unsynchronized environment.

- Distributed routing algorithm that adapts with the dynamic environment.

- Resource reservation that guarantees the available resources.
- Efficient resource release upon route adjustment.
- Instant QoS violation detection.
- Fast and efficient route recovery (Qi Xue and Aura Ganz 2003).

In MANET, increasing overall network throughput while maintaining low energy consumption for packet processing and communications is a challenging one. Directional antennas are employed to increase the throughput and it allows for more efficient use of the channel along with other benefits related to increased coverage and lower power consumption. Directional antennas offer sectoring which allows a base station serving more than one cell and hence the capacity of the network is increased. Because of these benefits, directional antennas are widely used in IS-95 and 3G cellular networks (Christopher Ware et al., 2000). MAC protocols presently used for MANETs are not suitable for use with directional antennas since they are used among unidirectional antennas. These MAC protocols are designed based on assumptions that are not valid for directional antennas. For instance, one of these assumptions is that nodes have equal reception sensitivity and radiate equal power in all directions. This is the assumption that lies behind using the RTS/CTS exchange for collision avoidance in the IEEE 802.11b prior to data transmission. The argument is, if any node can cause interference at a receiver then it will most likely hear the CTS from that receiver and defer from transmitting. The radiated power and reception sensitivity between any two nodes is a function of the angular orientation of these nodes as directional antennas are applied. Hence all potential interferers could not be prevented from transmitting by using equal power for RTS/CTS and data packets (Aman Arora et al., 2004).
1.6 POWER CONTROL IN WIRELESS MULTI HOP NETWORKS

In wireless multi hop networks (Wang et al., 2007), energy efficiency is the major issue because most of the mobile devices are operated by batteries. Energy efficiency is achieved by reducing the transmission power whenever probable. Conversely, in a multi rate-enabled network, reducing transmission power affects the transmission rate reduction. Therefore, power control and rate adaptation have to be mutually considered. In an IEEE 802.11-based multi hop network, it is challenging that attaining energy efficiency by the joint design of power control and rate adaptation as the required throughput is maintained. More specifically, in an IEEE 802.11-based multi hop network, the hidden terminal phenomenon will cause some node may have smaller contention probability than another node, and hence, different nodes will have different probabilities to win the channel access. This inequality of channel access causes overall energy inefficiency as dangerous.

In multi-hop wireless ad hoc networks, nodes forward packets to other nodes when the target node resides in out of the transmission range of the source. While nodes in multi-hop wireless ad hoc network are energy constrained and packet transmission consumes a certain amount of power, energy conservation may be achieved by dynamically adjusting transmission ranges (Edmond Poon and Baochun Li, 2003) on the fly at each node. The benefits of dynamic power adjustments are,

- Power consumption rates can be considerably reduced.
- Total system throughput for an end-to-end flow may increase due to the spatial reuse of spectrum.
- Involving small number of neighbor nodes minimizes the contention with flows that shares the same channel.

This approach allows each node to make local decisions for adjusting its transmission power to cover the minimum area, with a target of minimizing the number of nodes that it can reach. But, the reduction of transmission power on each node may establish serious problems in traditional RTSCTS- DATA-ACK (CSMA/CA) MAC layer protocols, such as the IEEE 802.11 MAC standard. Power control in MANETs has recently received a lot of attention for two main reasons (Alaa Muqattash and Marwan Krunz 2004). First, power control has been shown to increase spatial channel reuse, hence increasing the overall (aggregate) channel utilization. This issue is particularly critical given the ever-increasing demand for channel bandwidth in wireless environments. Second, power control improves the overall energy consumption in a MANET, consequently prolonging the lifetime of the network. Portable devices are often powered by batteries with limited weight and lifetime, and energy saving is a crucial factor that impacts the survivability of such devices.

Power control affects the performance of the physical layer in two ways. First, power control impacts the traffic carrying capacity of the network. On the one hand, choosing too high a transmission power reduces the number of forwarding nodes needed to reach the intended destination, but as mentioned above, this creates excessive interference in a medium that is commonly shared. In contrast, choosing a lower transmission power reduces the interference seen by potential transmitters, but packets require more forwarding nodes to reach their intended destination. In Piyush Gupta and Kumar., 2000, the authors show that, when considering the physical layer only, reducing the transmission power is a better approach because this increases the traffic carrying capacity of the network. Second, power control
affects the connectivity of the resulting network. By a connected network, the network means in which any node has a potential route of physical links (or forwarding nodes) to reach any intended receiver node. A high transmission power increases the connectivity of the network by increasing the number of direct links seen by each node, but this is at the expense of reducing network capacity. However, it is not possible to arbitrarily reduce the transmission power to any value to promote a higher capacity and energy savings. Rather, there is a minimum bound for the transmission power necessary to avoid network partitions (Javier Gomez et al., 2011).

However, the finite and non-renewable battery power of mobile stations represents one of the greatest limitations to the utility of MANETs. It is well known that, due to technology limitations, the battery capacity will not be dramatically promoted in the not-so-distant future. Therefore, it is essential to investigate power saving strategies to prolong the lifetime of both individual nodes and the network. One way to reduce energy consumption is simply to use low-power hardware components. Another way is to adopt software controllable power management protocols that allow transceivers to be used in energy-conserving ways. One of the most common techniques to attain this goal is the discontinuous reception namely, battery power could be greatly saved by periodically turning the radio off when not in use since the network interface may often be idle. However, in such environments, it may take longer time to activate the link between Power Saving (PS) neighbors. Definitely, a good power management protocol ought to minimize the power consumption without significantly deteriorating the connectivity or capacity of the network (Hih-Lin Wu et al., 2005).

Power management schemes range from proactive to reactive like to ad hoc routing protocols. The extreme of proactive can be defined as always-on which means all nodes are active all the time and the extreme of reactive
can be defined as *always-off* which means all nodes are in power saving mode by default. The dynamic nature of ad hoc networks have to be balanced between proactiveness and reactivity. Proactiveness generally provides more efficient communication whereas reactivity provides better power saving (Rong Zheng and Robin Kravets 2003).

### 1.7 RATE CONTROL IN WIRELESS AD HOC NETWORKS

Rate control is the process of switching data rates dynamically based on channel conditions, with the target of selecting the rate that will provide the maximum throughput feasible for a given channel condition. The rate control process has two major elements and they are Channel estimation and rate selection.

The rate based transmission technique can avoid exploding nature of the network and self-locking scenario as packet is entered. In order to meet the bandwidth and delay requirements of real time traffic, rate control is done in a localized manner at each mobile node in entirely scattered and decentralized way. The rate control restricts the best effort traffic for creating the necessary bandwidth and also permits the best effort traffic to make use of the bandwidth in efficient way. The total rate of all best effort traffic and real-time traffic distributed over each load shared media channel is maintained below a certain threshold, thus the excessive delay gets minimized.

The explicit technique of rate control mechanism offers a method to recognize the approved data rate and hence the flows take action rapidly to modulation in bandwidth and re-routing events. (Alaa Muqattash and Marwan Krunz 2004). The requisite transmission rate for the available resource facility can be adjusted with the help of controlling the flow which avoids congestion. The objective of rate control is completely utilizing the available capacity of the network and to guarantee the fairness and good QoS for the users.
Although rate control has been studied extensively for wire line networks, these results cannot be directly applied to multi hop wireless networks. In Wire line Networks, the sum of the data rates at each link should be less than the known link capacity and this is known as capacity region. In multi hop wireless networks, the capacity of each radio link depends on the signal and interference levels, and is thus correlated with the capacities of other links. Hence, the capacity region of the multi hop wireless network is usually a complex function where as the capacity of Wire line Network is a simple form (Xiaojun Lin and Ness Shro 2004).

The channel quality estimation is engaged in measuring the channel condition with respect to time in order to generate the future quality predictions. There is no spesification (short or long-term) for matrices used in channel quality indication and prediction method. Hence following two issues are essential in the channel estimation process:

- Identifying metrics to be used as indicators of channel quality such as Signal to Noise Ratio (SNR), signal strength, symbol error rate, Bit Error Rate (BER)

- Algorithms to be used for channel prediction.

By using the channel quality predictions, the rate selection selects suitable rate. Commonly, the threshold selection technique is used by the rate selection for selecting the suitable rate. In this technique, the value of an indicator is compared with threshold value list that indicates boundaries among the data rates. In practice data transmission rates can be varied by different modulation schemes and/or coding techniques. Modulation is the process of translating an outgoing data stream into a form suitable for transmission on the channel. It converts the data stream into a sequence of symbols. Each symbol may encode a number of bits depending on the
modulation scheme used. The symbol sequence is then transmitted at a certain rate, the symbol rate, such that the data rate is determined by the number of encoded bits per symbol for a given symbol (Manzur Ashraf 2009).

Each link capacity is predetermined in wired networks where as the link capacity differs at each time in wireless networks. The accuracy of the channel quality estimates decides the effectiveness of rate adaptation. Besides, after generating good estimates, it must be used before they become outdated (Aditya Karnik et al., 2006). Thus, the delay between the time of the channel estimate and the time of the packet transmission among the selected data rate can be reduced.

1.7.1 Rate Control by MAC

The physical layer of the protocol architecture provides the multi rate properties. To utilize the full potential of multi rate transmissions, different transmission rates should be adapted by MAC layer of the protocol architecture. Several rate adaptive MAC layers have been proposed and they are suited to 802.11 multi rate physical layers (Manzur Ashraf 2009).

1.7.2 Auto Rate Fallback (ARF)

ARF was the first commercial 802.11 based MAC layer that supports the multiple transmission rates. It was mainly intended to improve the throughput which in turn resulted in 802.11 Direct Sequence Spread Spectrum (DSSS). Following a set of successful transmissions at specified rate, every sender in ARF tries to utilize higher transmission rate. Similarly, one or two successive failures, sender shifts to lower rate. In case of two successive transmission failures in a row, the algorithm minimizes the current rate and initiates the timer. Whereas the timer is reset and transmission rate is enhanced when timer expires or set of successfully received per packet
acknowledgments attains value 10. Thus at the time of increase in rate, the primary transmission following the rate increase should succeed or else the rate is directly decreased and the timer is restarted rather than trying the higher rate a second time. This technique results in two issues.

The rapid changes in channel conditions is not adaptable in an efficient manner. For example, The maximum changes in rate occur in packet transmission from one packet to another in ad hoc network in which the interference bursts are generated by other 802.11 packet transmission. Since the algorithm necessitates one or two packet failures to reduce its rate and maximum of 10 successful packet transmissions for rate enhancement, it is difficult to synchronize it with the sub-packet channel condition changes. In case there is nil or slight channel condition changes, it attempts to utilize a higher rate for each 10 successful packet transmissions. This in turn maximizes the retransmissions activity and thereby decreasing the application throughput.

1.7.3 Receiver-Based Auto Rate (RBAR)

This is the only alternative algorithm (Mathieu Lacage et al., 2004) for rate adaptation to improve the application throughput. This algorithm necessitates alterations in IEEE 802.11 standard. The understanding of certain MAC control frames is altered and every data frame should contain a new header field. This algorithm allows the utilization of RTS/CTS techniques. In prior to initiation of every data transmission, a pair of request termed as to send and clear to send control frames are swapped among the source and destination nodes. Depending upon the received RTS frame’s Signal to Noise Ratio (SNR) and a priori wireless channel model based computation of set of SNR thresholds, the RTS frame computes the transmission rate to be utilized by the upcoming data frame transmission. Later, the rate to be utilized is then forwarded to the source in the CTS packet.
The rate to be utilized is feedback to source using CTS packet. For updating the Network Allocation Vector (NAV) exactly, the RTS, CTS and data frames are altered to hold the size and data transmission rate information for permitting every nodes within the transmission range. The issues concerned with this protocol are as follows.

- Each receiver selects a optimal feasible rate using threshold mechnanism that necessitates a computation of SNR thresholds according to priori channel model.

- The assumption that availability of SNR of a given packet at the receiver is false.

- It necessitates the RTS/CTS protocol although hidden nodes are absent.

- The RTS and CTS frames interpretation and data frames format does not match with 802.11 standard.

1.7.4 Opportunistic Auto Rate (OAR)

OAR (Cao Trong Hieu and Choong Seon Hong 2010) algorithm helps in utilizing high quality channels during the transmission of multiple back-to-back packets. Specifically, following the indication of optimal channel quality by the multi rate MAC, this algorithm allows channel access for multiple packet transmissions. As a result, OAR nodes transmits more packets under high quality channels when compared to low quality channels. But OAR cannot randomly support flows with optimal channel quality, since flows access with everlasting bad channels need to be guaranteed. This algorithm also make sure that entire flows are allocated with similar temporal share of channel access. OAR can offer various throughputs for flows,
according to their channel conditions but all flows can attain about identical time shares. The demerits of this approach are:

- It needs a multi rate MAC protocol namely RBAR or ARF for medium access at rates above the base rate though it is applicable to both sender and receiver based protocols.

- It needs a mechanism contain the channel for an extended packet transmissions set during the provision of high rate channel by RBAR.

1.8 MOTIVATION AND OBJECTIVES

1.8.1 Motivation

- A candidate of congestion signal should reflect the condition of MAC contention and collision owing to the fact that MAC contention is tightly coupled with congestion.

- The candidate must specify the available bandwidth to completely exploit the shared channel without causing severe congestion and packet collision.

- Medium Access Control (MAC) protocol plays an important role in providing fair and efficient allocation of limited bandwidth in wireless LANs.

- In IEEE 802.11 standard protocol, data rate selection is not specified.
• Although rate control has been studied extensively for wired networks, these results cannot be directly applied to multihop wireless networks.

• The MANET nodes which are outside the transmission range are energy constraint and they consume more power for packet transmission.

• Since each node in wireless multi hop networks is energy constrained and packet transmission consumes a certain amount of power, energy conservation may be achieved by dynamically adjusting transmission ranges on the fly at each node. Thus for the same MAC protocol, a power adjustment algorithm is required in order to reduce power consumption rates, increase spatial reuse of spectrum and to minimize the contention among the flows sharing the same channel.

1.8.2 Objectives

• To design a cross-layer based MAC protocol to completely utilize the channel bandwidth and increase the fairness of each flow without causing congestion.

• To propose an Optimal Rate Adjustment Algorithm (ORAA) based on the channel state conditions.

• To propose a power adjustment algorithm to provide higher throughput and consume less energy in the Mobile Ad hoc Networks.
1.9 OVERVIEW OF PROPOSED WORKS

1.9.1 A Cross-Layer Based High Throughput MAC Protocol for 802.11 Multi hop Adhoc Networks (CLBHT)

A cross-layer based MAC protocol has been proposed to completely utilize the channel bandwidth and increase the fairness of each flow without causing congestion. In the first part of the protocol, whenever a source wants to transmit data flows, it sends a probe request to the destination. The destination node will send probe packets to the source node so that the source node could estimate the available bandwidth and contention between them. Each forwarding node estimates its channel busyness ratio and bandwidth and the feedback is carried back to the source.

The channel busyness ratio is a timely and accurate metric for the network utilization as well as congestion. It is defined as the ratio of time intervals when the channel is busy due to successful transmission or collision to the total time. Then the source selects the path that has enough bandwidth and the least channel busyness ratio, using the routing protocol.

In the second part of the protocol, a scheduler is designed which schedules the flows instead of nodes. When a flow is scheduled for transmission, all hop-by-hop transmissions for that flow are scheduled sequentially. If after a flow is scheduled but before its first hop transmission commences, another flow with a lower service counter arrives, the former flow may be re-scheduled to accommodate the latter flow to ensure short-term fairness.
1.9.2 An Optimal Rate Adjustment Algorithm for Mac Protocol in 802.11 Multi Hop Ad Hoc Networks (ORAA)

An Optimal Rate Adjustment Algorithm (ORAA) has been proposed and it is based on the channel state conditions. In this algorithm a two level channel estimation is followed, one at the receiver end and another at each intermediate node along the path.

Channel state estimation: The ad hoc networks is devoid of base station for functioning either as central controller or dedicated control channel to feedback the channel state. Due to these characteristics, estimate the channel state based on packet success rate, checked at two levels as follows:

- At the receiver end

- At each intermediate node along the path

Only if the requirements at both the levels are satisfied, the channel is confirmed to be in good condition.

At the receiver end: By exchanging the two short control packets between a sender and a receiver, all neighboring nodes recognize the transmission and back off during the transmission time advertised along with the RTS and CTS packets. In channel state estimation, the CTS packets and ACK packets are checked at the receiver side. Based on the results of these packets, classify the channels with three states namely GOOD1, BAD1 and AWAITING1. Thus, a flag (FL) is associated to indicate the corresponding channel state. The flag can take three values: GOOD1, BAD1 or AWAITING1.
- Check for the CTS packets, which informs the sender that the packets are confirmed to be sent

- Also check for the ACK packets, which is an acknowledgement of successful data transmission

If both the above conditions are satisfied, then the channel is in GOOD state and will be checked for the subsequent conditions at the nodes. If any of the above condition is not satisfied then the channel is in BAD state and eventually the further transmissions are dropped out.

**At each intermediate node along the path:** The fraction of the successful transmission count over the most recent transmissions is termed as Packet success rate ($P_s$). Furthermore at each node, the packet success rate ($P_s$) is checked against a threshold value ($P_{th}$). If the value falls above the threshold value, the link is in good condition with its state marked as GOOD2 else the link is considered bad and marked as BAD2. Since the channel condition is checked at each and every node, the changes in channel are updated with the exact channel conditions.

Suppose if a path has many links with both GOOD2 and BAD2 states, then in such cases the path is valid only if it contains maximum number of links with state GOOD2 else the path is invalid (i.e.,) not suitable for transmission and will be kept in the AWAITING2 state for a particular time period ($t_{th}$). For instance if there are totally 5 links in a path with 3 of the links in state GOOD2, then the path is valid as the maximum links have GOOD2 states. Suppose if only 2 of the links are in GOOD2 state, then the path is invalid. Once the channel condition improves and if the maximum number of links in the path have state GOOD2, then the path is valid. Also once the $t_{th}$ value is exceeded, then also the path is invalid and is not suitable for transmission.
1.9.3 Power Adjustment Algorithm for Higher Throughput in Mobile Ad hoc Networks (PAA)

Initially, each node creates two tables’ namely Recent data Table (RT) and Inspection Table (IT). The transmitter checks the record of the receiver initially in the RT and if it not present it checks in the IT for transmitting RTS packet to the receiver. Once the receiver obtains the RTS packet, it calculates the data payload length and the interference amount based upon the SIR. The optimal transmission power is determined using these and the receiver sends this optimal transmission power to the transmitter through the CTS packet. After receiving the optimal power, transmitter checks the number of neighbors. When the number of neighbors is more than the desired number of neighbors, then the power level is decremented for the neighboring nodes. If the number of neighbors is lesser than the desired number of neighbors then the power level is incremented. The new transmission power is retransmitted to the receiver via the RTS packet. Since equal optimal transmission power is maintained both at the receiver and the transmitter the throughput can be improved and the energy can be conserved effectively. This also reduces power consumption rates, increases spatial reuse of spectrum and minimizes the contention among the flows sharing the same channel.

1.9.4 Fair Scheduling Algorithm for 802.11 MAC Protocol in MANET (FSAMAC)

The main goal of the proposed algorithm is to increase the network utilization by assigning as many slots as possible to the network flows and when a flow is created, an information discovery phase is initiated, which helps the source node to retrieve information concerning the network topology. Then, a routing algorithm is applied to determine the optimal path for the specific network flow to achieve high fairness in transmission.