2. LITERATURE REVIEW

2.1 INTRODUCTION

Recent advances in wireless technologies are required to support video traffic applications in MANET. Providing Quality of Service (QoS) for Mobile Ad-Hoc Networks (MANETs) is a tough task due to the dynamic topology and limited resources in MANETs. But the need for sustaining real time applications for users of MANET has become very important. The QoS is the performance level of a service offered by the network to the user. As the main objective of this research is to develop routing protocols and evaluate them, it becomes necessary to review the literature on existing broadcasting schemes in route discovery, disjoint multipath routing schemes, packet scheduling schemes over multimedia traffic and queue management schemes over multimedia traffic which are also included in this chapter. The performance of routing protocols is analyzed based on routing metrics such as Inter-packet delay, queuing delay and end to end delay, which is required for real-time application transmission by simulating in MANET environment. The existing TCP variants for evaluation with routing protocols, the existing broadcasting schemes in route discovery, disjoint multipath routing schemes, packet scheduling schemes and queue management schemes over multimedia traffic are elaborated in the rest of the sections of this chapter.

2.1.1 Routing, Scheduling and Queue Management

This research is focused on providing QoS support for applications that require soft real-time guarantees. Routing is the mechanism of forwarding packet towards its destination using most efficient path. The efficiency of the path is measured by various metrics such as traffic, number of hops and so on. As for as MANET is concerned, each node is acted as the router itself. Resource Constraints, Mobility of Nodes, Dynamic topology, Misinterpretation of Congestion, Completely decoupled transport layer are
some of the issues considered to achieve the performance improvement in routing and delivery. To improve the performance required to select the appropriate scheduling algorithms for real-time applications. There are various packet scheduling algorithms are supported in MANET, such as First-In-First-Out (FIFO), Priority Queuing Algorithm, Round Robin, Weighted Fair Queuing and Class-Based Weighted Fair Queuing. To manage queue effectively, there are a variety of queue management algorithms which are existed. Some of them are drop-tail, Random Early Detection (RED), Random Exponential Marking (REM), weighted fair-queuing and so on. In the traditional drop–tail technique, the queue drops the incoming packets only when it reaches the overflow conditions. If it reaches, then the packets that are arrived last will be dropped and no early congestion detection states are in this policy. Normally, the congestion will occur, whenever the resources exceed the available limits (Ex. Link bandwidth). The popular queue management scheme namely RED, which is one of the early congestion detection mechanisms. It maintains the queue size efficiently and hence queuing delay, end to end delay can be reduced. From literature survey, it is learned that early detection of congestion is the best way to manage the queue and hence can minimize the packet latency.

2.1.2 Mobility Models

Performance analysis of Routing Protocols in MANET has studied for the effect of the different mobile node movement pattern. The three important mobility models used in MANET are Random Waypoint Mobility Model, Random Walk Mobility Model and Random Direction Mobility Model. The review of literature finds the gap that Random Waypoint Model is the best model which outperforms than both Random Walk Model and Random Direction Model.

2.1.3 Performance Metrics

The performance metrics that are required for performance analysis over real-time application for routing and end to end data transmission are
Routing overhead, packet delivery ratio, packet drop, inter-packet delay, queuing delay and end-to-end delay. In wireless ad hoc networks, nodes often change their location within the network. So, some stale routes are generated in the routing table which leads to unnecessary routing overhead. The routing overhead is the total number of control packets transmitted during the simulation time. It can be calculated using Equation (2.1).

\[
\text{Routing Overhead} = \frac{\text{Total Bytes Transmitted for Control Packets}}{\text{Total Bytes Transmitted}}
\] (2.1)

As far as multimedia transmission is concerned, the Routing Overhead (RO) can be calculated using Equation (2.2).

\[
RO = \frac{T_{cp}}{T_p}
\] (2.2)

Where,

\(T_{cp}\) is the total number of control packets transmitted and

\(T_p\) is the total number of packets including the size of decoded video frames

The packet delivery ratio can be computed using Equation (2.3).

\[
\text{Packet Delivery Ratio (PDR)} = \frac{\text{Number of Data Packets Received}}{\text{Number of Data Packets Sent}}
\] (2.3)

The number of packets dropped can be determined by the Equation (2.4) as follows:

\[
\text{No. of packets dropped} = \text{No. of data packets sent} - \text{No. of data packets received}
\] (2.4)

A time delay between successive data packets is referred as Inter-Packet Delay (IPD). The IPD between \(j^{th}\) and \((j+1)^{th}\) packet with ‘m’ intermediate nodes can be computed using Equation (2.5).
IPD = \sum_{j=1}^{m} D(j+1) - \sum_{j=1}^{m} D(j) \tag{2.5}

Where,

‘D’ is the delay for a packet.

The queuing delay can be defined as the time gap between a packet entered into the queue and departed from the queue. Average end to end delay is an average delay incurred by the packets between their generation time and their arrival time at the destination.

2.2 DESIGN ISSUES FOR WIRELESS AD HOC NETWORKS

The major issues that affect the design, deployment and performance of an ad hoc wireless system are medium access scheme, routing, multicasting, transport layer protocol, pricing scheme, Quality of service provision, self-organization, security, energy management, addressing and service discovery, scalability and deployment considerations.

2.2.1 Issues in Designing a MAC Protocol

The primary responsibility of Medium Access Control (MAC) protocol in ad hoc wireless network is the distributed arbitration for the shared channel for transmission of packets. The major issues to be considered in designing a MAC protocol for ad hoc wireless network are bandwidth efficiency, Quality of service support, synchronizations, hidden and exposed terminals, error-prone shared broadcast channel, lack of central coordination, the mobility of nodes and real-time traffic support. Majority of the recent researches focused on efficient way of utilizing the bandwidth and to provide QoS in ad hoc network.

2.2.2 Issues in Designing Routing Protocol
The major challenges that a routing protocol designed for ad hoc wireless networks faces are mobility of nodes, resource constraints, error-prone channel state and hidden terminal exposed terminal problems. Mobility of nodes is a crucial matter of concern in ad hoc network as the routing path once established is not guaranteed to remain the same till the end of data transfer. This is a very challenging issue to be resolved and there arises a prime requirement to enhance the existing routing algorithms by considering the mobility of nodes.

2.2.3 Issues in Designing Transport Layer Protocol

While designing a transport layer protocol for ad hoc wireless networks, the major issues are induced traffic, induced throughput unfairness, separation of congestion control, reliability and flow control, power and bandwidth constraints, misinterpretation of congestion, completely decoupled transport layer and dynamic topology. In wired networks, the performance of each layer is decoupled with each other. As the layers are not completely decoupled in ad hoc network, the performance of one layer will affect the other. Review of the literature suggests that based on the routing protocols, appropriate transport layer protocols have to be chosen thereby increasing the packet delivery ratio at the destination. Further based on the traffic, selection of suitable transport layer protocol makes the QoS enhancement. Much of the publications recommend that the type of traffic determines the appropriate transport layer protocol to improve the performance metrics such as reliability. If reliability is the utmost concern then TCP may be used, whereas for delay-sensitive applications where delay is of paramount concern, UDP may be used as transport protocol. In MANET, the packet drops happens not always due to link breaks, but also due to congestion. Therefore, the selection of a suitable transport layer protocol improves the delivery ratio from source to destination.

2.3 Classifications of MANET Routing Protocols
The routing protocols for MANETs are divided into three types based on routing table updates, namely Proactive (Table Driven), Reactive (On-Demand) and Hybrid Protocols. Figure 2.1 depicts the Classification of MANET Routing Protocols.

Figure 2.1: Classification of MANET Routing Protocols

### 2.3.1 Proactive Routing Protocol

Proactive protocols are also called as table-driven protocols and will actively determine the layout of the network. Through a regular exchange of network topology, packets between the nodes of the network, at every single node an absolute picture of the network is maintained. Hence, there is minimal delay in determining the route to be taken. This is especially important for time-critical traffic.

When the routing information becomes worthless quickly, there are many short-lived routes that are being determined and not used before they become invalid. Therefore, another drawback resulting from the increased mobility is the amount of traffic overhead generated when evaluating these unnecessary routes. This is specially altered when the network size increases. The portion of the total control traffic that consists of actual practical data is further decreased. If the nodes transmit infrequently, most of
the routing information is considered redundant. The nodes, however, continue to utilize energy by continually updating these unused entries in their routing tables as mentioned, energy conservation is very important in a MANET system design. Therefore, this excessive expenditure of energy is not desired. Thus, proactive MANET protocols work best in networks that have low node mobility or where the nodes transmit data frequently. Examples of Proactive MANET routing Protocols are Optimized Link State Routing (OLSR), Destination-sequenced Distance Vector (DSDV) and Cluster-head Gateway Switch Routing Protocol (CGSR).

2.3.2 Reactive Routing Protocol

Reactive routing protocols are also called as On Demand routing protocols. The mobility of the nodes causes the topology of the network to change constantly. Keeping track of this topology is not an easy task, and too many resources may be consumed in signaling. Reactive routing protocols were intended for these types of environments. These are based on the design that there is no point in trying to have an image of the entire network topology since it will be constantly changing. Instead, whenever a node needs a route to a given target, it initiates a route discovery process on the fly, for discovering out a pathway.

Reactive protocols start to set up routes on-demand. The routing protocol will try to establish such a route, whenever any node wants to initiate communication with another node to which it has no route. These kinds of protocols are usually based on flooding the network with Route Request (RREQ) and Route reply (RREP) messages. By the help of Route request message, the route is discovered from source to destination node and as the destination node gets a RREQ message in it, then it sends RREP message for the confirmation that the route has been established. This kind of protocol is usually very effective on single-rate networks. It usually minimizes the number of hops of the selected path. However, on multi-rate networks, the number of hops is not as important as the throughput that can be obtained on a given path. Examples of On Demand MANET routing Protocols are Ad
hoc On-Demand Distance Vector (AODV), Dynamic Source Routing protocol (DSR), Temporally Ordered Routing Algorithm (TORA), Associativity Based Routing (ABR), Signal Stability-Based Adaptive Routing (SSA) and Location-Aided Routing Protocol (LAR).

Through the literature, it is observed that AODV routing protocol performs with the highest efficiency than Destination-Sequenced Distance Vector (DSDV) routing protocol with respect to real-time applications. Hence, AODV is chosen to modify with the proposed strategies for the delivery of time-critical multimedia applications.

Ad hoc On-Demand Distance Vector (AODV) is a routing protocol for mobile ad hoc networks. It is jointly developed by Nokia Research Centre of the University of California by C. Perkins and S. Das. It is an on-demand and distance-vector routing protocol, meaning that a route is established by AODV from a destination only on demand. AODV is capable of both unicast and multicast routing. It keeps these routes as long as they are desirable by the sources. Additionally, AODV creates trees which connect multicast group members. The trees are composed of the group members and the nodes needed to connect the members. The sequence numbers are used by AODV to ensure the freshness of routes. It is loop-free, self-starting, and scales to large numbers of mobile nodes. AODV defines three types of control messages for route maintenance; they are Route Request (RREQ), Route Reply (RREP) and Route Error (RERR) messages.

A RREQ message is transmitted by a node requiring a route to a destination node. As an optimization, AODV uses an expanding ring technique when flooding these messages. Every RREQ carries a TTL value that states for how many hops this message should be forwarded. This value is set to a predefined value at the first transmission and increased at retransmissions. Retransmissions occur if no replies are received. Figure 2.2 (a) shows the Route Request (RREQ) packet format.
Figure 2.2 (a): Route Request (RREQ) packet format

A RREP message is unicast back to the originator of a RREQ if the receiver is either the node using the requested address or it has a valid route to the requested address. The reason one can unicast the message back is that every route forwarding a RREQ caches a route back to the originator. Figure 2.2 (b) shows the Route Reply (RREP) packet format.

Figure 2.2 (b): Route Reply (RREP) packet format

A RERR message is used to notify other nodes of the loss of the link. Figure 2.2 (c) shows the Route Error (RERR) packet format.

Figure 2.2 (c): Route Error (RERR) packet format
AODV maintains routes for as long as the route is active. This includes maintaining a multicast tree for the life of the multicast group. Because the network nodes are mobile, it is likely that many link breakages along a route will occur during the lifetime of that route. The main advantage of AODV protocol is that routes are established on demand and destination sequence numbers that are used to find the latest route to the destination. Hence, the delay for the connection setup is less. The HELLO messages supporting the routes maintenance are range-limited, so they do not cause unnecessary overhead in the network.

2.3.3 Hybrid Routing Protocol

Hybrid method uses both the proactive and reactive protocols which work in the best scenarios both in the small and large domain. It is used to find a balance between both protocols. Proactive operations are restricted to a small domain, whereas, reactive protocols are used for locating nodes outside those domains. Examples of hybrid protocols are Zone Routing Protocol (ZRP) and Wireless Ad hoc Routing Protocol (WARP).

2.4 TCP OVER AD HOC NETWORKS

Transmission Control Protocol (TCP) is the predominant Internet protocol and it carries approximately 90% of Internet traffic in today's heterogeneous wireless and wired networks. TCP is a reliable end to end protocol because TCP is trying to provide reliable data transmission between two entities.

2.4.1 TCP Variants

There are a number of TCP variants which can suit for MANET environment. The important variants are TCP Tahoe, TCP Reno, TCP Vegas, TCP SACK and TCP FACK. Figure 2.3 shows the TCP Variants.
2.4.1.1 TCP Tahoe

The first or basic variant of TCP is the TCP Tahoe. It is better at congestion avoidance and therefore uses network resources efficiently.

2.4.1.2 TCP Reno

The Reno retains the basic principle of Tahoe, however, it adds some intelligence over it so that lost packets are detected earlier and the TCP Channel is not emptied every time whenever a packet is lost. The advantages which are in congestion avoidance and bandwidth utilization over Tahoe also exist in TCP Reno. It can suffer from performance problems when multiple packets are dropped from a window of data.

2.4.1.3 TCP Vegas

Vegas is a TCP implementation which is a modification of Reno. It builds on the fact that proactive measure to encounter congestion is much more efficient than reactive ones. Each TCP variant uses different mechanisms for congestion control, flow control and making the decision for retransmission of the dropped packets.
2.4.1.4 TCP SACK

TCP with Selective Acknowledgements (SACK) is an extension of TCP Reno. In TCP SACK, the segments are not being acknowledged cumulatively but it should be acknowledged selectively. If there are no such segments outstanding, then it sends a new packet. Thus more than one lost segment can be sent in one Round-Trip Time (RTT). Through minimizing the number of acknowledgement packets transmitted for end to end data delivery improvement in the Packet Delivery Ratio can be obtained. TCP SACK variant uses selective acknowledgements for data delivery, and this TCP variant can considerably increase the delivery ratio. TCP SACK is best suited for applications that need selective acknowledgement.

2.4.1.5 TCP FACK

FACK or Forward Acknowledgement is a special algorithm that works on top of the SACK options and is geared at congestion controlling. The main idea of FACK algorithm is to consider the most forward selective acknowledgement sequence number as a sign that all the previous unselected acknowledged segments were lost.

Reliability is defined as the probability of successful communication between any two terminals in a network; so consequently, terminal reliability depends on the participating terminals and also the connecting link [24]. The disadvantages of Radio Frequency communication are bandwidth scarcity, lack of security, high interference, and high bit error rates. These limitations make providing scalable quality of service (QoS) support difficult [25].

The review and comparison of existing variants of TCP represent the TCP’s performance depends on the type of its variants due to missing of congestion control or improper activation procedures such as Slow Start, Fast Retransmission and Congestion Avoidance, Retransmission, Fast Recovery, Selective Acknowledgement mechanism and Congestion Control. Hence, the performance analysis of TCP Variants is essential to aware about
a better TCP implementation for a specific scenario and then to nominate a suitable one [26].

Due to congestion, the packet loss heavily occurs in the particular link. In order to avoid congestion, cross-layer based congestion control scheme is proposed for reducing the packet losses in the network [27]. The design of ad hoc network protocol is generally based on a traditional ‘layered approach’, that has been found ineffective to deal with Receiving Signal Strength (RSS) related problems, affecting the physical layer, the network layer and transport layer. Hence, a new design approaches towards enhancing the cross-layer interaction among different layers namely physical, MAC and network [28].

Ad hoc QoS On-demand Routing (AQOR) that provides end to end quality of service (QoS) support, in terms of bandwidth and end to end delay in mobile ad hoc networks (MANETs). The increasing use of MANETs for transferring multimedia applications such as voice, video and data leads to the need to provide QoS support [29].

Ad hoc Transport Protocol (ATP) uses feedback from the network nodes for three different purposes: Firstly, the initial rate feedback for start-up rate estimation, secondly, the progressive rate feedback for congestion detection, congestion avoidance, and congestion control and lastly, path failure notification [30].

2.5 CROSS-LAYER APPROACH

In layered communication, the functionality of each layer is well defined and appropriate protocol performs the defined task. This kind of communication approach is the layered approach; here the defined interfaces connect only the neighbouring layers of the protocol stack. In this approach, one layer performance will not affect the performance of the other. In contrast, cross-layered approaches attempt more interactions between network and transport layers to improve the performance gains. In cross
layered approaches one layer performance will affect the other. In this research work, based on the type of defined routing algorithm in the network layer; the suitable end to end delivery protocol from the transport layer is identified. Thus, it is a cross-layered approach.

2.6 BROADCASTING SCHEMES IN ROUTE DISCOVERY

In the establishment of communication in an ad hoc network, broadcast is the fundamental operation. It is a process of sending a control message from one node to all other nodes in an ad hoc network. This process is used to update the routing information in the route establishment from source to destination.

![Broadcasting Methods Diagram](image)

**Figure 2.4: Broadcasting methods for RREQ packets**

There are different types of broadcasting methods are existed to flood the RREQ packet for the establishment of the route. This section highlights four important schemes of broadcasting, namely Heuristic-Based Broadcasting, Neighbour Coverage Based Broadcasting, Dominating Sets-Based Broadcasting, and Cluster-Based Broadcasting.
Based Broadcasting and Cluster-Based Broadcasting. Figure 2.4 shows the various broadcasting methods to send for RREQ packets.

2.6.1 Heuristic-Based Broadcasting

This broadcasting method is highly dependent on the selected parameters and their thresholds in the heuristic. Hence this method needs a careful selection of parameters which are closely related to MANET environment. Three main kinds of heuristic-based broadcasting are counter-based, distance or location-based and probability-based. In counter based rebroadcasting, the number of duplicate packets will be checked based on the threshold value of duplicate packets received by the broadcasting node. If the duplicate packet is lesser than the threshold value, then the node will rebroadcast; otherwise, it will not. The approach used in distance or location-based broadcasting is the distance between nodes. Each node will have its GPS device. In probability-based broadcasting, the decision of rebroadcasting is based on a random probability. The probability calculation or setting may depend on the parameters such as node density or duplicate packets received and so on.

2.6.2 Neighbour Coverage Based Protocols

In this broadcasting method, the nodes periodically broadcast beacon message to the neighbour nodes to advertise their existence or to discover the existence of neighbour nodes that are present within the same transmission range or within that hop. Normally the beacon messages contain the neighbouring nodes that address and broadcasting node’s address.

2.6.3 Dominating Sets–Based Broadcasting

It is a simple and efficient broadcasting method used to control the broadcast storm problem through limiting the broadcasting nodes to those
gateway nodes. A dominating set may be any node in the network or the direct neighbour of the node.

2.6.4 Cluster-Based Broadcasting

Grouping the nodes into a set is usually referred as a cluster. In this process, a representative of each group is referred as cluster-head. A cluster consists of all the nodes within the cluster head's transmission range. The nodes other than the cluster-head are referred as ordinary nodes. The cluster-head node is responsible for propagating messages.

2.6.5 Routing Overhead Analysis for Reactive Routing Protocols with TCP-Variants

This literature pertaining to reduce the routing or control overheads generated during the route establishment from source to target node. Although several routing protocols have been proposed that can be used in mobile ad hoc networks, there is a very little formal analysis that considers the communication overhead or in other word routing overhead for these procedures. A new mathematical framework is provided for quantifying the overhead of reactive routing protocols such as Dynamic Source Routing (DSR) and Ad hoc On-Demand Distance Vector Routing (AODV) in wireless ad hoc networks with the random location of the nodes. This algorithm will find routing overhead using a probabilistic model. The physical distance between any two communicating nodes of the network will determine the number of hops required for relaying the data packets from a source to a destination [31]. The main character of AODV is to keep timer-based state of every node. Routing table will expire when a route is rarely used. AODV have route discovery and route maintenance mechanism. The routing flags represent the state of the route as up, down or in repair [32].

TCP (Transmission Control Protocol) is still needed for MANET since it is widely used in the current Internet and suitable for smooth integration with the fixed Internet. Particularly, TCP has its variants, namely TCP Reno
and TCP-Vegas. However, there has been no research work on extensive performance comparison of TCP-Reno and TCP Vegas over AODV and OLSR. TCP-Vegas perform better for AODV. On the other hand, TCP-Reno is more suitable for OLSR [33].

TCP SACK uses selective acknowledgements to detect lost segments. Selective acknowledgements allow the receiver to inform the sender of additional non-contiguous data that have been received. Cumulative acknowledgements indicate only contiguous received segments, but selective acknowledgement is more advantageous and it helps to detect the lost segments in a faster manner [34]. A unicast-type multi-hop local repair protocol is proposed for multicast MANETs to recover lost links efficiently while achieving several advantages; such as increasing network reliability, increasing packet delivery rate, minimizing the number of control messages and reducing repair delay [35].

In MANET, routing is performed by nodes with limited resources; load should be efficiently distributed through the network. Otherwise, heavily-loaded nodes may make up a bottleneck that lowers the network performances by congestion and larger delays [36]. The routing function is particularly challenging in these networks because the network structure is constantly changing and the network resources are limited. This is particularly true in wireless ad hoc networks where node mobility and link failures produce constant changes in the network topology. Hence, an Intelligent Routing and Flow Control mechanism is needed in MANETs [37].

2.6.6 Broadcast Storm Problem and Analysis of the TCP variants

Broadcast is a fundamental operation used in MANETs for many services, such as route discovery and sending information messages. The Simple flooding method broadcasts more number of RREQ packets to establish the route and hence performance degradation occurs. The Smart Probabilistic Broadcasting (SPB) method is used to solve the broadcast storm problem, which leads to the collision, contention and duplicated
messages. Along with this routing protocol, the appropriate transport protocol is not chosen to increase the end to end delivery [38].

Providing QoS is desirable for many applications if the routing protocols are able to find the neighbours and the destination within a short interval with limited route messages like Route Request (RREQ) and Hello messages. AODV is one of the most widely used reactive routing protocols. The MAC layer protocols and Network layer protocols with transport layer mechanisms in a mobile ad hoc network attempt to improve the performance of MANET. These results show that the interaction between transport layer with the Network and MAC protocols has a significant impact on the achievable throughput, Packet Delivery Ratio [39].

The topology of a MANET can be very dynamic due to the mobility of mobile nodes. Because of the dynamic topology and wireless link characteristics, the Quality of Service (QOS) support in MANETs is a very challenging task. Routing algorithm is a very important mechanism for QoS guaranteeing in networks [40].

Several different TCP variants have been developed in order to refine congestion control in Mobile Ad-hoc Networks. These variants of TCP perform better under specific scenarios. An Analysis is made using the variants of TCP is based on three performance metrics, namely TCP Throughput, Average End to End delay and Packet Delivery in high and low mobility. The main mechanisms of end to end congestion control that implemented by TCP are Additive Increase/Multiplicative Decrease and Fast Retransmit and Fast Recovery [41]. Flooding the network for sending a message to all devices may lead to the network congestion due to the high number of collisions performed, the big amount of redundant broadcasts and contention problems [42].

In the analysis of the TCP variants, TCP BIC and TCP Vegas congestion control algorithms are analyzed in small network size. In this MANET scenario, the algorithm BIC provided good throughput after 75
seconds but algorithm Vegas provided stable and excellent result almost all over on the whole run time. So we conclude the algorithm Vegas will be the good algorithm for small and short duration communication [43].

2.7 DISJOINT MULTIPATH ROUTING SCHEMES

Multipath routing establishes multiple routes between source and destination nodes. When one route fails due to path break, source nodes can maintain connections by using other routes. So multipath routing protocols can reduce data losses and delay times that are caused by route disconnection.

2.7.1 Loop-Free Proactive Source Routing Scheme

Real-time applications consume much network resources and so, need high flow rates and very small transfer delay. The MANETs in their original state are not able to satisfy the requirements of quality of service (QoS). A new variant based on the AODV which gives better results than the original AODV protocol with respect to a set of QoS parameters and under different constraints, taking into account the limited resources of mobile environments (bandwidth, energy). Modified AODV (M-AODV) protocol suggests that the discovering operation for paths reconstruction should be done from the source. It also defines a new mechanism for determining multiple disjoint routes. In original AODV when the path is broken, local repair phase is initiated and if failure is declared a new discovery phase is initiated by the source node. In this modification, to eliminate local repair phase to minimize modified protocol (M-AODV) task and the discovery phase is delegated in all scenarios to the source node for a number of attempts without M-AODV local repair [44].

The need for reliable communication with no data loss, no duplication and no out of order delivery of packets becomes a vital necessity for all application programs in all networks. This analysis is carried out in different sophisticated TCP Variant protocols with AODV, a MANET routing protocol to
enable reliable communication by measuring different parameters required such as the performance of packets delivery rate, average end to end delay and packet dropping rate. From various differentiable results, a combination of TCP Vegas and AODV ad hoc routing protocol is chosen and refined to achieve desirable reliable communication. The refinement proves a better solution for deploying TCP in MANET with the decidedly mobile environment [45].

A protocol named ‘Reliability Map Routing’ (RMR), which uses end to end Quality of Service metrics that include spatial reliability and trust. RMR constructs and disseminates the local reliability and trust maps of the network by periodic advertisements while it discovers an optimized end to end path, that is, a chain of contiguous cells to the destination on demand [46]. Several MANET specific TCP versions like TCP Reno, TCP New Reno, TCP Tahoe and TCP Vegas have come into prominence. In this analysis, the performance of the different TCP versions are evaluated for the same network topology over certain fixed parameters like number of packets generated per node, average packet loss, average delay incurred by the packets while in transit from source to destination and the processing time taken by the intermediate nodes. Ad hoc On-demand Distance Vector Routing (AODV) is used as the routing protocol [47].

Pre-emptive routing in Ad hoc networks is the technique reduces the number of route failures and the latency required in route reconstruction. This is mainly achieved by switching to a new route from source node to destination node when a link of the current route is expected to fail in the future [48].

Each node periodically broadcasts a ‘hello’ message within its maximum transmission range, which contains information about its position and current moving speed. The ‘hello’ message sending interval is referred to as the topology update interval [49]. The primary advantages of wireless networks in comparison with their wired counterparts include flexible mobility management, faster and cheaper deployment, and ultimately easier
maintenance and upgrade procedures [50]. A novel pre-emptive solution for AODV called performance degradation monitoring (DEMON), which allows pre-emptive route recovery based on the passive estimation of link data loss rate. The performance of DEMON in combination with TCP congestion control mechanisms [51].

An efficient routing protocol called multiple next hops (MNH) routing protocol, which is based on the ad hoc on demand distance vector (AODV) routing protocol compared to AODV, which only provides a single route to the destination. MNH provides multiple alternative routes. These routes are maintained by intermediate nodes. This speeds up finding an alternate path when link fail [52]. A QoS-aware MAC protocol for multimedia traffic in MANETs introduces a packet switching concept and it minimizes the need for re-transmissions. This fact will, in turn, conserve scarce resources such as battery power and bandwidth [53].

In ad hoc network, an on-demand routing protocol is more suitable, if the network resources such as bandwidth, memory capacity, battery power, and the storage capability of network information among mobile hosts are limited. To establish a Loop-Free Multi-Path Routing with QoS protocol in the route request phase, intermediate nodes record multi-reverse links to construct multiple-path during the route reply phase [54]. Network control with Quality of Service (QoS) support is a key issue for multimedia applications in MANET. Most of the real-time applications have stringent requirements on bandwidth, delay, jitter, packet loss ratio, cost and other QoS metrics [55].

Alternate Route for improving Quality of Service (ARQoS) is an on-demand routing protocol for mobile ad hoc network, where the routing table of ARQoS maintains an alternate route to the specified node by considering the bandwidth requirement of the source node. The route is discovered by calculating the corresponding QoS provision parameter to find the primary route and the alternate route from the source node to the destination by applying the mechanism of carrier sense in IEEE 802.11b [56].
Opportunistic data forwarding (ODF) has drawn much attention in wireless networking. The effectiveness of ODF in wireless networks is heavily depended on the choice of proper routing protocols which can provide effective source routing services. Proactive source routing (PSR) is featured by loop-free and extremely small routing overhead. PSR provides every node with a breadth-first spanning tree (BFST) of the entire network rooted at it[57].

### 2.7.2 Performance of TCP Variants over Loop-Free Multipath Routing

TCP is unable to distinguish between losses due to route failures and network congestion. TCP suffers from frequent route failures, the contention on the wireless channel and TCP unfairness. The first two problems are the main causes of TCP performance degradation in MANETs. In cross layer design, the transport layer protocols and the underlying layer protocols work jointly.

For example, if the routing layer experiences the routing failure then, it sends feedback to TCP. On receiving the notification, the TCP enters into freezing state. TCP stops sending packets. After the route is established TCP goes to the normal state. In layered, the issues are addressed at any one of the OSI layers. The layered concept is primarily used in the wired network. Ad hoc network opposes layered protocol because of dynamic nature, infrastructure less architecture, limited resources, and mobility of nodes, time varying stable links and topology [58].

### 2.7.3 On-demand Loop-Free Multipath Routing

The path for data transfer can be selected on the basis of many metrics like least hop counts, bandwidth quality of the path, residual lifetime of path etc. Most of routing protocols address selection of paths based on least hop counts of the path. In this routing algorithm based on the reliability of the paths (multipath) quantitatively wherein the route selection is done on
the basis of residual lifetime of the routes. Reliability of the path is computed using the residual lifetime of each link of the path [59].

Video transmission over ad hoc networks is more challenging than the transmission over other conventional networks due to the changes in the topology that result in a relatively short lifetime of the network paths. The optimal protocol is identified and chosen by simulating three major routing protocols namely Destination-Sequenced Distance Vector (DSDV) that maintains a complete list of routes to the destination, Dynamic Source Routing (DSR) that makes use of source routing and route cache where the sender knows the complete hop-by-hop route to the destination and Ad hoc On-Demand Distance Vector (AODV) routing protocol. The optimum protocol for the transfer of video over Mobile Ad hoc Network is identified to be AODV. Hence an enhancement has been suggested to AODV routing protocol [60]. An example of a node-disjoint path and partially-disjoint path are shown respectively in Figure 2.5 and Figure 2.6.

Figure 2.5: Example of a node-disjoint path

Figure 2.6: Example of a partially-disjoint path

2.8 PACKET SCHEDULING SCHEMES OVER MULTIMEDIA TRAFFIC

A centralized scheduling scheme can be divided two main stages in practice. Firstly, the topology of the network is transferred into a routing tree. Secondly, the mini slots are allocated or scheduled to the nodes of the routing tree. For this reason, the centralized scheduling problem sometimes is also called the Routing and Packet Scheduling (RPS) problem. An efficient
centralized algorithm is applied to construct a routing tree that allows more concurrent transmissions to improve the network performance [61].

Quality of Experience (QoE) enhancement for a transmitted video sequence in MANETs is a challenging and important issue in networking research community. For each video source, the underlying multipath routing protocol, introduces N node-disjoint multi-hop paths between each source-destination pair (S, D) periodically. Each path is associated with a traffic flow and these multiplexed flows are aggregated in the destination node to reproduce the initial source-generated traffic stream. Each path ‘j’ related to the source contains M_j wireless links from source to destination for 1\leq j \leq N. The total transmission rate associated with the i^{th} link in the j^{th} flow of the source is denoted by R_{ij} and it can be calculated by using the Equation (2.6). It consists of two components; one is the traffic rate allocated to the j^{th} flow of the source which is denoted by x_j and another part is associated with the time-varying j^{th} link’s cross traffic a_{ij} [62].

\[ R_{ij} = x_j + a_{ij} \text{ for all } i, j (1 \leq i, j \leq N) \quad (2.6) \]

The performance of video streaming depends greatly on delay. In order to handle with it, streaming clients employ playout buffers where video frames are stored before being displayed. The playout of a video starts after initial buffering, which is supposed to compensate for expected delay. However, if the transmission rate is lower than the bit-rate of the video stream, the playout buffer might run out of video frames. The 'Video Streaming Performance under Proportional Fair (PF) Scheduling' algorithm discussed using simulations and mobility models. The problem addressed in this algorithm is the throughput-delay trade-off that the PF scheduler needs to balance when the offered traffic contains a mix of elastic and streaming applications [63].

Many MANET standards, such as 802.11a, 802.11b, and 802.11g, can be operated at various rates for QoS constrained multimedia communication to more efficiently use the limited resources of MANETs.
Since the radio channel is shared among neighbours in MANETs, calculating one-hop delays and determining delay-sensitive routes [64]. The urgency-based packet scheduling and routing algorithm are used to deliver the delay-sensitive video data effectively over mobile ad hoc networks [65].

Partially-disjoint paths are the paths between a (source, destination) pair with one or more overlapping nodes. Node-disjoint paths refer to the paths between a given (source, destination) pair which do not contain any overlapping node(s). The partially disjoint paths play a key role in enhancing the packet delivery reliability of an ad hoc routing protocol [66].

2.8.1 Real-time Traffic Support in MANET

Real-time applications require mechanisms that guarantee bounded delay. The end to end delay in packet delivery includes the queuing delay at the source and intermediate nodes, the processing time at the intermediate nodes and the propagation duration over multiple hops from the source node to the destination node. Providing real-time guarantees in ad hoc wireless networks is extremely difficult due to reasons such as the unrestricted mobility of nodes, dynamic varying topology, time-varying channel capacity and the presence of hidden terminals. This research is focused on providing QoS support for applications that require soft real-time guarantees.

2.8.2 Scheduling Algorithms for Real-time Application

Adaptive selfish scheduler queue management scheme have a scheduler which is enclosed by the packet classifier. The packet classifier differentiates the packet and scheduler will monitor the buffer status. Then the scheduler will make the decision to transmit the data packet either from M/M/1 or M/M/n. If the average trust value is higher than the trust value then the node is a reliable node otherwise it is a selfish node [67].

The impact of mobility on video streaming over multi-hop wireless networks is investigated by utilizing a class of scheduling schemes. The node
spatial mobility has the ability to improve video quality and reduce the transmission delay without the help of advanced video coding techniques. In this analysis, it does not exploit any advanced coding techniques, such as scalable video coding, multiple description coding, compressed-sensing video coding, etc, instead the node mobility, which has been considered in the multimedia communications [68].

2.8.3 Cross-Layer Design for Delay-Sensitive Applications

An Adaptive Delay-Aware Multipath Routing (ADAMR) framework for reliable transmission of delay-sensitive applications over mobile ad-hoc networks (MANETs) uses cross-layer design to abstract the QoS constraints of requesting applications in terms of end to end delay. In an adaptive flow admission control technique, each admitted data session packet gets the required delay. This procedure admits only those data sessions for which our multipath routing protocol is able to find a delay-aware route. Proposed multipath routing protocol not only discovers routes that satisfy the given delay constraints but also makes sure that the discovered routes are node-disjoint. ADAMR uses a reactive approach to discover multiple routes for a source-destination pair and is based on ad-hoc distance vector (AODV) routing protocol. When a delay-sensitive application wants to start a data session, it sends a request to the underlying network layer by specifying its delay constraints. At the network layer, the ADAMR protocol initiates a low routing overhead route discovery process to discover all the available routes that satisfy the delay requirements of the application [69].

2.8.4 Packet Scheduling Technique to Minimize the Inter-Packet Delay

QoS factors vary from application to application. For example, for real-time applications, the data rate and delay are the vital factors, whereas, in military use, security and reliability become more important. In case of emergency situations, the key factor should be the availability. Five types of scheduling algorithms namely First-In-First-Out (FIFO) Scheduling Algorithm, Priority Queuing Algorithm, Weighted Fair Queuing (WFQ) Algorithm, Class-
Based Weighted Fair Queuing (CBWFQ) Algorithm and Low Latency Queuing (LLQ) Algorithm have been analyzed using OPNET simulator in the real-time application's traffic [70].

Reliability in real time data transmission can be assured by confirming the connectivity of the network. In order to provide and maintain connectivity, a reliable real-time data transmission technique in MANET is used [71]. The routing protocol is the most integral part of any type of QoS provisioning. It has to decide which route is able to fulfill the requirement of the desired QoS for specified application. The modification has been made in the existing MANET protocols to get the information about total path bandwidth for delay sensitive applications [72].

The performance of transport layer flows are influenced by the issues such as MAC protocol, routing protocol, the length of a route, buffer size, active queue management algorithm and the congestion control algorithms. An Adaptive packet scheduling technique is used to minimize the packet delay time in MANET by maintaining a Queue for each flow through Finite State Machine (FSM) Mechanism. The rate of data transmission, the queue management, routing path and packet scheduling technique are considered in the FSM mechanism. Through this method, the delay in the network is reduced [73].

2.9 QUEUE MANAGEMENT SCHEMES OVER MULTIMEDIA TRAFFIC

The resources shared mostly are the bandwidth of the links and the queues on the routers or switches. Packets are queued in these queues awaiting transmission. When too many packets are contending for the same link the queue overflows and packets have to be dropped [74].

The application of fuzzy control techniques to the problem of congestion control in networks is suitable due to the difficulties in obtaining a precise mathematical model using conventional analytical methods. A Fuzzy Inference Engine (FIE) is designed, which uses separate linguistic rules for
each predefined class in the router queues to preferably drop packets in networks. A leaky-bucket traffic shaper is used to check if the packets comply with the Service Level Agreement (SLA). The Random Early Detection (RED) algorithm is an Active Queue Management (AQM) approach [75]. With respect to dropping of packets, the queue management algorithms are two main types. They are Active Queue Management (AQM) and Passive Queue Management (PQM).

2.9.1 Active Queue Management

In AQM, the packets are dropped possibly before the buffer is full. It improves the routers to detect the congestion in advance and manage the queue in such a way that the sender to reduce their packet sending rate into the queue. The key objectives of AQM are to reduce the number of packets dropped in routers, to provide minimum delay by maintaining the average queue size as small.

2.9.1.1 Introduction

In recent, the congestion controls in communication networks have been of more research interest among researchers. An AQM is one of the key areas to control congestion in networks. However, the existing AQM algorithms help in controlling the congestion, the survey is made with the aim to further reduce the queuing delay and packet drops over the transmission of the real-time application. The Random Early Detection (RED) queue management algorithm is one of the well-known examples for AQM.

2.9.1.2 Fuzzy AQM for congestion control

Hop Based Queuing (HBQ) is an Active Queue Management Technique for Multi-Hop Wireless Networks. HBQ explores the number of wireless hops traversed by the packets currently in the buffer of the node. In that sense, packets are not dropped randomly from the queue, but the logic
behind which packet to be dropped is given by a well-defined set of probabilities [76].

An early dropping of the incoming packet is an effective technique to avoid congestion and to minimize the packet latency. Such approach is known as Active Queue Management (AQM). Uncertainty associated with queue congestion estimation and lack of mathematical model for estimating the time to start dropping incoming packets makes the Fuzzy-AQM algorithm the best choice. Fuzzification is a process where crisp input values are transformed into membership values of the fuzzy sets. After the process of fuzzification, the inference engine calculates the fuzzy output using the defined fuzzy rules [77].

The static estimated link lifetime (LL) is used in wireless ad-hoc networks for nodes affinity management during the connection time. An adaptive LL can be used to effectively reduce routing overhead and end to end delay in ad-hoc networks. An adaptive-LL used linear function while the second method fuzzy-LL used fuzzy reasoning. These two methods map the relationship between nodes affinity and their LL. Fuzzy-LL method showed more consistency to LL fluctuation and more robust to topology changes than adaptive-LL method [78].

Fuzzy logic techniques promise to be efficient for reducing delay transmission of multimedia applications in wireless ad hoc networks. Many multimedia applications such as VOIP (Voice over IP) and MOIP (Multimedia over IP) are delay sensitive or bandwidth sensitive applications. A fuzzy logic QoS approach for wireless ad hoc network makes use of fuzzy logic theory for best-effort traffic regulation and proposes schemes for real-time traffic regulation and admission control [79].

With the increase of multimedia traffic over the past few years and traffic differentiation introduced by IEEE 802.11e, nodes with delay-sensitive multimedia traffic tend to be busy for long periods, thus exacerbating the congestion problem in Mobile Ad Hoc Networks (MANETs). The performance
of MANETs routing protocols is highly dependent on the type of traffic generated or routed by intermediate nodes. A Type of Service Aware (TSA) routing protocol is an enhancement to AODV, which uses both the Type of Service (ToS) and traditional hop count as route selection metrics. TSA avoids congestion by distributing the load over a potentially greater area and therefore improving spatial reuse. The amount of multimedia traffic is rapidly increasing in today’s networks. These types of traffic are delivered in form of UDP flows without the capability of managing congestion. TSA is a cross-layer solution that works in conjunction with the MAC layer [80].

Guaranteeing the quality of service is a key problem to multimedia stream in mobile Ad Hoc networks. In a mobile environment, the changing of the queue is quite different from those in static conditions. Calculating the queue delay is a challenging task in mobile Ad Hoc networks [81]. Congestion in mobile ad hoc networks leads to transmission delays and packet losses. This problem becomes more visible especially in the large-scale transmission of heavy traffic such as multimedia data, where congestion is more probable and the negative impact of packet loss on the service quality is of more significance. In a distance vector routing protocol, every host maintains a routing table containing the distances from it to possible destinations. A mobile host in an ad hoc network can be viewed as a single server queuing system.

The delay of sending a packet is positively correlated with congestion. Every host estimates the expected delay based on the mean of delay for all data packets sent in a past short period of time. Currently, the length of the period is equal to the interval between two periodical updates. The expected delay is computed using the Equation (2.7).

\[
E(D) = \sum_{i=1}^{n} \left( D_i \cdot \frac{L}{n} \right)
\]  

(2.7)
Where ‘n’ is the number of packets sent and ‘L’ is the length of Medium Access Control (MAC) layer packet queue. E (D) estimates the delay time for a newly arrived packet has to wait before it is sent out and ‘D_i’ represents the delay for the i^{th} packet [82].

The DSR protocol is modified to define the occurrence of congestion by monitoring and reporting multiple resource utilization thresholds as QoS attributes and use multi-path-routing and load-balancing during the periods of congestion to improve QoS in MANETs for Constant Bit Rate (CBR) multimedia applications [83]. Queue management method employed by the routers is one of the important issues in the congestion control study. AQM algorithms run on routers and detect incipient congestion by typically monitoring the instantaneous or average queue size. When the average queue size exceeds a certain threshold but is still less than the capacity of the queue, AQM algorithms infer congestion on the link and notify the end systems to back off by proactively dropping some of the packets arriving at a router [84].

The primary objective of congestion control is to best utilize the available network resources and keep the load below the capacity. Dynamic Congestion Detection and Control Routing (DCDR) in ad hoc networks based on the estimations of the average queue length at the node level. Using the average queue length a node detects the present congestion level and sends a warning message to its neighbours[85]. Since the congestion problem is prevalent in transport, data link and network layer in Mobile Ad hoc networks, a cross-layer based congestion control technique is necessary to overcome the congestion problem. A cross-layer based technique to overcome congestion that occurs in MAC and transport layer in MANET. The proposed technique is applied over Ad hoc On-demand Multipath Reliable and Energy-Aware QoS Routing Protocol (AOMP-REQR) [86].

The main goal of congestion control is to effectively utilize the existing network resources and maintain the network load below the capacity. The Congestion Free Routing (CFR) in Ad hoc networks, based on
dynamically estimated mechanism to monitor network congestion by calculating the average queue length at the node level [87]. To overcome the congestion issue, each node estimates the parameters such as queue length, data rate, and medium access control (MAC) contention. The upper and lower limits of these parameters are compared and the node is marked with the congestion status such as normal, medium or high level. When data is to be transmitted from the source to destination, the intermediate nodes along the path verify its congestion status [88].

2.9.1.3 Buffer management scheme for packet queues

A new scheme of buffer management to handle packet queues in Mobile Ad hoc Networks through an active queue management strategy by assigning dynamic buffer space to all neighbouring nodes in proportion to the number of packets received from neighbours and hence controlling packet drop probabilities. Using this scheme to achieve efficient queuing in the buffer of a centrally communicating MANET node; call the node as Queue Management Node (QMN). The node QMN allocates equal buffer space to all of its neighbours in the initialization phase of allocation. For each neighbour, the Allocated Buffer Space (ABS) can be computed using the Equation (2.8).

\[
ABS = \frac{B_s}{N_n}
\]  

(2.8)

Where, ‘\(B_s\)’ is buffer space and ‘\(N_n\)’ is number of neighbours of QMN [89].

AQM is a proactive congestion control scheme by which the network sends information to the sources when it detects early congestion. The information can be sent explicitly in the form of Explicit Congestion Notification (ECN) marks [90]. The method for dynamic congestion detection and control routing (DCDR) in ad hoc networks is based on the estimations of the average queue length at the node level. DCDR is a unicast routing
protocol for MANET. It reduces network congestion by ways of reducing the unnecessary flooding of packets and finding a congestion-free path between the source and the destination. In this method, when a source host has to transmit a data packet to a destination, the DCDR protocol first constructs a congestion-free set (CFS) to connect both one-hop and two-hop neighbours. Then the source initiates the route discovery procedure using the CFS to identify a congestion-free path to the destination [91].

The Effective Congestion Avoidance Scheme (ECAS), which consists of congestion monitoring, effective routing establishment and congestion-free based routing. Based on the congestion standard, the congestion-free based routing is established to reduce the packet loss, high overhead, long delay in the network [92]. The Priority Based Weighted Queue QoS model provides a queue by dividing the resources of the traffic based on the weights of the packets. It uses the traffic priority management system. The packets are transmitted in a timely fashion. In this model, bandwidth is allocated on priority basis [93].

2.9.2 Passive Queue Management

Another type of queue management algorithm with respect to the dropping of packets is the Passive Queue Management (PQM).

2.9.2.1 Introduction

In PQM, the packets are not dropped until the buffer becomes full. That is, the packets are allowed to enter into the queue until the queue reaches its maximum size. If it reaches its full size then all the incoming packets are dropped. When a packet is departed from the queue then one packet is allowed to enter into the queue. The Drop-Tail queue management algorithm is one of the well-known examples for PQM. In drop tail method the most recently arrived packet will be dropped when the queue is full and it gives a signal of congestion to all other sources. However, the PQM has two important limitations namely lock-out and full queue.
2.9.2.2 Limitations of PQM

Lock-out is the scenario that occurs when drop tail allows multiple flows monopolize the queue space and prevent other flows to enter into the queue. The result is inequitable sharing of network resources between the flows.

In PQM, the queue maintains almost maximum length for long period of time and it leads to more queuing delay while the main objective of queue management is to decrease the end to end delay and to increase the throughput.

2.10 MANET ROUTING, SCHEDULING AND QUEUE MANAGEMENT SCHEMES

QoS routing is an essential component of QoS architecture. There are many challenges in design QoS routing protocol over wireless ad hoc network due to its dynamic and physical nature. Based on AODV protocol, an improved QoS routing protocol in wireless ad hoc network is devised. It extends the route table that improves request reply packet and employs selected flooding and local recovery mechanism to effectively increase packet delivery ratio and reduce the control overload and route searching time [94]. As there is a development in communication technology, the communication between the wireless mobile network and the traditional wired network is an important part that needs QoS between these different networks are also emerging [95].

Broadcasting is the process in which a source node sends a message to all other nodes in MANET. Network wide broadcasting in Mobile Ad Hoc Network provides important control and route establishment functionality for a number of unicast and multicast protocols. Broadcasting in MANET poses more challenges than in wired networks due to node mobility and scarce system resources [96]. A Comparison of the TCP variants performance is made over different Routing Protocols on Mobile Ad Hoc
Networks. A variant of TCP (Tahoe, Vegas) is the most widely used transport protocol in both wired and wireless networks [97].

Scalability of a lot of on-demand routing protocols is limited because of nodes’ movement. When the number of users is increased, ad-hoc routing protocols need it. Scalability for wireless routing protocols basically depends on extra routing messages. If the intermediate nodes do not receive RREP after a predetermined time, it sends a RERR message to the source and all nodes which use this connection to reach their destinations for updating the routing table by receiving RERR. When the source receives RERR, it deletes the related routes from its table and then starts the route discovery operation to establish a new route [98].

SACK is a type of selective acknowledgements for the TCP to provide the sender with sufficient information to recover quickly from multiple packet losses within a single transmission window. TCP with SACK option performs better than standard TCP in situations where there are multiple packet losses within a window of outstanding data [99].

The multipath routing scheme is called Multipath On-demand routing in order to minimize the route break recovery overhead. This scheme provides multiple routes on the intermediate nodes on the primary path to the destination along with source node. The primary path is the first path received by the source node after initiating the route discovery, which is usually the shortest path. In order to eliminate any possibility of loops the ‘advertised hop count’ is introduced. The advertised hop count of a node ‘i’ for a destination ‘d’ represents the maximum hop count of the multiple paths for ‘d’ available at ‘i’. The protocol only accepts alternate routes with hop count lower than the advertised hop count, alternate routes with higher or the same hop count are discarded. The advertised hop count mechanism establishes multiple loop free paths at every node [100].

The Routing On-demand Acyclic Multipath (ROAM) algorithm maintains multiple loop-free paths to destinations. Each router maintains
entries only for those destinations for which data flows through the router, which reduces storage space requirements and the amount of bandwidth needed to maintain correct routing tables. To maintain loop-free routes, each router can pick a node as successor node that satisfies either of the two feasibility conditions. To remain passive and have a loop-free route, a router needs to have a neighbour that is a feasible successor. The feasible successor provides the shortest loop-free path to the destination. The Passive Feasibility Condition (PFC) is to be satisfied by a router’s successor when a router is passive. The Active Feasibility Condition (AFC) comes into play only when a router is active, that is, there is no longer any feasible successor [101].

It is commonly stated in protocol specifications that sequence numbers are sufficient to guarantee loop freedom if they are monotonically increased over time. The use of sequence numbers is popular in Ad hoc On-Demand Distance Vector (AODV) routing protocol. But, it is proved that monotonically increasing sequence numbers by themselves do not guarantee Loop Freedom and thus AODV Can Yield Routing Loops [102].

Kairat Jaroenrat suggested a Design Algorithm for QoS Network with Flow Delay Control as the process of Network design is composed of topology design and traffic routing. Topology design is to choose links among network nodes to be installed and determine the link capacity so that the cost of the overall network is minimized. Traffic routing distributes the load for given traffic demands over the installed link such that performances are optimized [103].

In the process of enhancing real-time video streaming over mobile ad hoc networks using multipoint-to-point communication, the UDP is used as the transport layer protocol. Video applications have rigid requirements on bandwidth, delay, and jitter [104]. The unique features of an effective Cross-layer Packet Scheduling and Routing Algorithm for delay-sensitive media transmission over MANET is that packet scheduling algorithm at the MAC layer and routing algorithm at the network layer are tightly-coupled to improve
end to end QoS. Based on the delay requirement and route topology, packet urgency, node urgency, and route urgency are defined. An effective tightly-coupled packet scheduling and routing algorithm have been designed by using these metrics. The proposed algorithm can significantly improve the number of packets delivered in the tolerable delay bound by distributing urgency over the entire network [105].

Simulation-based performance evaluation and comparison of three queuing techniques (First-In-First-Out, Priority Queuing and Random Early Detection) for different number of nodes, packet size and pause time for the impact of packet delivery ratio. It is also noticed that using RED has greatly improved all the performance measures. The reason is that RED monitors the average queue size and randomly drops packets when congestion is detected [106].

The research in the area of QM shows an improvement in performance by implementing the state of the art active queue management technique like RED and REM. Now optimizing these queue management techniques by varying different network parameters like delay, channel error rate, jitter can yield unexpected performance improvements. The testing of this active queue management technique with these varying network parameters becomes a challenging task [107]. Table 2.1 shows the existing routing, scheduling and queuing strategies.

Table 2.1: Existing Routing, Scheduling and Queuing Strategies

<table>
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<tr>
<th>REFERENCES</th>
<th>METHODOLOGY</th>
<th>LIMITATIONS</th>
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<tbody>
<tr>
<td>Sachin Kumar Gupta et al (2011)</td>
<td>“Performance Metric Comparison of AODV and DSDV Routing Protocols in MANETs Using NS-2”, based on network load, mobility, and network size have been analyzed with</td>
<td>With respect to the routing overhead was not analyzed using AODV.</td>
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<td>Author</td>
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<td>Teerapat Sanguankotchakorni et al (2011)</td>
<td>&quot;A Cross-Layer Framework for Efficient MPEG-4 Video Streaming Over IEEE 802.11e in MANETs&quot;, a new design paradigm 'Cross-layer architecture' in the domain of Mobile Ad hoc Networks (MANET), enables knowledge sharing between layers to provide optimization and better Quality of Service (QoS).</td>
<td>With respect to the routing overhead was not analyzed.</td>
</tr>
<tr>
<td>Biradar S. R. et al (2010)</td>
<td>“A Comparison of the TCP Variants Performance over different Routing Protocols on Mobile Ad Hoc Networks&quot; was studied by simulation experiments and results are reported.</td>
<td>In the comparison of TCP variants the packet drops were not calculated.</td>
</tr>
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</table>
of Broadcasting methods in Mobile Ad Hoc Network“, presented an overview of the broadcasting techniques in mobile ad hoc networks, and simulated the simple Flooding algorithm using NS2 simulation.

For better QoS Cross-layer paradigm is not used and also Packet Delivery Ratio (PDR) is not calculated.

| Ming-Hong Jiang et al (2002) | "An efficient multiple-path routing protocol for ad hoc networks“ proposed a modified AODV routing protocol to establish multiple paths for route discovery, thus reducing route reconstruction time when routing path fails. | Time To Live (TTL) value is not considered. Establishing multiple paths for route discovery may leads to routing loops and hence the more packets are possible to drop due to the allowable TTL value. |

<p>| Rob van Glabbeek et.al (2013) | &quot;Sequence Numbers Do Not Guarantee Loop Freedom — AODV Can Not analyzed with more than one layer |  |</p>
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<th>Author(s)</th>
<th>Title</th>
<th>Description</th>
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<tr>
<td>Yield Routing Loops</td>
<td>proposed a node, chooses another backup path to send data without performing route discovery when the routing path breaks which could increase network performance.</td>
<td>In MANET it is better to consider more than one layer. In this work the performance of the routing layer only considered. The importance is not given to the TTL value that may leads to more packet drops.</td>
</tr>
<tr>
<td>Zehua Wang et al (2011)</td>
<td>“A New Loop-Free Proactive Source Routing Scheme for Opportunistic Data Forwarding in Wireless Networks”</td>
<td>update messages are harmoniously integrated into the tree structure. Packet looping is a harmful phenomenon in which packets are forwarded among the same nodes. Looping packets significantly consume resources of Reactive routing is not considered. Normally, Compared to proactive routing, in the reactive routing the overhead can be significantly reduced. Also the packet drops were</td>
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<td>Chee-Onn Chow et al (2007)</td>
<td>“Enhancing real-time video streaming over mobile ad hoc networks using multipoint-to-point communication“ to achieve better quality of video streaming, they investigated using the number of transmission points through which control overhead is reduced.</td>
<td>As for as real-time video streaming is concerned the reduction of Inter packet delay (IPD) is important than other performance metric. IPD was not measured.</td>
</tr>
<tr>
<td>Rukmani P. et. al. (2013)</td>
<td>“Scheduling algorithm for real time applications in mobile ad hoc network with OPNET modeler”, the scheduling algorithms have been analyzed using OPNET simulator.</td>
<td>Packet delay was not measured.</td>
</tr>
<tr>
<td>Sasikala K. et al (2014)</td>
<td>“Adaptive packet scheduling technique to minimize the packet delay time in MANET by maintaining a queue for each flow through FSM mechanism “, proposed the Finite State Machine algorithm and the ATP is used for performance measure.</td>
<td>Analysis is performed using the data traffic. In data traffic rather than delay the PDR is important. In real time traffic minimizing the</td>
</tr>
<tr>
<td>LyesKhoukhi et. al. (2008)</td>
<td>&quot;Experimenting with Fuzzy Logic for QoS Management in Mobile Ad Hoc Networks&quot;, the performance evaluation of the proposed model was studied under different mobility, channel, and traffic conditions based on a fuzzy logic system for wireless mobile ad hoc networks.</td>
<td>Managing the link queue size in an efficient manner is not considered and also queuing delay was not measured.</td>
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<tr>
<td>ShalluBedi et. al., (2015)</td>
<td>&quot;Active Queue Management in MANETs – A Primer on Network Performance optimization&quot;, discussed different queue management algorithms to control congestion.</td>
<td>Recent advances in wireless technologies needed to support video traffic applications in MANET. Queuing Management algorithm over delay sensitive application was not considered in this work.</td>
</tr>
</tbody>
</table>
2.11 SIMULATION ENVIRONMENT AND NS 2.34 OVERVIEW

Simulator is the basic tool used in the development of wired, wireless and ad hoc network protocols. Deployment of MANET in real networks is very difficult and the simulations make easy in the analysis and verification of the routing, delivery and application layer protocols. The simulator tools help flexible testing in various topologies, traffic patterns, mobility models, routing, transport and application protocols. The renowned simulators used for MANET simulations are Network Simulator 2 (NS2), Optimized Network Engineering Tool (OPNET) and Global Mobile Information System Simulator (GloMoSim). The NS2 is used as a simulator tool for this research work because it supports wired, wireless, MANET environment and it is a scalable simulator. This tool supports thousands of ad hoc nodes in MANET environment. Figure 2.7 depicts the Architecture of Network Simulator Tool.

![Architecture of Network Simulator Tool](image)

Figure 2.7: Architecture of Network Simulator Tool

Network simulator is an event-driven simulation tool and useful in studying the mobile nature of ad hoc nodes, simulation of routing algorithms, UDP, TCP protocol modification can be done using NS2. The NS 2.34 is a version of NS2 has got more popularity in the networking research community. This tool consists of two main languages: C++ and Object-oriented Tool Command Language (OTcl). The C++ used as a backend to define the internal mechanism of the simulation elements and OTcl is used as a frontend to set up the nodes. The tool generates two types of output namely trace file and network animated output. The trace file can further
represent as a graph by providing the trace file as input to X-graph tool or Trace graph tool.

2.12 CONCLUSION

This chapter has given a detailed description of characteristics and design factors of MANET followed by a meticulous survey on existing routing protocols, TCP Variants and mobility models in MANET. The chapter has also presented a set of challenges, problems encountered by the existing routing protocols, discussed various broadcasting schemes in route discovery, benefits of disjoint multipath routing schemes, existing packet scheduling schemes over multimedia traffic and a survey on queue management schemes over multimedia traffic, which brings about further research in these areas. Hence, the ensuing chapters present the proposed routing, scheduling and queue management techniques that provide the improvement of overall performance of the ad hoc networks by the method of increased efficiency in packet-forwarding.