1. INTRODUCTION

1.1 GENERAL

A Mobile Ad hoc Networks (MANET) is an autonomous system of mobile routers connected by wireless links. The routers are free to move randomly and organize themselves arbitrarily. Thus, the network's wireless topology may change rapidly and unpredictably. Such network may operate in a stand-alone fashion or may be connected to the Internet. Ad hoc network is an emerging technology in the wireless network. It is an infrastructureless wireless network which can work without administrative support.

In the modern era, a lot of research has been done in the area of MANET as the necessity has increased to support video traffic applications in MANETs. The increased multimedia traffic in MANET makes the nodes busy for a long time and causes high congestion leading to packet loss and poor Quality of Service (QoS) in data delivery. Many research papers which are published in this area provides separate solutions for routing, scheduling, queuing and end to end delivery issues to the independent layers namely network layer or transport layer. Hence, it is not in an integrated approach. Further, the existing works deal with data traffic, which does not include the time-critical traffic in MANETs. Providing QoS in MANETs for the transmission of real-time applications require the high packet delivery ratio with minimum delay. This study explores the possible opportunity for the need of delivering multimedia applications through performance enhancements in routing and end to end delivery with the available limited resources.

It is important to utilize the limited bandwidth, by minimizing the control packets during the route establishment. The packets may stay longer time period in the routing loop and hence it is essential to establish the disjoint routing. The Inter-Packet Delay (IPD) is the major issue in transmitting the multimedia applications from any ad hoc node to any other

node and therefore it is required to propose an efficient packet forwarding strategy. Good channel conditions are required for a smooth video transmission in MANET. Here, congestion is the significant problem that will occur when a link is carrying more data than its capacity and this may increase the queuing delay and the packet loss. Therefore, an improvement is needed in queue management algorithm to achieve better video transmissions. The requirements for routing the delay sensitive applications are minimized control overheads, packet drops, inter-packet delays, queuing delays, end to end delays, and ensured high packet delivery ratios.

With the requirement of providing a better design for ad hoc networks with a cross-layer based approach, the main motivation of this work is to support video traffic applications in MANET by providing effective routing, packet scheduling and queue management schemes. Real-time multimedia communications between peers are characterized by imposing QoS constraints on the underlying networks, such as minimum bandwidth, maximum delay and jitter requirements [1]. Ad hoc routing protocols are responsible for re-establishing lost links within the network and reconnecting partitioned ones. Then, it is obvious that the behaviour of these routing protocols will affect TCP performance [2].

Transmission Control Protocol (TCP) is considered as the most popular reliable transport protocol. It is compatible with almost all other Internet protocols and applications. Different version of TCP variants exists for an end to end delivery in ad hoc networks. A new TCP variant for Wireless Environment, Link losses, and COngestion packet loss ModEls (WELCOME) in MANETs is an end to end, implicit, loss differentiation and recovery algorithm solution referred as TCP-WELCOME [3].

Providing QoS in wireless ad hoc networks is an intrinsically complex task due to node mobility, distributed channel access, and fading radio signal effects. This goal can be successfully accomplished only through the cooperation of the different protocol layers involved. The proposed QoSarchitecture including cross-layer interactions that are able to support for

the applications with bandwidth, delay and jitter requirements in MANET environments [4]. The rapid increase in the development of different real-time applications with stringent maximum packet loss requirements in such environments and the existence of difficulties in satisfying the pre-specified QoS limits is a great motivation for designing some type of differentiated QoS guaranteeing mechanisms that can satisfy the demands of this class of the real-time traffics. A cross-layer technique is being introduced which is based on the packet loss information from the lower layers, some optimal bandwidth is assigned to the real-time applications which need some levels of the maximum packet loss guarantees [5].

It is clear that treating route failure as congestion is not advisable because congestion and route failure are different phenomena which are to be handled independently for performance improvement in MANETs as a Cross-Layer Approach via TCP [6]. The Challenges for QoS in MANETs are discussed and analyzed to provide the required QoS for the delivery of real-time communications such as audio and video that creates a number of different technical challenges [7].

Performance analysis of Random-Based Mobility Models in MANET Routing Protocol have studied for the effect of the different mobile node movement patterns in Random Waypoint Mobility Model, Random Walk Mobility Model and Random Direction Mobility Model on the performance of Ad hoc On-demand Distance Vector (AODV). From the observation, it shows that Random Waypoint Model is the best model which outperforms than both Random Walk Model and Random Direction Model in the Testbed scenarios [8]. The Cross-Layer Analysis is dealt in making the modification of contention and congestion Window Size to provide the solution for Contention Window Cheating problem based on congestion details provided by the Transport layer to the MAC layer and thus the overall efficiency is improved [9]. TCP Performance through Simulation and Testbed in Multi-Hop Mobile Ad hoc Network has been carried out to test the effect of throughput [10].

A Survey on QoS Based Routing Protocols for MANET has been analyzed and presented using different QoS parameters such throughput, Packet Delivery Ratio (PDR) and end to end delay [11]. A classical MANET is shown in Figure 1.1. In this figure, the circles represent the communication ranges of individual nodes and the dashed lines indicate a network link [12].

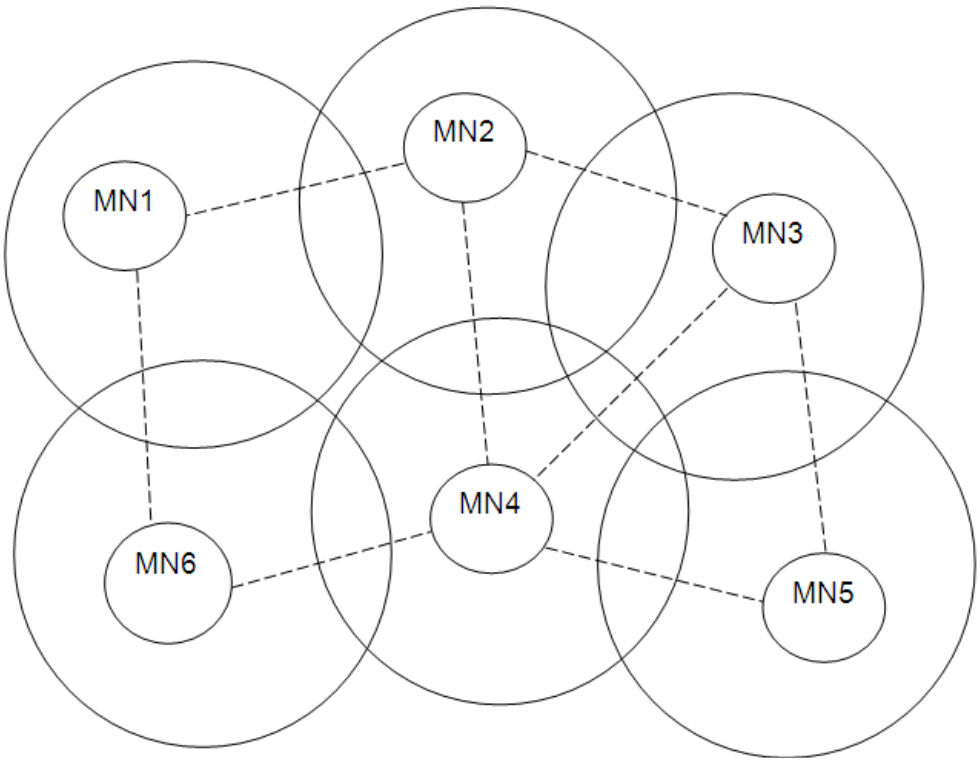

Figure 1.1: Typical Mobile Ad hoc Networks

The Characteristics of MANETs are, (i) the nodes that can perform both the roles of hosts and routers, (ii) bandwidth constrained, (iii) variable capacity links, (iv) Energy Constrained, (v) limited physical security, (vi) Dynamic Network topology and (vii) frequent routing updates. The advantages of MANETs provide access to information and services regardless of geographic position, these networks can be set up at any place and time. Some of the disadvantages of MANETs are Limited resources and physical security, intrinsic mutual trust vulnerable to attacks, lack of authorization facilities.

In spite of the tremendous amount of publications in this area, it is felt that there is a vital requirement for enhanced routing and queue management strategies for better improvements in the data delivery of time-critical multimedia applications in MANET. Since AODV routing protocol performs with the highest efficiency under high mobility than Destination-Sequenced Distance Vector (DSDV) routing protocol with respect to real-time applications, AODV is chosen to modify with the proposed strategies for the delivery of time-critical multimedia applications [13]. In this research, enhanced reactive routing techniques and queue management strategies are suggested to modify the AODV routing protocol to establish routing paths for multimedia applications from source to destination with a significant reduction in routing overhead, packet drops, Inter-Packet Delay and queuing delay. Selection of suitable TCP variant for a better end to end delivery is arrived at by testing and comparing the performance of the AODV and the modified routing protocols in different versions of transport protocols such as TCP Vegas, TCP Tahoe, and TCP SACK. Further, to manage the link queue size effectively and to reduce queuing delay a queue management technique is proposed.

Performance enhancements in routing and end to end delivery to support multimedia applications over MANET with the available limited resources have become an area of extensive interest among researchers. QoS is the performance level of a service offered by the network to the user. The goal of QoS provision is to achieve a more deterministic network behavior so that the information carried by the network can be better delivered and network resources can be better utilized. 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. The real-time application can be classified as hard real-time applications and soft real-time applications. Hard real-time applications include nuclear reactor control systems, air traffic control systems and missile control systems. In these applications, the failure to meet the required delay

constraints may lead to disastrous results. In soft real-time applications can tolerate degradation in the guaranteed QoS to a certain extent. Some of the real-time applications are voice telephony, video-on-demand and video conferencing. In these applications, the loss of data and variation in delay may degrade the service but do not produce hazardous results.

Providing real-time guarantees in ad hoc wireless networks are 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. In mobile ad hoc networks, there are many applications in which mobile users share information, e.g., collaborative rescue operations at a disaster site and exchange of word-of-mouth information in a shopping mall. For such applications, improving data availability is a significant issue and various studies have been conducted with this aim [14].

The quality of service guarantees is important if the network capacity is insufficient, especially for real-time streaming multimedia applications such as voice over IP, since these often require fixed bit rate, these can be called as a delay-sensitive application. Providing suitable quality of service (QOS) support for the delivery of real-time audio, video and data in mobile ad hoc networks present a number of significant technical challenges. QoS is used sometimes as a quality measure, with many alternative definitions, rather than referring to the ability to reserve resources. The quality of service sometimes refers as the degree of satisfaction to the end-users. High QoS is often confused with a high level of performance or achieved service quality, for example, high bit rate, low latency and low bit error probability. The research on QoS support in MANETs spans over all the layers in the network.

The Route establishments from Node ‘A’ to Node ‘J’ using AODV Routing Protocol is depicted in Figure 1.2. When a source has data to transmit to an unknown destination, it broadcasts a Route Request (RREQ) for that destination. If the receiving node is the destination or has a current route to the destination, it generates a Route Reply (RREP). The RREP is

unicast in a hop-by - hop fashion to the source. Control messages are route request, route reply and Hello message. The ad hoc nodes are named as A, B, C, D, E, F, G, H, I and J. The nodes A and J are the source and destination node respectively.

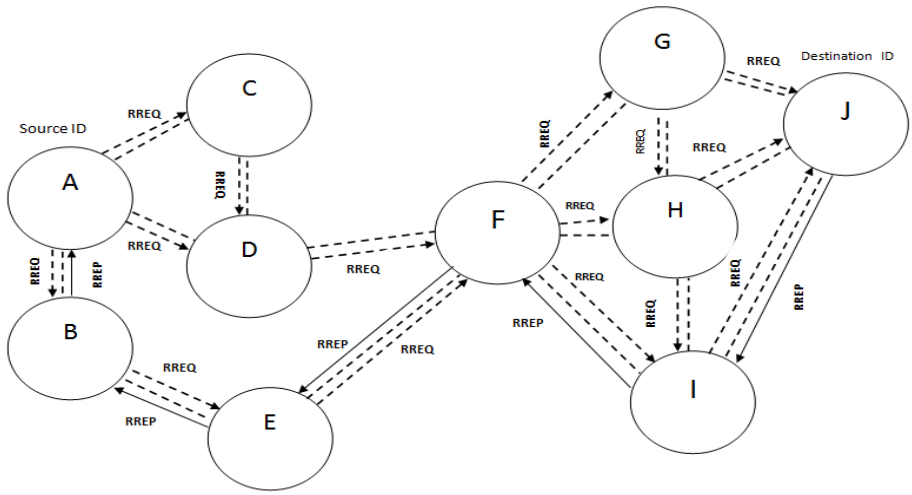

Figure 1.2: Route establishments from Node 'A' to Node 'J' using AODV Routing Protocol

The existing AODV routing protocol and Comparing the performance the protocol with TCP variants, such as TCP Tahoe, TCP SACK and TCP VEGAS. TCP is the reliable protocol. The reliability (R) of the system (S) is defined as the probability (p) that system (S) is operational during a period of time [15].

To solve the problem timeout, TCP Vegas uses a modified retransmission strategies, which are based on the Fire-Gained measurements of RTT. Among the different TCP Variants, the Retransmission Time Out (RTO) is calculated using Adaptive Backoff Response Approach (ABRA) in TCP New Reno to improve the performance in terms of congestion control [16]. The impact of mobility on delay-throughput performances is evaluated in multi-service Mobile Ad-Hoc Networks using AODV routing protocol. In this study, there are three mobility models are considered namely, Random Waypoint, Mobgen-Steady State

and Random Direction [17]. Cross-layer architecture, a new design paradigm in the domain of MANET, enables knowledge sharing between layers to provide optimization and better Quality of Service (QoS). The congestion control techniques that are applicable for wired networks will not directly apply as it is to ad hoc networks. It has the issues like limited bandwidth, power constraints and frequent link failures lead to high packet loss and delay will get increased. However, this packet drops and delay need not caused congestion, but it may be misinterpreted as caused by congestion [18].

The Figure 1.3(a) represents the Typical Layered Architecture and the Figure 1.3(b) represents the proposed Cross-Layer-Based Architecture for MANETs to improve the performance. In MANET, the layers are not completely decoupled and therefore the better design for ad hoc network is suggested as a cross-layer based approach. In this approach, one layer will affect the performance of another layer.

Some of the applications of MANETs are Military or police exercises, disaster relief operations and urgent business meetings. To improve the performance of the real-time applications, the values of three performance metrics (IPD, queuing delay and End to End delay are) can be minimized. These can be reduced by using the appropriate packet scheduling technique with suitable queue management technique. The delay may happen due to various reasons such as nodes mobility, routing, scheduling of packets etc. To achieve, the performance improvement in routing and delivery, some of the major issues in routing and the policies for congestion control are considered. Packet routing algorithm, packet lifetime control policy, packet scheduling procedure, packet queuing strategy and acknowledgement policy are the strategies considered for effective routing and to control congestion.

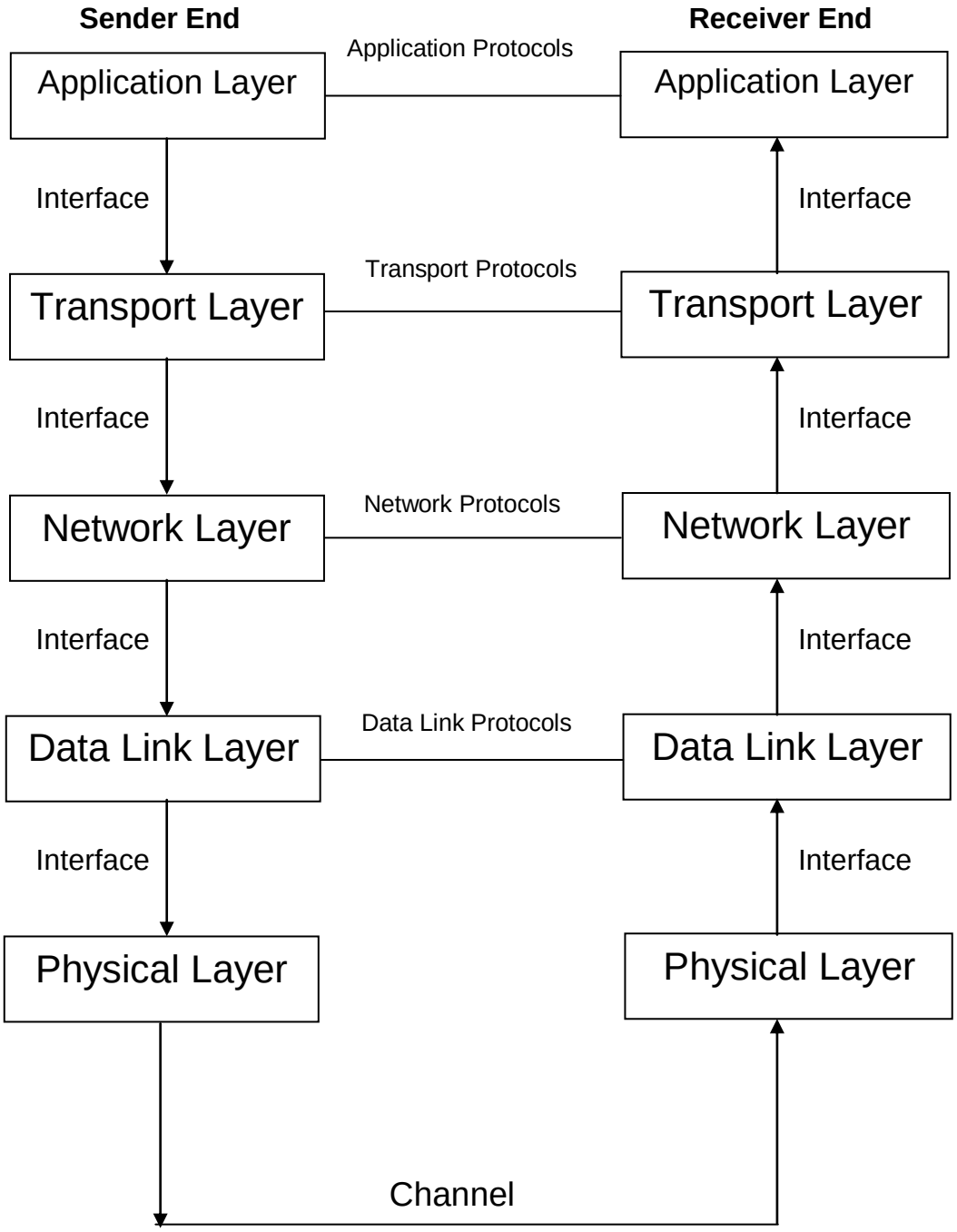

Figure 1.3 (a): Typical Layered Architecture

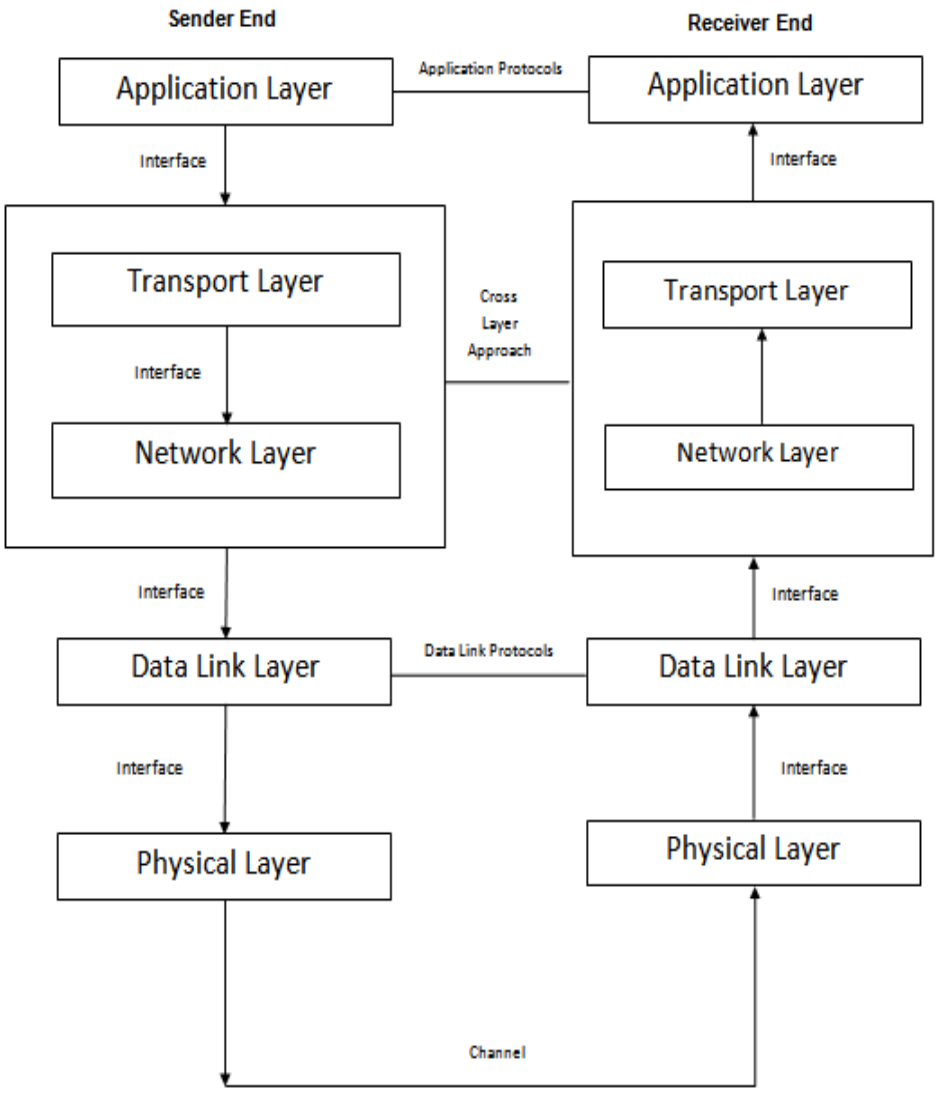

Figure 1.3 (b): Cross-Layer-Based Architecture

The MANET Layers Interaction and its important functions are shown in Figure 1.4. The vital functions of network layer are routing, rebroadcasting and packet scheduling.

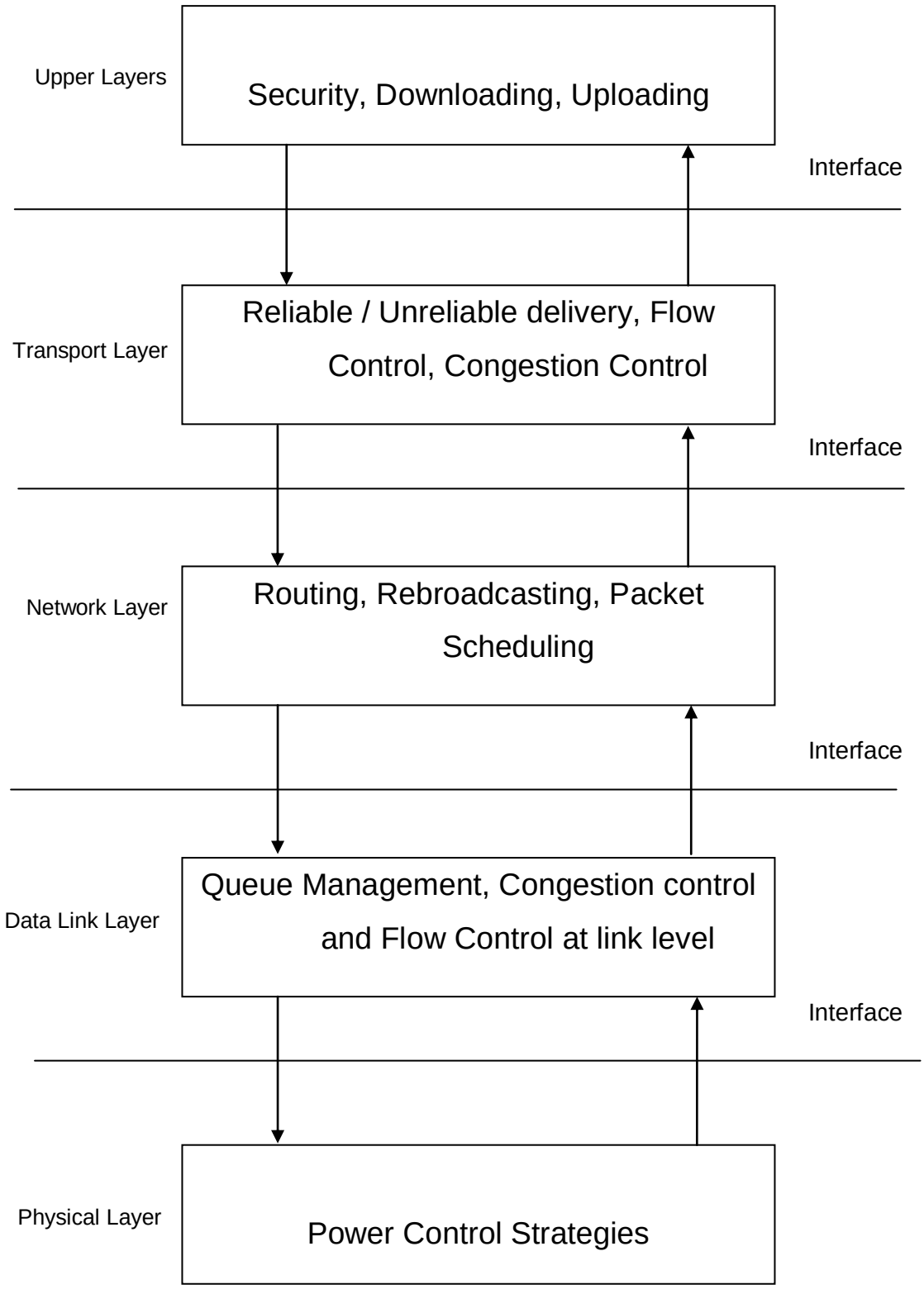

Figure 1.4: Layers Interaction and its important functions

1.2 STATE OF ART TECHNOLOGY AND MOTIVATION FOR THE PRESENT WORK

A good deal of literature is available pertaining to routing, scheduling and queue management algorithms to improve the performance of ad hoc network. In spite of the tremendous amount of publications in this area, it is felt that there is a vital requirement for enhanced routing and queue management strategies for better improvements in the data delivery of time-critical multimedia applications in MANET. Many research papers have been reported routing, scheduling, queuing and end to end delivery issues as a separate layer. Most of the reports deal with data traffic, which does not include real-time traffic to support video traffic applications in MANETs as they grow popularity.

QoS routing is part of the network layer and searches for a path with enough resources but does not reserve resources [19]. Several cross-layer routing metrics have been developed to improve wireless multi-hop mesh routing. Most of the research work in the literature considers user perspectives, network performance and routing stability as the key factors for enhancing the MANET performance [20]. The performance of the MANET is enhanced by a Cross-layer Solution that deals with congestion and removes false interpretation of link failure due to node movement [21]. A real-time MAC Protocol for mobile ad hoc networks are proposed and this feature is essential for earthquake surveillance application, especially the traffic intensity is heavy [22]. QoS can be improved by effectively using the available limited resources in an optimized manner such as discovering a path that augments the MANET users to deliver massive data [23].

The routing protocols for MANETs are divided into three types, namely Proactive (Table Driven), Reactive (On-Demand) and Hybrid Protocols. Examples of Proactive MANET Protocols are Optimized Link State Routing (OLSR), Destination-Sequenced Distance Vector (DSDV) and Cluster-head Gateway Switch Routing Protocol (CGSR). The different types of On Demand protocols are Ad hoc On-Demand Distance Vector (AODV),

Dynamic Source Routing protocol (DSR), Temporally Ordered Routing Algorithm (TORA) and Location-Aided Routing (LAR) Protocol. Examples of hybrid routing protocols are Zone Routing Protocol (ZRP) and Wireless Ad hoc Routing Protocol (WARP).

TCP is widely used as a connection oriented transport layer protocol that provides reliable data packet delivery over unreliable links. TCP primary purpose is to provide a connection oriented reliable data transfer service between different applications to be able to provide these services on top of an unreliable communication system. TCP needs to consider data transfer, reliability flow control, multiplexing, TCP segment, and congestion control and connection management. TCP does not depend on the underlying network layers and, hence, the design of various TCP variants is based on the properties of wired networks. However, TCP congestion control algorithms may not perform well in heterogeneous networks. The TCP protocol has been extensively tuned to give good performance at the transport layer in the traditional wired network environment.

However, TCP in its present form is not well suited for mobile ad hoc networks (MANETs) due to frequent path breaks, asymmetric link behaviour. The reason behind the variations of TCP is that each type possesses some special criteria, such as the traditional TCP has become known as TCP Tahoe. TCP Reno adds one new mechanism called Fast Recovery to TCP Tahoe. TCP New Reno uses the newest retransmission mechanism of TCP Reno. The uses of TCP SACK permit the receiver to specify several additional data packets that have been received out-of-order within one dup ACK, instead of only the last in order packet received.

In MANET broadcasting is an essential operation for discovering neighbours. The routing protocol such as AODV uses broadcast mechanism for route discovery. AODV allows mobile nodes to obtain routes quickly for new destinations and does not require nodes to maintain routes to destinations that are not in active communication. AODV discovers routes as and when necessary, does not maintain routes from every node to every

other node. Routes are maintained just as long as necessary. Whenever routes are not used then the routes get expired and discarded.

Various packet scheduling algorithms like First-In-First-Out (FIFO), Priority Queuing Algorithm, Weighted Fair Queuing and Class-Based Weighted Fair Queuing are supported by MANET. Queue scheduling algorithms are important components in the provision of guaranteed Quality of Service (QoS) parameters. It will manage the changes in queuing dynamics in different situations also improve the performance of the network. The emergence of new multimedia and Internet applications has insisted on studying the scheduling algorithms for providing QoS guarantees.

Guaranteeing the quality of service is a key problem to a multimedia stream in mobile Ad Hoc networks. The existing study deals with the channel delay and bandwidth which are based on the MAC layer with little focus on queuing delay. The queuing delay is an important performance metric, which should be reduced in the transmission of multimedia applications. In a mobile environment, the changing of the queue is quite different from those in static conditions. In static networks, nodes are connected with the fixed neighbours; it is relatively easy to estimate the queue length and the changing. However, in mobile networks, especially for ad hoc networks, due to the mobility of nodes, it is very difficult to judge how the changing of neighbours, so it is hard to estimate the condition of the queue. Therefore, reducing the queuing delay is a challenging task in mobile ad hoc networks. It can be reduced by the effective management of link queue size.

Most of the modern networks are developed based on continuous end to end paths and data packets which are delivered through the network via both. The end to end fairness in an ad hoc wireless network is a challenging task compared to wired networks, which has not been tackled efficiently. The issues such as MAC protocol, routing protocol, the length of a route, buffer size, active queue management algorithm and the congestion control algorithms influences the features of transport layer flows. The ad hoc network is dynamic in nature due to various parameters such as transmission

of control packets, multi-hop nature of forwarding packets, changes in source and destination nodes, changes in the routing path influences determining throughput and fairness among the concurrent flows. A queue is maintained for each flow and the delay information of each flow is maintained accordingly. The proposed methods are important to resolve the problems, such as:

- To control the broadcast storm problem through limiting the broadcasting nodes
- To reduce the packet drops due to the occurrences of routing loops between same two nodes while selecting the next neighbour node for rebroadcasting.
- To minimize the Inter-Packet Delay while transmitting the multimedia applications from any ad hoc node to any other node
- To control congestion at the link level on delivery of time critical multimedia applications.

1.3 OBJECTIVES

Keeping in the background, the contributions made so far in the area of routing, scheduling and queuing techniques, the main aim of this research is to focus on developing a hybrid model that supports video traffic applications in MANET by addressing the routing issues in mobile ad hoc networks. The research gap and the contributions made for the research is a critical requirement for enhanced routing and queue management strategies for better improvements in the data delivery of time-critical multimedia applications in MANET. This thesis suggests new routing and queue management algorithms for MANET that ensure high packet delivery ratio, minimized packet drop, Inter-Packet delay, Queuing delay and End to End delay with reduced control overhead. This thesis presents the results of the investigation on three important aspects, (i) the routing, (ii) scheduling and (iii) queue management techniques in MANET. The specific objectives of this thesis work are detailed as follows:

- The introduction of a new Probabilistic Scheme based AODV (PSAODV) routing as a modified AODV routing for reduction of routing overhead (control overhead) and selection of a suitable TCP variant in MANET.
- The exploration of a Loop-free Multipath in Probabilistic Scheme based AODV (LM-PSAODV) routing as a modified AODV for reduction of packet drops and selection of a suitable TCP variant in MANET.
- The implementation of an Enhanced Round Robin Packet Scheduling Strategy (ERR-PSS) in LM-PSAODV for reduction of the Inter-Packet Delay (IPD) in mobile ad-hoc networks for multimedia applications.

- Deployment of fuzzy based random early detection (FL-RED) technique as a queue management scheme for congestion control and reduction of queuing delay in delay sensitive applications.
- Integration of LM-PSAODV, ERR-PSS and FL-RED algorithms and development of an improved routing and queue management framework for better performance achievement in MANET.

1.4 SCOPE OF THE THESIS

This thesis describes Loop-free Multipath Probabilistic Scheme based routing, Enhanced Round Robin packet scheduling and of Fuzzy Logic based Random Early Detection queue management algorithms in the challenging environment of both high mobility and density of wireless ad-hoc nodes tune for MANET to transmit the multimedia applications. The methodology used in this thesis is the development of a framework that will be helpful in an efficient way for reduction of routing overhead, packet drops and queuing delay in delay sensitive applications. This dissertation is divided into seven chapters including the introduction.

Well-known and the very important MANET routing protocols and TCP Variants have been reviewed in Chapter 2. The characteristics and design factors of MANETs are discussed elaborately. The classifications of MANET routing protocols are presented, describing neatly their advantages and disadvantages. The performance of routing protocols for evaluation with different TCP variants, such as TCP Tahoe, TCP SACK and TCP VEGAS for the cross-layer interaction between network and transport layers. The existing TCP variants for evaluation with routing protocols have been reviewed. The existing broadcasting schemes in route discovery, disjoint multipath routing schemes, packet scheduling schemes and queue management schemes over multimedia traffic have been reviewed.

A new Probabilistic Scheme based AODV (PSAODV) is introduced for control overhead reduction and suggests a suitable selection of TCP variant for data traffic in Chapter 3. The PSAODV routing protocol and AODV protocol are experimented with different TCP variants namely TCP Vegas, TCP Tahoe and TCP SACK in a simulation environment on varying node density and pause time. The performance of the protocols is compared in terms of routing overhead and packet delivery ratio for accurate data delivery from source to destination.

The proposed Loop-free Multipath in Probabilistic Scheme based AODV routing (LM-PSAODV) aims to reduce the occurrence of packet drops in routing loops and suggests a suitable selection of TCP variant for more accurate data delivery from source to destination is explored in Chapter 4. Whenever the routing loop occurs, the proposed strategy establishes an alternate path from the current node to the destination node by calling the route repairing mechanism in AODV, based on the Time To Live (TTL) value of the packet.

Enhanced Round Robin Packet Scheduling Strategy (ERR-PSS) is proposed as an Improved Packet Scheduling (IPS) Strategy and is implemented as an integrated component to the modified AODV (LM-

PSAODV) for the reduction of IPD while transmitting the multimedia applications from source to destination. This enhanced packet scheduling algorithm uses the features of round robin and priority scheduling algorithms as a hybrid packet scheduling approach for better scheduling of packets to reduce inter-packet delay. The hybrid packet scheduling approach (ERR-PSS), First-In-First-Out Packet Scheduling Strategy (FIFO-PSS) and Round Robin Packet Scheduling Strategy (RR-PSS) are implemented and integrated with the modified AODV (LM-PSAODV) in a simulated environment on varying number of connections and pause times is deployed in Chapter 5.

The limitation of bandwidth and the subsequent queue size limitations in MANET links lead to congestion at the link level and significant queuing delays on delivery of time critical multimedia applications. The proposed fuzzy logic-based random early detection (FL-RED) queue management technique aims to reduce the queuing delay by controlling the congestion through effective management of link queue size while transmitting the delay sensitive applications. The proposed FL-RED queue management algorithm is tested with the existing Random Early Detection (RED) queue management algorithm in a simulation environment on varying node density is presented in Chapter 6. Further, an integrated routing and queue management (IRQM) framework resulted in a comprehensive reduction of routing overhead, packet drops, inter-packet delay, queuing delay and end to end delay providing QoS in MANETs for the transmission of real-time applications is also deployed in this Chapter.

In Chapter 7, the major conclusions reached and contributions made are dealt with. Recommendations for further research are also stated.