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Design and Development of MANETs with Quality of Service Parameters

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Abstract: ***Mobile Ad Hoc Networks (MANETs) are a self-configuring network of mobile nodes connected by wireless links. In MANETs, each mobile node works as a host as well as a router. MANETs are used in various and varied applications like setting up of conferences, e-classrooms, patient monitoring, detection of earthquakes etc. With the growth and proliferation of these devices in every aspect of society, the need for such devices to communicate in a seamless manner is becoming increasingly essential. Also, as MANETs gain popularity, their need to support real time and multimedia applications is growing as well. Real time and multimedia applications supported by MANETs have stringent Quality of Service (QoS) parameters such as efficient bandwidth utilization, minimum delay, minimum packet loss, good throughput etc. Providing QoS is difficult in MANETs due to a lack of centralized infrastructure based system, limited bandwidth availability, constant movement of nodes, contention for channel access and the highly dynamic topology of the wireless network. This paper is a study on the design and development of MANETs with necessary QoS parameters like low packet loss, good throughput, less delay.***

Keywords: Mobile Ad Hoc Networks, quality of service, routing.

1. Introduction

A Mobile Ad Hoc Network (MANET) is a collection of mobile nodes with no pre-established fixed infrastructure [1] [2]. In MANETs, network nodes act as routers by relaying each other's packets and all the nodes form their own cooperative infrastructure [3]. A MANET is wireless network in which nodes communicate through single hop or multi-hop paths. Such networks are characterized by dynamic topologies, bandwidth constraints, variable capacity links, energy constrained operations etc. MANETs are increasingly becoming popular due to their advantages such as low cost and ease of deployment. These networks are characterized by complete self-organized behaviour. Thus, nodes in a MANET should be able to perform the necessary routing functions to discover the optimum route and also be able to forward data packets in such a network [4] [5].

Various MANET applications include military deployment, rescue operations, disaster recovery operations, formation of network in meetings and conferences, electronic classrooms etc. [6]. MANETs can be used effectively where no fixed infrastructure is available but real time, reliable and multimedia communication is needed [7]. To provide a reliable MANET set up that adheres to certain QoS parameters, it is necessary to ensure that an optimum route is found between source and destination but due to dynamic nature of MANETs, the routing problem is much more complicated as compared to wired networks [8]. Besides finding an optimum route, it is also imminent to provide various QoS parameters like good throughput, minimum delay, least packet loss, less jitter etc. in such networks. Many multimedia and real time applications like file sharing, video conferencing, mobile learning etc. require high bandwidth and have stringent delay, jitter and packet loss requirements. Providing real time or multimedia applications in MANETs with QoS guarantees is quite a challenging task as these applications demand high bandwidth and is delay sensitive in nature. Moreover, the inherent nature of MANETs is characterized by frequent link breakages and node failure due to which providing QoS in such networks becomes still more difficult [9][10]. The performance of Ad Hoc networks also depends upon the effectiveness of the Medium Access Control (MAC) protocol [11]. MAC protocol in MANETs should provide distributed arbitration for the shared channel for transmission of packets. Most of the research work on routing protocol has been focussed on the static MANET topology whereas in the real time scenario MANETs are dynamic in nature. So, there is a need to focus on the improvement of QoS parameters of dynamic MANETs. Figure 1 shows a typical MANET of devices D1 to D7.

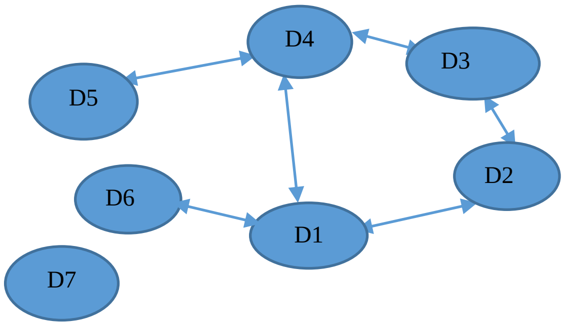

Figure 1: A typical MANET

2. Types of MANETs

2.1 Single-hop MANETs

A single-hop MANET is the simplest network that can be formed by a collection of several stations [12]. Here, stations that are within the range of each other dynamically configure themselves to set up a single-hop MANET. Examples of single hop networks are Bluetooth piconet, 802.11 WLAN that enables communication without an access point. The major limitation of this system is that it connects only those devices that are within the same transmission range.

2.2 Multi-hop MANETs

Multi-hop systems try to overcome the limitation of single-hop networks. Here, the nodes connect together over a wireless medium. Nearby nodes can communicate directly whereas the devices that are not connected directly forward the packets via intermediate nodes for communication. Since, the users' devices are mobile; these networks are also referred as mobile multi-hop ad hoc networks. They have a wide spread application in vehicle-to-vehicle communication, military network set ups etc.

3. QoS Parameters in MANETs

QoS is defined as a set of certain service requirements that needs to be met by the network while transferring data from source to destination. The service requirements vary from network to network and are generally governed by the type of data being transmitted and certain end user specifications. Various difficulties in providing QoS in MANETs are [14]. Dynamic nature of nodes, hidden and exposed terminal problem, limited availability of bandwidth and other resources, frequent link breakages and limited battery life. Also, the network is expected to guarantee various set of measurable QoS parameters such as end to end delay guarantee, low Packet Loss, throughput, security and jitter.

4. QoS MANET Models

QoS models for MANETs should consider the challenges posed by such systems such as dynamic topology, constraint in resources and accommodating time critical applications. Initially, Internet Protocol (IP) was considered the best effort protocol and it was designed to deliver the packets to its destination in minimum time. There was no guarantee of delivering the packets. This system worked fine when only data packets needed to be sent. However, with the expansion in the services provided by the Internet, it became essential that these IP based services provided QoS guarantees. The Internet Engineering Task Force (IETF) has defined two QoS architectures for internet: Integrated Services (IntServ) and Differentiated Services (DiffServ). These traditional models were mainly proposed for providing QoS across wired networks [15]. So, there is a need for providing flexible QoS models for MANETs [16].

4.1 IntServ and MANETs

IntServ is a framework that provides the applications with the ability to choose defined QoS for their data. The routers that carry traffic from source to destination must implement mechanisms to control the QoS offered to those packets. Moreover, the application's requirement must also be communicated to the routers. Here, the Resource Reservation Protocol is used to set up and maintain the virtual connection. In IntServ, the amount of state information increases proportionally with the number of flows, resulting in a large overhead. This is not suitable in systems like MANETs where resources are limited. Moreover, IntServ is not scalable, hence, it is not possible to expand the MANETs. Also, the signalling packets in IntServ contend for bandwidth with the data packets and consume quite a large amount of bandwidth which is not desirable in a system where resources are limited. All the above mentioned features make IntServ unsuitable for a flexible network like MANETs.

4.2 DiffServ and MANETs

DiffServ is a protocol for specifying and controlling network traffic by class. Certain type of traffic, which requires uninterrupted flow of data, like voice, video, get the first preference in DiffServ. At the boundary of the DiffServ enabled domain, the router marks the packet's Differentiated Services (DS) field. This enables the interior routes to forward the packets based on the DS field. Unlike IntServ, interior routes don't need to keep per flow state information, thus reducing the overhead and making the system fast. Moreover, DiffServ also provides Assured Services (AS), Despite few advantages it is still not easy to implement DiffServ in MANETs because DiffServ was basically developed for fixed infrastructures. DiffServ also needs a system boundary to be defined which is not feasible in MANETs. Since the source nodes cannot be predefined, every node should function as both boundary router and interior router. This results in heavy storage cost in all the nodes. Also, the concept of Service Level Agreement (SLA) in the Internet does not exist in MANETs. SLA is a contract between Internet Service Provider (ISP) and the customer that specifies the kind of services the customer should receive. SLA is necessary to receive Differentiated Services. All these factors make the implementation of DiffServ difficult in a dynamic system like MANETs.

5. MANET Routing Protocols

Wireless and Ad Hoc Networks mainly use on-demand based routing protocol [17] [18]. The routing protocol in MANETs should various characteristics [19]. The protocols should be adaptive to frequent topology changes with the number of broadcast packets kept minimum so as to reduce packet collisions. Also, transmission should be reliable to reduce message loss. Routing should be fully distributed in nature since centralized routing involves high control overhead and also there is a chance of single point failure. Moreover, routing maintenance should be localized so as to reduce control overhead. Resources such as bandwidth, computing power, memory and battery power should be optimally used.Every node in the network should try to store information regarding the stable local topology only. Frequent changes in the local topology and changes in the remote parts of the network need not be updated in the topology information maintained by the node.

The existing routing protocols also need to be modified or other routing protocols need to be specifically developed so as to find an optimal path to cater to the specific needs of MANETs.

5.1 Classification of MANET Routing Protocols

Mobile Ad Hoc Network Routing Protocols can be classified into three major categories:

5.1.1 Proactive or Table driven Routing Protocols

Here, every node maintains the network topology information in the form of routing tables. To find a path from source to destination, the node runs an appropriate path finding algorithm.

5.1.2 Reactive or On-Demand Routing Protocols

These protocols do not maintain any network topology information and save a lot of control overhead as there is no need to exchange routing information periodically. The necessary route from source to destination is acquired as and when required through a connection establishment process. Most commonly used on-demand based routing protocol are Dynamic Source Routing (DSR) and Ad hoc On-demand Distance Vector (AODV).

5.1.2.1 DSR Protocol

A route setup message makes a record of all the nodes it has passed through and based on this record an optimal data exchange path is selected by the destination node. Intermediate nodes do not require to store any routing information. The data header stores complete path information. In DSR protocol the path set up for data transfer is done only when there is some data that needs to be transferred to a destination. That is why, DSR is called an on-demand routing protocol.

5.1.2.2 AODV Protocol

It closely adapts the Destination Sequenced Distance Vector (DSDV) protocol in ad hoc wireless networks [20]. The DSDV is a proactive table-driven protocol. In DSDV protocol, a routing table is maintained by all nodes in the network. This routing table contains the route information of all nodes that exist in that ad hoc network. Every destination is assigned a sequence number that is maintained in the route table. Table is updated whenever a destination with new sequence greater than the previous one is initiated. In AODV the route is established only when there is a need for data transfer at the source node. Hence, AODV is also an on-demand scheme. AODV also employees a data sequence number to identify the most recent path. A simplified version of AODV also exists in which the sequence number is removed. The Split Multipath Routing (SMR) protocol is also based on the DSR protocol [22].

5.1.3 Hybrid Routing Protocols

Hybrid Routing Protocols are a combination of proactive as well as reactive routing protocols. All the nodes that are within a certain radius of a particular node are said to be within the routing zone of the given node and for these nodes a table driven approach is used. For the nodes outside this radius, an on-demand approach is used.
Reactive routing protocols eg. DSR, AODV or other protocols based on DSR have limited deliverable hop count value [21]. This leads to a scalability problem in these reactive routing protocols. Although these reactive protocols work well for smaller sized wireless network like MANETs expanding the size of MANETs becomes a major bottleneck. Also, AODV and other reactive routing protocols cause routing overhead which results in major limitation in case of real time video streaming, data transfer etc. So, there is a need to develop routing protocols that are suitable for dynamic MANETs and real-time application.

6. Related Work

Routing is extremely challenging in MANETs as due to frequent change in position of nodes even the efficient nodes may become unusable or inefficient. Several routing protocols have been specifically designed for ad hoc networks. They can be mainly classified as reactive and proactive. In the proactive routing protocols such as Optimized Link State Routing Protocol (OLSR) [22] and Destination Sequenced Distance Vector (DSDV) [23], the routes are established in advance. This resulted in a considerable overhead especially when the topology changes frequently. This is highly inefficient when updating routes that hardly carry any traffic. In reactive routing protocols like Ad Hoc On Demand Distance vector (AODV), routes are only discovered when required [24]. This resulted in better utilization of resources. Although AODV was found to be better than proactive routing protocols, still it resulted in considerable protocol overhead due to the system-wide broadcasts of Route Request (RREQ). Moreover, reliable delivery of packets was not considered in AODV based routing systems and only the routing issue was considered and none of the QoS parameters were discussed. Another reactive routing protocol is Dynamic Source Routing (DSR). In DSR protocol, a record of all the nodes passed through it is maintained and based on this data, the optimal path is selected [25]. In DSR, again record of the nodes is maintained which leads to overhead and also when the system is dynamic, it is not feasible to maintain route records. Another extension of AODV was also proposed. It was Destination Sequenced Distance Vector (DSDV). Here, destination sequence numbers are used to maintain the routing information [26] [27]. In DSDV protocol, all nodes have a routing table that contains the route information of all nodes in the network. When the system is dynamic and nodes are many, it becomes cumbersome to maintain all the routing information. It again results in large overhead and bandwidth consumption. Another routing protocol Split Multipath Routing (SMR) was also proposed. It is based on DSR protocol [28]. It provides a back up path in addition to the primary path set up. However, the hop count value is limited. [29] [30]. Hence, it cannot be implemented in scalable systems.

Another routing protocol Ad Hoc On-demand Multipath Distance Vector (AOMDV) was also proposed. It was again based on AODV [31]. It uses multi path connections, where one connection can be used as a back up when the main connection is broken. However, when the topology is dynamic, even the backup path can break. Scalable Multipath On-Demand Routing (SMORT) reduces the overhead while recovering from route breaks using secondary paths [32]. However, here too the backup connection can break in case of dynamic systems. Also, in multi-hop dynamic system, these algorithms fail to provide any backup path. Lee has also addressed the problem of routing in a Multi-hop environment. In his work, a backup routing along with a primary route is created so as to have a back up path in case of link failure. Here, a primary and a secondary backup path are created as a result of a route control message exchange process. Control messages contain information for guaranteeing service quality. After detecting a failure when sending data, a repairing procedure occurs near the failed node of the primary path. The information exchanged between nodes in the form of route request and route reply is used to create a backup path. The backup routing scheme uses a one-hop search method, and the rerouted path length is two-hop at maximum. The QoS parameters considered here are error rate and delay. To achieve the target of back up routing, a new AODV protocol with guaranteed bandwidth routes (AODV-GBR) is proposed. Here every node is assigned a routing table, into which new route elements are added on an on-demand basis. If data has to be sent from a certain node to destination, then first route information is searched in the routing table. In case no routes are available, then new routes are found out and set up from source node to destination node is made. A Route Request (RREQ) message is sent from the source node. This RREQ is broadcasted to all nodes in networks including the destination node. After receiving a RREQ message, a Route Reply (RREP) message is sent by the destination node. On reception of the RREP message by the source node, the route setup is completed and data is sent from source node to destination node. In case, there is a break in a route, a backup mechanism is started to find an alternate route so as to guarantee the required service quality. This backup mechanism is started only if there still remain any data packets to be sent. The results obtained in terms of error rate and packet delivery ratio is very good. Moreover, this protocol ensures service quality even in case of route failure by providing a backup path. However, the major issue of dynamic topology has again not been considered here. The backup path is discovered for static systems in a small sized MANETs. The issue of scalability is also not addresses. Moreover, various other issues of QoS like packet loss, throughput has been overlooked.

Various reactive routing protocols discussed so far provide no QoS guarantees to the users. These algorithms work well when the system has a fixed topology and only data packets need to be transferred. However, when real time multimedia voice, video etc. need to be sent with bandwidth, delay, packet loss guarantees in a dynamic set up, then these algorithms fail to give the desired results. All these services demand Quality of Service along with efficient routing. Since the conventional routing protocols suffer from many drawbacks especially when the topology is dynamic, there is a need to implement other techniques like optimization so as to ensure an error free and reliable route. Ant Colony optimization algorithms can be applied to routing problem in MANETs. Swarm intelligence techniques like ant colony algorithms artificial bee colony algorithms [33] have emerged as a possible solution to find optimal routes from source to destination. Ant Colony Optimization can be employed to find an efficient route from source to destination. Ant Colony Optimization algorithm (ACO) is a member of Swarm Intelligence (SI). SI is the collective behaviour of individual or self-governed systems whose inspiration has been derived from nature like ant colonies, bees and birds. SI is also employed on Artificial Intelligence. ACO is a probabilistic technique to find optimal or good path between source to destination. This concept is based on real world ants. Ants travel randomly in search of food and leave a trail of pheromone on the travelled path. The pheromone attracts other ants on the same path. The path which is shortest is frequently used by ants and thus leaves a strong pheromone trail. Next set of ants also travel by the same path which has a strong pheromone trail. In this way ant colony algorithms can be used to find a short and optimal route from source to destination.

An Ant-based Multipath Routing (AMPR) scheme is an ant colony based multipath routing for wireless networks [34]. AMPR deals with the problem of traffic congestion. Although AMPR is a multipath routing protocol for wireless networks, it does not deal with backup routing problem. Also, the protocol is not implemented for dynamic set up. Another traffic distribution protocol Colony-based Multipath Routing (CMPR) deals with traffic distribution problem. Though this protocol increased network lifetime, the packet loss and delay values were found to be better in AMPR than CMPR. Other drawbacks are that this protocol also does not consider the backup routing problem and system set up is again static. Also, another protocol was based on ACO was proposed [35]. Here, initially position of the ants is the source node and each node monitors neighbour nodes to maintain local connectivity. Each ant chooses its nest step according to a set of pre-defined formulas. This step continues recursively until the destination is reached. The packet loss ratio and delay was found to be less than AMPR and but the overhead was high as compared to AMPR. Drawbacks are that in this paper again static topology is considered. There is no backup routing provision in case of link failure. Moreover, the system considered is a medium sized MANET. The issue of scalability is also not considered. A QoS enabled routing algorithm (QAMR) based on ant-colony optimization has been proposed by Krishna et al. [36] to solve the bandwidth allocation problem in MANETs. QAMR uses ant like agents, forward ants (FANT) and backward ants (BANT) to measure various parameters like next hop availability, delay and bandwidth. Using these parameters path preference probability is calculated. Path with the highest value is then selected for transmission. QAMR leads to a higher packet delivery ratio than AODV but still it suffers from many drawbacks. QAMR is tested for static systems. Moreover, the problem of backup routing in case of a link failure is also not considered. Also, in this protocol, frequent routing is required which leads to large overhead routing. So, overhead is also high compared to protocols like AODV. The scalability issue was also not considered, only six routes were considered.

A hybrid protocol AntHocNet [37] [38] based improved routing (AntOR), combining the features of proactive and reactive routing protocols, has also been proposed by Villalba et al. [39]. AntOR protocol is based on Ducatalle algorithm [40]. The system was set up for sparse settings. Throughput and packet delay achieved were found to better than AntHocNet but value of packet delay was found to be less. AntOR was not compared with other routing protocols. Also, the backup routing problem was not considered. Another disadvantage was that in case of smaller set up no improvement was achieved in overhead routing.

Another Ant Colony based technique was proposed by Deepalakshmi and Radhakrishnan [41]. The biggest challenge in MANETs with dynamic topology is to find a path between source node and destination node that satisfies QoS requirements despite frequent path failure. In this work, an Ant-based Multiobjective on demand QoS Routing algorithm (AMQR) is proposed for mobile ad hoc network. In this paper, a medium sized system is considered. The proposed algorithm is inspired by ant food foraging intelligence and is an on-demand QoS routing algorithm for MANETs. AMQR approach has two phases, namely, route exploration and route maintenance phases. When there is some data that needs to be transmitted then route discovery process is started. When a source node has data for passing to a destination node with QoS requirements, it starts with route discovery phase. Data transfer takes place once the route is found. The proposed algorithm incorporates positive feedback, negative feedback, and randomness into routing computation. Here, Ant-like packets are used to locally find new paths. Artificial pheromone is laid on communication links between adjacent nodes. The route reply and data packets are always inclined towards strong pheromone. Positive feedback is initiated from destination nodes to reinforce existing pheromone on recently learned good paths. Exponential pheromone decay is adopted as negative feedback to prevent old routing solutions from remaining in the current network status. Every node contains three tables, namely neighbour, path preference, and routing. Each neighbour is listed along with pheromone substance indicating goodness of outgoing link to various destinations and available bandwidth of outgoing link from that neighbour. In AMQR, a path is considered good not only based on the no. of hops, but also on other parameters like available bandwidth. AMQR is tested for medium sized MANETs. Although AMQR achieves better packet delivery ratio and shorter delay compared to AODV but the major drawback is that the control overhead is highest compared to AODV and AntHocNet. Also, the system considers nodes to be mobile but assumes that the entire nodes move at the same time towards the same destination and stay there for some time called pause time. When the pause time between packets increases, the packet delivery ratio becomes lesser than AODV and AntHocNet. This is again a drawback that the system is not completely dynamic. Nodes should move at random, which does not happen here. Moreover, backup routing in case of link failure has not been discussed.

Another technique to find optimal path from source to destination using Genetic Algorithm (GA) was proposed by Kumar et al. [42]. The proposed protocol was Secure Back up on Demand Routing Protocol. It discovers multiple routes from source to destination so that a backup route may be saved and used in case a node or link failure occurs and to select the optimal path from source to destination, GA can be used. This work has been carried in static environment and for small sized MANETs. Although a backup route was proposed in case of link failure but it works only in case of static networks. The overhead problem is again not addressed. Since the system was set up for small sized MANETs, the issue of scalability is also not considered. There is a need to test the system for dynamic set up and medium or large sized MANETs.

Another technique of QoS routing was presented in MANETs called Quality of Service Mobile Routing Backbone over AODV (QMRB-AODV) [43]. It makes better use of available bandwidth by distributing the traffic throughout the network and reducing the control messages needed to establish a route from source to destination node. In this paper, a small to medium sized system is considered. QMRB-AODV is tested for static as well as dynamic systems. Here, packet delivery and throughput are higher as compared to AODV and DSR when the system is static. The drawback is that the same improvement is not achieved when the system is dynamic. Moreover, the problem of backup routing in case of link failure is also not considered. Also, the overhead problem in dynamic systems is not discussed and for static systems the overhead is found to be more as compared to AODV for small sized systems and in medium sized systems it is almost equal to AODV. So, no significant improvement is achieved in control overheads.

Salem et al. [44] have developed a hybrid multiagent routing protocol and compared them with DSDV, AODV and AntHocNet protocol [45]. This paper considers a large sized static MANET. Here, a hybrid method that combines both proactive and reactive processes is proposed. The routes are established as well as maintained with a constant number of mobile agents called Ant-Agents. In the various ant colony optimization techniques for wireless networks [46] [47], the ant-agent is created by each node periodically and the source node broadcasts an ant-agent whenever a route needs to be built between a source and destination. However, the protocol proposed here does not employ the broadcasting technique but sets up a local route request whenever a node plans to send a data packet. The ant-agents moving within the network during the proactive phase spreads this information and provides routes towards the required destination. The proposed ant-agent protocol tries to provide the best possible. For routing two types of agents are suggested. The first agent called ant-agent is responsible of establishing routes and the second agent called rectifier-ant is issued by a node whenever a change in the network is detected. Packet loss, as compared to AODV and DSDR, is found to be less when only few nodes are used. However, when the number of nodes increases the packet loss also increases. Another drawback is that the packet delay although better than DSDV but is still poor compared to AODV and AntHocNet. Also, the backup routing issue in case of link failure is not considered. Moreover, the system is static and stability issue is not considered. Also, the control overhead is found to be less than AODV but it has not been tested in dynamic set up and comparison with other protocols is required.

A comparison of various routing algorithms was also presented for dynamic systems [48]. Here AODV, Gateway Routing Protocol (GRP) and OLSR protocols were compared. The system was a medium sized dynamic MANET. The comparison showed that throughput was found to be least in AODV and comparatively better in OLSR and packet drop was highest in AODV. Other drawbacks were the issue of backup routing to increase system performance was not discussed. Scalability issue and control overhead problem was also not addressed.

A hybrid multipath algorithm AntHocNetM was designed along the principles of ACO routing [49]. The system set up was dynamic and routes were setup as and when desired. The protocol combined the features of both hybrid and reactive routing protocols. With the help of a routing table, link failure can be detected among the neighbours but link notices sometimes go undetected also and there is no backup link support in such cases. Moreover, the system considers small sized MANETs. The performance is compared only to AODV and not with other protocols like AntHocNet. There is no mention of scalability in the system. Although delay, packet loss and jitter were less when compared to AODV, the overhead congestion was not considered.

Another ant colony based algorithm, ARA has also proposed [50]. Here, a small sized static topology is considered to send the nodes from source to destination. It generates all possible paths from source to destination and data is sent through optimal path. Also, to avoid retransmission, resources are reserved at nodes. Although it results in less packet loss but there are many drawbacks; the control overhead will be very high due to reservation of resources at all nodes. Also, the system considered is very small and if it expanded, it will not be practical to make all possible routes from source to destination.

A new routing mechanism to support real-time multimedia has also been proposed [51]. The proposed protocol considers a medium sized MANETs. The network is comprised of a node with multiple network interfaces to each of which a different wireless channel can be assigned. Information about channel usage is embedded in the control messages of the protocol. Based on this information, source node determines a logical path with maximum available bandwidth to satisfy QoS requirements. The system considered is static as well as medium sized. The congestion is avoided as the routes can be chosen more correctly due to the available route information. The drawback is that the routing overhead will be high due to the control messages. There is no mention of scalability of the system. Moreover, the issue of backup routes and the dynamic scenario is not considered. Table 1 shows the problem areas in MANETs and the improvement achieved over the years.

Table 1: A Comparison of Various Issues in MANETs

Year	Problem Areas	Improvements Achieved
1999-2000	• No QoS assurances were majorly provided. • Bandwidth consumption and routing overhead very high. • System was static and not scalable.	• Route records were maintained, so routing was more systematic.
2000-2003	• QoS assurances were still not properly provided. • Bandwidth consumption still very high.	• Organized routing • Better packet delivery.
2003-2008	• Systems developed were still small sized. • Issue of link failure not addressed properly.	• Delay and packet loss were less.
2008-2013	• Link failure is still an issue. • Packet delivery, throughput etc. still a problem issue when system is dynamic.	• Large sized MANETs are now being considered. • Genetic algorithms are being implemented in the area of MANETs

7. Conclusion

QoS requirements are especially important in the case of real-time and multimedia applications which are used in MANETs. These applications require that the system must adhere to certain QoS parameters in terms of low packet loss, efficient packet delivery and good throughput. Also, routing is extremely challenging in MANETs especially in a dynamic topology. Due to frequent change in position of nodes, even the efficient nodes may become unusable or inefficient. To ensure stable routing it is necessary to update routing information regularly. However, this in itself can pose a problem as it results in more control overhead which needs to be avoided due to limited resources availability. The problem is more when the MANETs are dynamic and medium or large sized. Much more research needs to be done in the area of dynamic MANETs.

Conflict of Interest

The authors declare that there is no conflict of interest whatsoever with anybody.

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