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QoS Routing for Multimedia Communication over Wireless Mobile Ad Hoc Networks:
A Survey

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ABSTRACT

A lot of intensive research has been carried out in the direction of providing multimedia communication over wireless mobile ad hoc network (MANET). In MANET, various QoS problems exist such as inefficient routing, handling node mobility, power conservation, limited processing capabilities of network devices, high error rates. Wireless routing introduces new challenges as applying basic routing algorithms directly on MANET could lead to large power consumption, interference, and load-balancing problems. Many routing algorithms have been proposed as extensions to the basic routing algorithms to enhance their performance in MANETs. This paper summarizes existing solutions on QoS routing and resource reservation mechanisms in order to provide multimedia communication over MANET. It also considers the limitations of existing QoS models with regard to satisfying QoS in serving multimedia over MANET. The newest QoS architectures give much better results in providing QoS support. However, more refinements must be proposed in order to enhance further their performance in MANETs.

KEYWORDS

MANET, Mobile Ad Hoc Networks, Multimedia Communication, QoS Frameworks, QoS Routing, Resource Reservation

INTRODUCTION

Delivering multimedia data over wireless MANETs has its own application domain, and also has its own challenges (Loo et al., 2012). Wireless MANET is a prominent solution in diverse emergency situations that require rescue operations, when disasters have destroyed the network infrastructure. There is no need to deploy any infrastructure to make MANET nodes to communicate with each other. The IEEE 802.11 wireless LAN can be implemented without any infrastructure or central controller (Crow et al., 1997). In ad hoc mode, all nodes participate in both data processing and routing task. The network also relies on the multi-hop type of routing for their data transmission. The concept of wireless MANET can give a new bloom to the multimedia industry because in MANETs we can provide the same without deploying any additional infrastructure. So, such networks can work in collaboration rendering services either without paying anything or paying a tiny share of revenue charged. In addition, we can define Quality of Service (QoS) models that will be used to provide the desired QoS efficiently (Nyambo et al., 2014). Existing high-speed networking and effective compression techniques utilize available bandwidth to serve a large number of connections, resulting in various multimedia applications. Basically, three types of multimedia services have been developed: accessing stored data, accessing live data, and accessing interactive data.

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The diverse nature of networked multimedia applications causes various problems because each application has its own requirements (Rao et al., 2002). An application might demand better quality data and can tolerate some acceptable amount of delay, while another application may be more sensitive to delay by compromising the quality of data. Every data flow of packets from a source to a destination in the network needs certain and prerequisite resources in order desired QoS to each individual flow to be provided. Obviously, the transfer of continuous media data (e.g. video and audio) need much more bandwidth than the transfer of discrete media (i.e. text or images–i.e. lightweight data). Also, a decision must be made in order to allocate proper bandwidth to each flow available in the network. For example, Vaidya et al. (2005) have proposed a distributed fair scheduling scheme that ensures that all packets will get a proper bandwidth of the wireless channel.

Multimedia applications can be categorized as per their delay requirements (Rao et al., 2002). Non real-time applications (e.g. image transfer) have no delay requirements, while real-time applications have delay requirements, and can be classified into hard real-time and soft real-time applications. Hard real-time application has very strict delay requirements and failure in satisfying them might result in hazardous side effect. It includes various applications like nuclear-reactor control system, missile control system etc. Soft real-time application has some delay requirements, but that are somewhat less strict than hard real-time application, where failure in satisfying the delay requirements would not result in any hazardous side effects. Examples of soft real-time applications are video-conferencing and video on demand. There is also an extra categorization. Non-interactive applications (e.g. video-on-demand) do not need any type of feedback from the receiver in order to continue application function. There is only the requirement of handling one-way traffic. On the contrary, interactive applications (e.g. gaming and video streaming) require some kind of feedback or commands from the receiver, so that application can proceed further. An interactive application requires two-way traffic, each of which is very much delay sensitive. In interactive applications, one single path may lead to network congestion ultimately affecting the overall network throughput and especially QoS (Rao et al., 2002).

In audio/video transfer, user may either download it or may allow for streaming. Audio/video streaming is preferable as it eliminates the end-to-end delay for user. However, streaming is more difficult to handle than simply downloading the contents, and the QoS may differ with the change of application raising to more difficult challenges. Different types of standards and techniques to successfully transmit multimedia over networks constitute the basic issues related to multimedia transmission. These research issues cannot be ignored, as they can also occur in wireless multi-hop networks. In addition, the wireless medium is very often influenced by the physical obstacles like noise, shadowing, interference and multi-path fading. During the transmission of text/images, these problems are insignificant, but for the audio/video transfer, these should be addressed properly. Actually, audio/video transfer demand better control over the end-to-end delay and minimum jitter (i.e. variation in delay). Moreover, if video or audio is live, these requirements are much more delay sensitive and should be handled strictly. Depending upon the type of access i.e. whether it is a point-to-point or multicast or even broadcast, the issues vary. For point-to-point communication, the network can provide better bandwidth to both end-points. However, in multicasting mode multiple nodes compete for the same wireless channel, resulting in interference. Broadcasting makes it worst, where every node is trying to get access to medium, which finally increases the interference levels of signal. The IEEE 802.11 uses distributed coordination function (DCF) as the basic medium access control (MAC) protocol or optionally it uses point coordination function (PCF). DCF makes use of the carrier sense multiple access with collision avoidance (CSMA/CA) scheme as a mechanism to deal with collision, and it increases the medium access delay in proportion to the load on the network (Wu et al., 2002). PCF uses a polling technique that aims towards providing the contention-free services.

Providing multimedia services over wireless MANET has many challenges:

- Wireless MANET devices have small size for supporting mobility. This imposes them to work with limited CPU processing capabilities, limited battery life, limited bandwidth support, limited storage etc.;
- It is not an easy task to handle multimedia. New difficulties arise, as we have diverse set of coding and decoding techniques for audio and video, different resolutions of images, and higher data rate demands for video transmission. Also, we have the stringent delay requirement of real-time audio/video transmission or even more reliable and secure transmission demands of security applications (Lian et al., 2009);
- The wireless links make it more complex due to higher error rate, fading, interference of signals etc.;
- Last but not least, the dynamic nature of wireless MANETs makes routing more difficult because of the frequent route change/route break leading to loss of connectivity. New challenges for multimedia transmission are imposed as the mobility of nodes (making frequent route breaks) adds an extra overhead. The routes have to be updated frequently. This situation even becomes worst in live streaming. If a node moves suddenly, then a few packets might take route having 'dead ends' and as the transmission is real-time, the time till which it will be detected and corrected using retransmission, the deadline would have been crossed already. This ultimately affecting the overall performance. Once more, after getting new route, the receiver might get out of order packets. In live streaming, it is just useless to retransmit the packets once the time has passed. Also, it becomes difficult to resynchronize the video or audio. Audio/video transfer suffer from the higher error rates occurred in wireless links. In real-time audio/video, there is no concept of retransmission as real-time media can't even tolerate loss of few frames. Thus, the loss of few frames would result in degradation of quality. As the nodes, which are part of the path, should be capable of processing the data it is going to transfer along with the routing, the paths should be chosen intelligently. Finding node capability in advance is vital in order to transfer data efficiently. As this might happen, that node suddenly moves out of order and less capable or even non-capable node becomes part of the network, finally resulting in degradation of quality. Again, it must reroute, and then start transmitting again. This is rather acceptable in stored video, but in live streaming this won't be entertained. Consequently, we must develop dynamic routing algorithms, those are able to change their behavior according to the network characteristics and are able to predict the node capabilities and node mobility.

In source routing algorithms, each node maintains global state allowing computation of the end-to-end path at the source. The Dynamic Source Routing (DSR) route discovery and route maintenance protocol is effective for the transfer of text and images (Johnson et al., 2001). But, let us examine what happens in real-time audio/video streaming. The route breaks, a number of retransmissions has to be attempted over the broken link, and the new route must be established resulting in delay. Rerouting is a spendthrift process because it must be well-confirmed before initiating it. It causes additional delay, and thus it is unsuitable for real-time streaming. We must check when the route is likely to break, and as we will get to know that route is possible to break soon, we can take decisions on rerouting or finding of any alternative root available (Hu & Johnson, 2002). A possible solution it to measure the Signal-to-Noise Ratio (SNR) parameter for received packets, as SNR indicates if the route is likely to break.

To achieve QoS provision in MANETs, the traffic-engineering approach is applied where available resources are used efficiently to meet the QoS requirements. This approach includes implementing different QoS models, QoS routing and resource reservation protocols, channel access mechanisms etc. And all these protocols associated with different sub-layers such as MAC, routing, resource reservation must work in synchronization in order a QoS model to guarantee the desired multimedia services.

This survey considers existing problems and issues that are currently present in providing multimedia communication over wireless MANET. It focuses on two modules of a QoS model: QoS-based Routing and Resource Reservation for providing multimedia communication over wireless MANET. These different modules work together to meet QoS. QoS-based Routing protocol tells on which particular paths, nodes can provide resources sufficiently to meet QoS (Crawley et al., 1998). Resource reservation protocol ensures how these paths or resources could be made available, when required. The survey gives an overview of the different techniques and solutions proposed in QoS routing and resource reservation in order to make efficient the multimedia communication over wireless MANET.

The paper is organized as follows: The next section highlights the wireless MANET characteristics. It also elaborates QoS models and frameworks, as well as routing and resource reservation schemes for wireless MANET. The third section presents advanced QoS routing protocols that can guarantee various QoS parameters. The fourth section presents recent advancements in QoS routing protocols, while the fifth section discusses novel approaches and techniques that resolve important problems of multimedia over wireless MANET. Finally, the last section concludes the paper.

MULTIMEDIA COMMUNICATION OVER WIRELESS MANETS

Wireless MANET is an IP-based network that works on the best-effort delivery concept. Although network components will try their best, this network won't guarantee that required QoS will be achieved. However, real-time applications need a guarantee that all the QoS requirements should be achieved irrespective of the network conditions.

QoS in Wireless MANETs

QoS is a set of service requirements to be met by the network, while transferring a flow (Kanellopoulos, 2011). Certain metrics such as bandwidth, delay, jitter and packet loss rate (PLR) can be used to measure and achieve the required QoS by any particular application. In wireless MANET, hop count and path reliability may also be considered. To provide better QoS services, we must consider the following characteristics of a wireless MANET:

- **Lack of Central Authority:** In wireless MANET, there is no central controller available. Also, there is not an analyzer which makes a decision, whether or not, the link and protocols currently being used are capable of providing desired QoS;
- **Limited Resource Availability:** There is a limited amount of memory, limited processing capability and limited battery power etc. So, the resource availability in wireless MANET is very much limited. All these limitations cause problems in providing the required QoS, as we cannot easily increase the node capacity. Therefore, we have to manage the available resources efficiently so that maximum throughput can be achieved;
- **Error Prone Shared Radio Channel:** The availability of bandwidth becomes very scarce to every node because the network uses the shared radio channel in broadcast mode. Again, the wireless medium gets badly affected by the channel properties like interference, attenuation etc.;
- **Variable Network Topology:** Without any notification, the nodes make moves very frequently. These moves may result into the different topologies causing frequent path breaks and establishment of new paths. It also requires some delay and still after investing the time it is not guaranteed that the required path will become available;
- **Insecure Medium:** The network shares one common radio channel in a broadcast mode. Consequently, everyone can get an easy access to the data being transferred among the devices. This issue is not bearable by the applications, which have privacy as their main concerned issue. For example, military applications, private video conferencing and some kind of banking transaction cannot bear this issue. Also, simple attacks such as denial-of-service, message tampering, impersonation etc. can be performed very easily (Lian et al., 2009);

- **Deficient State Information:** Most of the protocols and mechanisms in wireless MANET force nodes to maintain some kind of state information, which may be related to link or related to flow. However, the network devices have limited memory capacity. This limitation makes this task more challenging of maintaining a relevant information, and old information has to be vanished to make space for new information. Even, if we succeeded in maintaining all this state information, this information might become irrelevant just after an interval, as the dynamic nature of MANET might cause the network topology to change and all the information maintained so far will become irrelevant.

Video transmission requires higher bandwidth, and this requirement imposes some nodes to stop their transmission so that desired QoS can be achieved. In interactive communication, traffic also becomes two ways and might follow the same path both ways. And this might need external synchronization to avoid interference. Existing protocols and standards for audio/video transmission in wired environments have been evolved from years and have undergone many refinements. However, we cannot apply these protocols and standards to wireless MANET because:

- In the case of wireless medium, signal is transmitted through air in all directions, which ultimately requires higher transmission power to cover more distance;
- The transmission range or interference range is not visible and more efforts are required, while dealing with congestion, collision, packet colliding etc.;
- In the wireless medium, the problems of reflection, diffraction and scattering are present;
- Finally, the wireless medium is more error prone and problematic. Still, it becomes worst, when it comes to multi-hop networks. The packet drop ratio (PDR) drastically goes up, while delay increases in proportion to these, and ultimately it affects the QoS.

Conclusively, existing protocols and standards for audio/video transmission need extra refinements for wireless MANETs.

QoS Models and Frameworks

In MANET, QoS is characterized by the node resource constraints while the QoS provisioning needs the consideration of various issues (Bheemarjuna Reddy et al., 2006). So, some QoS models and frameworks have been proposed and work along with different protocols and mechanisms to fulfill the application QoS requirements. Such protocols and mechanisms address: QoS PHY (i.e QoS at the Physical layer), QoS MAC, QoS Signaling, Admission Control, Scheduling, QoS Routing, QoS at the Transport and Application layers. Its beyond the scope of this survey to present all these protocols and mechanisms. The survey aims only to analyze QoS routing issues that involve routing protocols and resource reservation mechanisms. Hereafter, we present the most important QoS models and frameworks.

IntServ

Integrated Service (IntServ) (Braden et al., 1994) is the earliest model used for providing QoS on the Internet. In IntServ, QoS is guaranteed on per flow basis. For each flow, proper amount of resources is reserved to meet QoS requirements. IntServ is an architecture that specifies the following modules for achieving QoS guarantees in each flow:

- A QoS specification mechanism in order each flow to specify its requirements;
- Admission control to determine if a new flow should be admitted without affecting the QoS of other ongoing flows;

- A QoS negotiation process so that as many flows as possible can be served. During the QoS negotiation phase, each peer computer/node must determine, if it can support the desired QoS. If so, certain resources are reserved for this session. If the user is satisfied with the suggested QoS, the session is established. Otherwise, the session is rejected;
- Resource allocation and Scheduling to meet the QoS requirement of accepted flows;
- Traffic policing to make sure that flows generate the correct amount of data within the agreed QoS specification;
- A QoS re-negotiation mechanism is required so that flows can request changes in their initial QoS specifications. The actual QoS provided to the ongoing sessions should be controlled, so that suitable actions can be taken in case of any problem in providing specified QoS guarantees. Media scalability and graceful quality degradation techniques should be used together with the above mechanisms to provide efficient services to flows;
- Traffic-shaping schemes. Traffic shaping refers to the act of delaying the packets in the flow so that packets conform to certain defined rules. Traffic shaping schemes are used, when the traffic pattern is too complicated to describe or the traffic is unsuitable for networks to support directly. For example, when video is variable bit rate coded, it may be hard to characterize the coded bit stream;
- Resource reservation protocols. IntServ uses RSVP (Braden et al., 1997) to make per-flow reservations at routers along a network path. While this allows the network to provide service guarantees at the flow level, it suffers from scalability issues. In IntServ, there is a potentially infinite number of different types of traffic, so each router has to store heavy information about each flow in order to provide QoS guarantees to each type of traffic. RSVP is a soft-state protocol, which implies that the router's state has to be refreshed at regular time intervals, and this adds to traffic overhead. The limited CPU processing capability and the limited storage capacity of wireless MANET devices enable IntServ unsuitable to maintain heavy information related to each flow.

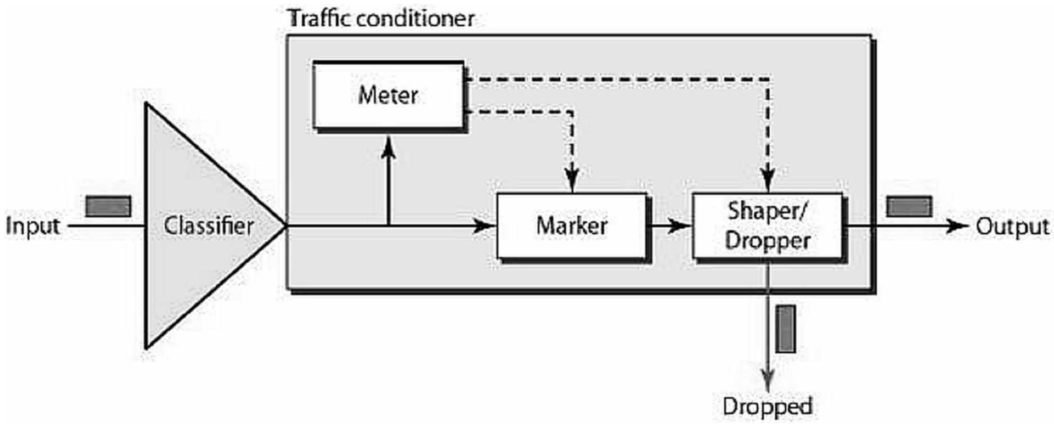
DiffServ

Differentiated Services (DiffServ) model (Blake et al., 1998) takes a middle ground between the best-effort service and IntServ. It defines a fixed number of packet classes (Figure 1). All traffic types/packets are aggregated into these classes, and the network/routers provide different services to different packet classes. But how service classification works? The IPv6 protocol has a header byte called traffic class. In DiffServ the type-of-service (traffic class) byte is re-defined as a Differentiated Services (DS) field. The first six bits of the DS field is called DiffServ Code Point (DSCP) field, which indicates the behavior each router is required to apply to the individual packet. Packets with the DSCP set to 0 receive the same service as they get in the best-effort service. Values between 1 and 7 are defined to be backward compatible with the original IP precedence mechanism, to ensure that DiffServ technology can be deployed in the operational Internet progressively. The DS filed can be assigned by the end-user to indicate the desired service. Alternatively, the ingress (source) router marks the DS field based on the MultiField (MF) classification. MF classification classifies packets based on the contents of multiple fields e.g. source address, destination address, type-of-service byte, protocols ID, source port number and destination port number. As a packet moves from one Internet service provider to another, it may be re-classified. Many service classes can be defined. However, DiffSev is designed for fixed networks, and it cannot be adopted in wireless MANETs (Xiao et al., 2000).

FQMM

Xiao et al. (2000) have proposed the Flexible QoS Model for Mobile ad hoc networks (FQMM). It is a hybrid model that provides both fine-grained behavior of IntServ and coarse-grained behavior

Figure 1. DiffServ model



of DiffServ. This hybrid model is shown in Figure 2, as it was depicted by Bheemarjuna Reddy et al. (2006). The traffic of highest priority will be given per-flow provisioning, while other priority classes will be given class-based provisioning. The FQMM model defines three different types of nodes: ingress, interior and egress nodes:

- An ingress node (i.e. source node) generates the traffic and performs also traffic shaping;
- An interior node is responsible for routing the packets towards desired location. It just forwards the packets towards desired locations, as directed by the traffic profile;
- An egreess node receives the traffic generated by the ingress nodes.

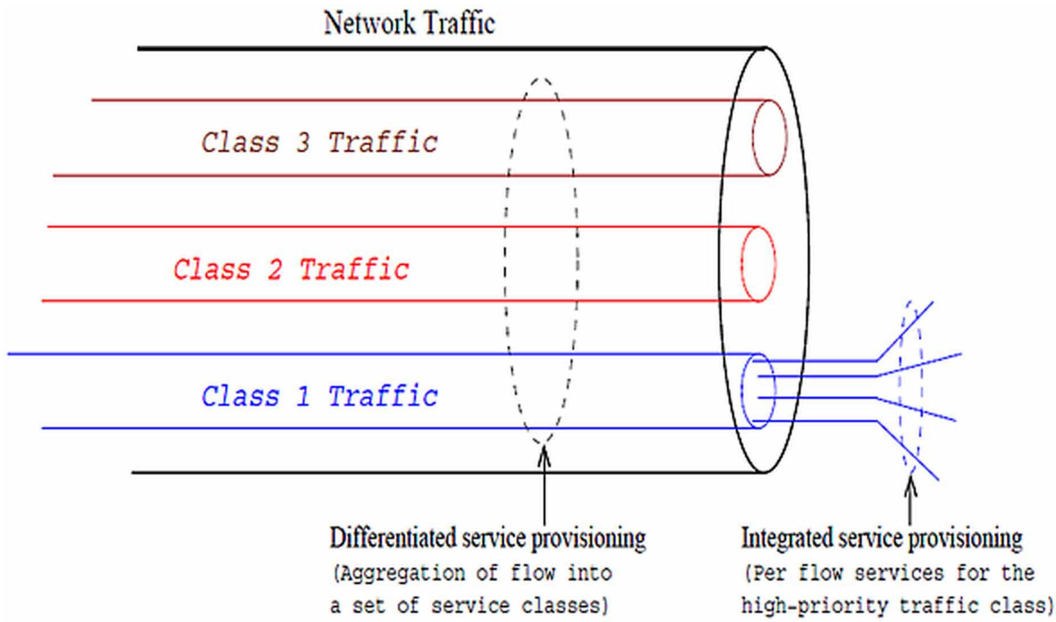
In MANET, the roles of mobile nodes change frequently as nodes move. For example, the node which is currently idle may in the next movement get the responsibility of forwarding packets. Similarly, the node which is currently acting as a packet forwarding node may become idle at very next movement. FQMM is unsuitable for wireless MANET, where nodes change their role continuously. This is why FQMM was originally defined for small to medium size wireless MANETs with less than 50 nodes (Xiao et al., 2000). Anyway, the FQMM model seems to be better approach than using IntServ or DiffServ alone.

INORA

Dharmaraju et al. (2002) have proposed the INORA QoS framework for wireless MANETs. INORA is based on the interaction of two subsystems: (i) the INSIGNIA in-band signaling system (Lee et al., 2000); and (ii) the Temporally-Ordered Routing Algorithm (TORA) (Park & Corson, 1997). The interaction of these subsystems aims to deliver the finer QoS. INSIGNIA supports fast reservation, restoration, and adaptation schemes to deliver the adaptive services. These services support applications that require only a minimum quantitative QoS guarantee (e.g. minimum bandwidth).

INSIGNIA is light-weight and responds rapidly to changes in the network topology and end-to-end QoS conditions. However, the drawbacks of INSIGNIA are: (1) its scalability problem due to the flow state information (which is kept within the nodes of a certain path) and (2) the inefficient bandwidth usage. Both drawbacks are inherited in the INORA architecture. TORA routing protocol is used because of the data structure it uses (i.e. Directed Acyclic Graph) and also because of the TORA's property that provides multiple paths between source and destination. TORA also limits its control packets for route reconfiguration to small regions. So, TORA does not cause unnecessary network traffic. INORA basically operates into two different schemes: coarse feedback scheme and

Figure 2. The FQMM model



class-based fine feedback scheme. The main benefit of INORA is that it can search for multiple paths. However, INORA cannot be used for hard real-time applications, since no resources are reserved before actual data transmission starts. This enables INORA inappropriate for providing QoS in hard real-time applications over wireless MANET.

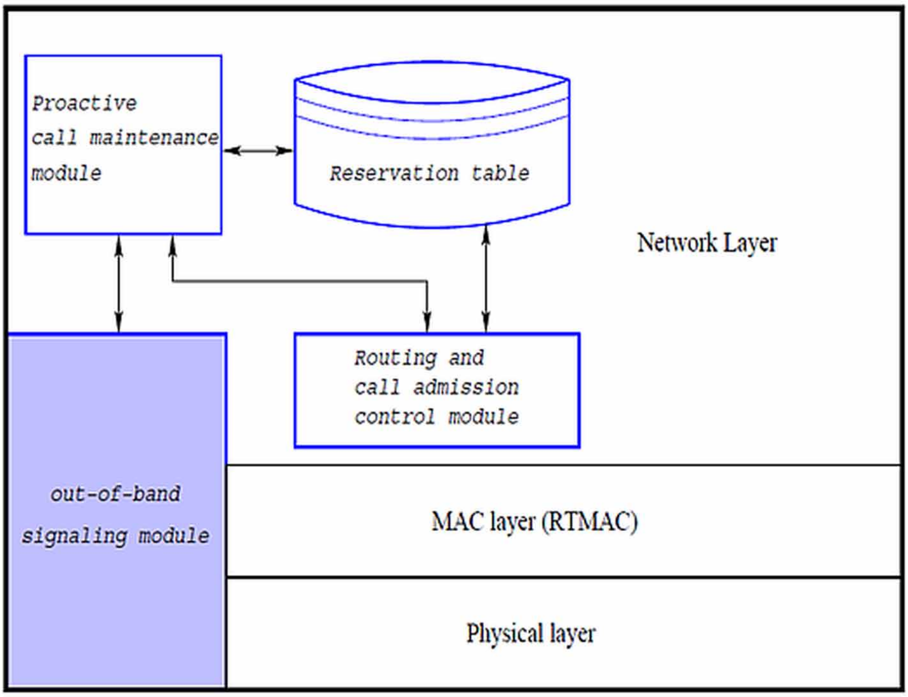
PRTMAC

Vishnumurthy et al. (2004) have proposed the Proactive RTMAC (PRTMAC) QoS architecture (Figure 3) that supports differentiated service classes. Three types of classes provide service differentiation:

- **Class 1:** This class has the highest priority. PRTMAC ensures that the calls for this class do not get disturbed, because of the calls belonging to other lower priority classes. If the situation arises that call could not be carried out further, then any on-going call from low priority class can be dropped in order to keep this call awake;
- **Class 2:** This class has somewhat low priority than class 1, but not the least one. The calls belonging to this class can only be dropped, if the network needs to serve the call belonging to class 1. The calls belong to class 2 are also real-time calls. However, class 2 accepts calls only, if end-to-end bandwidth is reserved for the call it is trying to accept. Otherwise, the call won't be accepted;
- **Best-Effort Class:** This class has the least priority. Under the best-effort class, non-real-time traffic falls. This type of traffic does not need any type of service guarantee and calls belonging to this class can be dropped without any notification, if the need arises to serve the higher priority classes.

PRTMAC includes an enhanced real-time support scheme that uses an out-of-band signaling mechanism to predict future mobility patterns and take corrective action when needed. This helps mobility affected nodes to take proactive measures so as to offer better real-time services to bandwidth critical applications. PRTMAC adopts a cross-layer designing approach. In such approach, optimization is achieved by permitting one layer to access the data of another layer; to exchange information

Figure 3. PRTMAC architecture (Bheemarjuna Reddy et al., 2006)



and enable interaction (Bin-Salem & Wan, 2012). In PRTMAC, some significant parameters are shared among the Network and MAC layers. At MAC layer, PRTMAC framework uses Real-Time MAC (RTMAC) protocol (Manoj & Murthy, 2002), while at Network layer, it uses a DSR routing protocol. PRTMAC demands the bandwidth reservation and bandwidth availability estimation from the RTMAC protocol. By using the out-of-band signaling channel, RTMAC collects the information about current real-time traffic. RTMAC can handle the link breaks and node failures, which makes it more robust. The PRTMAC is a better option than FQMM and INORA for providing the real-time support and service differentiation in high mobility MANETs (e.g. military networks formed by high speed combat vehicles). However, PRTMAC is not a reasonable solution because it makes use of narrow-band control channel as the out-of-band signaling channel. But having another channel in MANET (which is already struggling to make better use of available bandwidth) may not be an economically viable solution.

SWAN

Ahn et al. (2002) have proposed a Stateless Wireless Ad hoc Network (SWAN) model that is a QoS model for wireless MANET. SWAN supports both real-time UDP and best-effort UDP and TCP type of traffic. User Datagram Protocol (UDP) uses a simple connectionless transmission model with a minimum of protocol mechanism. UDP is often used by multimedia applications (e.g. voice over MANET) because dropping packets is preferable to waiting for delayed packets. SWAN supports real-time applications by using distributed control algorithms and also service differentiation. In distributed routing algorithms, the path computation is conducted in a distributed manner by intermediate nodes comprising an end-to-end path. As shown in Figure 4, the Classifier classifies real-time and best-effort traffic. Then, the Shaper (leaky bucket) gets best-effort traffic, which is processed at calculated rate by the Rate controller. The local Rate controller algorithm is used to control the traffic entering into the network. The real-time packets (marked) directly travel towards MAC protocol. So, these packets are getting channel fast, and thus improving QoS. The Rate controller decrements the rate of Shaper, when excessive delays are observed. SWAN does not get affected by the dynamic behavior of topology, as intermediate nodes do not maintain the per-flow or aggregate state information. However, SWAN fails to entirely utilize the DiffServ field that is used only for two classes of traffic. It would be more realistic if full advantage had been taken of differentiating the traffic into a variety of classes that exist in practice.

Network Architecture

Chen and Heinzelman (2004) have proposed a Network Architecture that is based on a cross-layer approach. The Network Architecture (Figure 5) supports QoS in wireless MANETs considering real-time traffic. This architecture considers QoS Transport layer protocol, QoS routing protocol, queue management, and priority MAC protocol. Narrow lines indicate the control flow while bold lines depict the data flow. Application layer manages two types of traffic: real-time and non real-time. Transport layer demands for information from the Packet queue and from the Network layer for achieving desired QoS. Network layer forwards the current network status to the Application layer. While MAC layer and Link layer provide appropriate information to the Network layer, so that performance can be improved. Link layer does the task of bandwidth estimation, which can be passed to Network layer to take appropriate routing decisions. The Queue Management unit does the task of scheduling different priority packets. The MAC Discriminator unit does the task of differentiating data packets and control packets that it has received from the wireless channel. The Priority Classifier classifies different data packets (real-time or non real-time) which it has received from the Queue Management unit. The Packet Scheduling unit handles the task of scheduling packets according to appropriate priority of packets. The Network Architecture can be efficiently used for achieving better video quality and to obtain lesser packet delay.

Figure 4. SWAN model adapted from (Bheemarjuna Reddy et al., 2006)

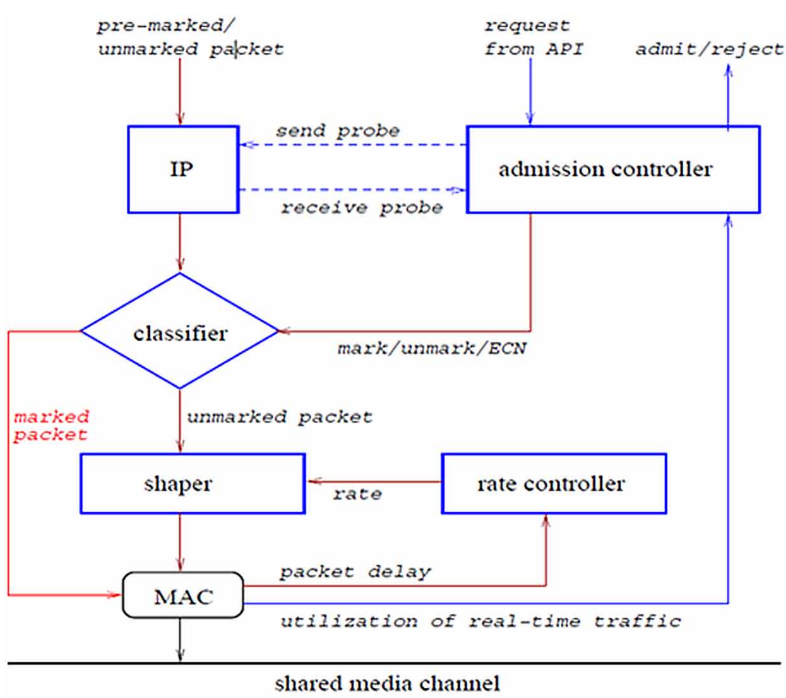
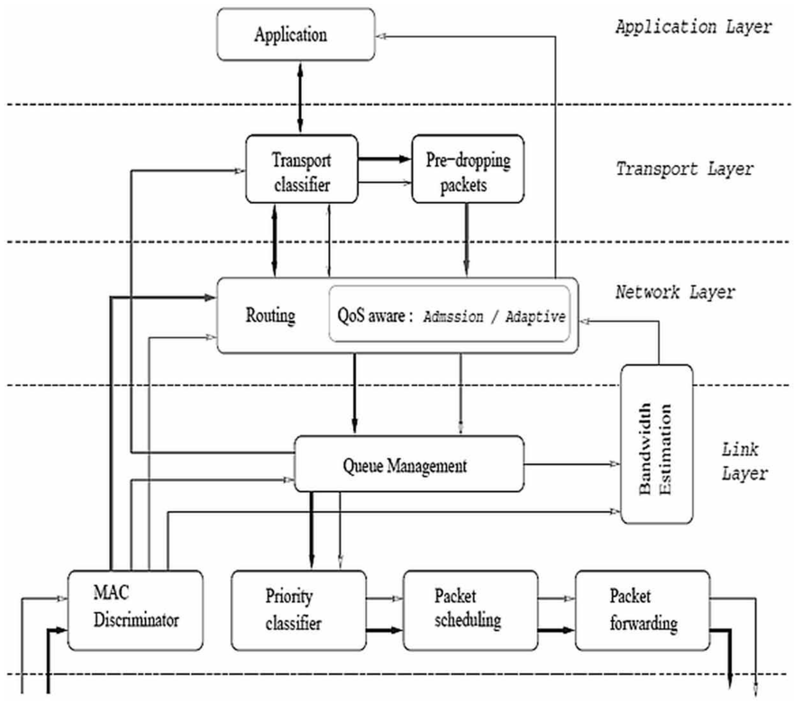


Figure 5. The Network Architecture (Chen & Heinzelman, 2004)



QPART

Yang and Kravets (2004) have presented a QoS Protocol for Ad hoc Real-time Traffic (QPART) that is a cross-layer solution used for providing QoS to real-time applications. In QPART, three different tasks are performed for ensuring desired QoS:

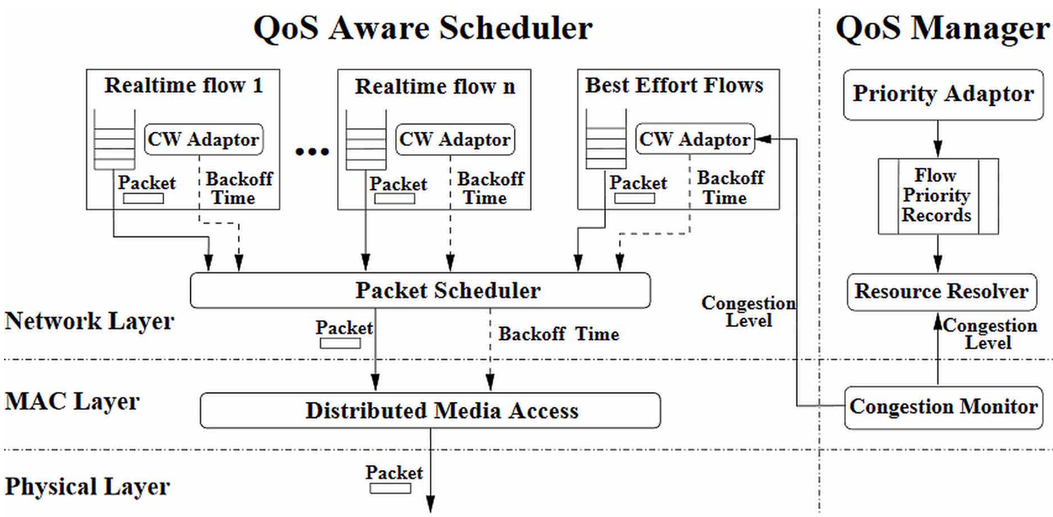
- Admission control that decides if a new flow can enter into the network;
- QoS-aware Scheduling that assigns resources to the admitted flows;
- Conflict resolution that selects and rejects the victim flow, which is causing problem to the other flows.

The QoS-Aware Scheduler and the QoS Manager are the main parts of the QPART architecture (Figure 6). The QoS-Aware Scheduler does the task of scheduling and operates on the principle of enhanced IEEE 802.11 MAC layer protocol [IEEE 802.11e (Mangold et al. (2002)]. The QoS Manager performs admission control and conflict resolution. OoS Manager does the flow prioritization in order to do the conflict resolution and admission control. However, the priorities are assigned dynamically by the Priority Adapter and a low priority flow becomes victim, if congestion occurs in the network. One remarkable advantage of QPART is that for resource allocation, no exchange of any control messages is necessary. In order to do so, it dynamically adapts the contention window size, based on local network congestion level. As it is a cross-layer solution, it also considers the received QoS while adapting the contention window.

CEQMM

Badis and Agha (2006) have introduced the Complete and Efficient QoS Model for MANETs (CEQMM). It is a hybrid model that combines the good features of IntServ and DiffServ. In CEQMM,

Figure 6. QPART model (Yang and Kravets, 2004)



QoS routing is implemented via the QOLSR protocol to decide the optimal paths available. QOLSR (Badis & Agha, 2005) is an extension of the Optimized Link State Routing (OLSR) protocol. OLSR makes use of MultiPoint Relay (MPR) nodes to forward broadcast messages during the flooding process (Clausen & Jacquet, 2003). The QoS metric is used to calculate the QoS-MPR's, which are then given to every node in the network. Firstly, it will decide whether or not the path is available to fulfill the required QoS provisioning. If no path is available to fulfill the QoS requirements, the traffic is simply rejected. Figure 7 shows the functional model of CEQMM. The Priority Classifier classifies the traffic according to its priority. Then, the Queue Management unit makes queues for this traffic. And the traffic Scheduler schedules each traffic class according to its priority and allows channel access (i.e. can be passed to MAC layer). CEQMM model also confronts the congestion control problem. For congestion control, each node that generates the best-effort traffic, limits the packet flow to available bandwidth. CEQMM also includes a Metric Measurement unit that predicts the QoS metric parameters like jitter, delay, bandwidth, loss probability etc. One limitation of implementing CEQMM for MANETs is that the average delay is very long when node moves continuously. Thus, many packets are dropped, which makes it unfavorable for multimedia traffic (Muhammad et al., 2011). However, CEQMM model is better than FQMM as it confronts the congestion control problem.

Table 1 shows a comparison among all these QoS models and frameworks.

Routing in Wireless MANETs

The multi-hop nature in wireless MANET introduces many problems. As the number of hops increases, jitter gets badly affected. In addition, links come into existence and break down more frequently than static network. Because of users mobility, routing becomes more complex. It cannot just simply stop and wait for the link to regenerate every time it fails, it has to find alternate path and eventually this comes at a cost of increase in end-to-end delay. On the other hand, the hard real-time application needs the high bandwidth link to be available continuously, and the delay introduced by the link or node should be as minimum as possible. Also, the processing power of intermediate nodes should be enough to process the heavy amount of data. From all perspective, hard real-time applications demand for best services from all participating units.

Figure 7. The CEQMM model

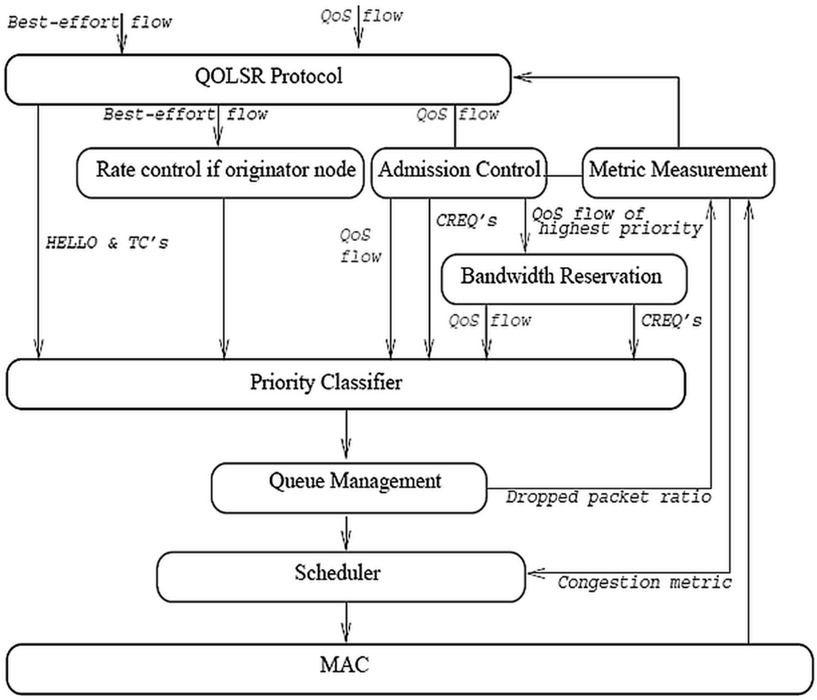


Table 1. A comparison of QoS models and frameworks

QoS Model	Features	Comments
IntServ	It provides a fine-grained and flow-based technique.	QoS is guaranteed on per-flow basis.
DiffServ	It provides a course-grained and class-based mechanism.	It uses a limited number of service classes.
FQMM	It combines IntServ and DiffServ models.	It is scalable.
INORA	It combines INSIGNIA signaling system and TORA routing protocol.	No resource reservation is done. It cannot be used for real-time application.
PRTMAC	It adopts a cross-layer approach.	It is useful for real-time communication.
SWAN	It is based on distributed routing and provides services differentiation.	Does not require QoS support from MAC layer.
Network Architecture	It adopts a cross-layer approach.	It provides better video quality and less average packet delay.
QPART	It adopts a cross-layer approach.	It supports real-time application. There is no need of any control messages for resource reservation.
CEQMM	It is a hybrid model and combines good features of IntServ and DiffServ.	It faces congestion control via an effective mechanism.

To make routing more efficient, many routing protocols' categories have been proposed such as:

- Proactive routing protocols (e.g. Optimized Link State Routing - OLSR): In this category, all nodes periodically exchange routing information to maintain a consistent, updated, and complete network view. Each node uses the exchanged information to calculate the costs towards all possible destinations. In proactive routing schemes, there is no initial delay when a route is required;
- Reactive routing protocols. Examples are DSR, Ad hoc On Demand Routing protocol (AODV) (Perkins et al., 2003), and the dynamic on-demand routing protocol (DYMO) (Chakeres & Perkins, 2008). Reactive routing does not depend on periodic exchange of routing information or route calculation. When a route is required, the node must start a route discovery process.

Royer and Toh (1999) have compared many naive routing protocols. They have concluded that none of these protocols are uniquely sufficient to give best results for particular application. That implies that we must consider the application specific requirements (e.g. minimum power usage, minimum delay tolerance etc.) in order to use specific routing protocol. For example, in video downloading more throughput is desirable, while in live streaming more focus should be on delay and jitter. Thus, we must develop more specific (as per the application's requirements) efficient routing algorithms. Earliest, Chen and Nahrstedt (1999) have presented a ticket-based distributed QoS routing scheme, named as Ticket-Based Probing (TBP) for wireless MANETs. The simulation results prove that TBP has higher success ratio than most of the flooding algorithms. Pearlman et al. (2000) have presented the simulation results for the Alternate Path Routing (APR) protocol. They have concluded that it gives 40% improvement in end-to-end delay. The use of APR is beneficial, if the data being transmitted is more of delay sensitive. Feeney (1999) has explained and categorized the routing protocols as:

- **Topology-based:** Examples are DSR and the Global State Routing (GSR) protocol (Chen & Gerla, 1998);
- **Destination-based:** Examples are the Destination-Sequenced Distanced Vector (DSDV) (He, 2002) and AODV protocols;
- **Neighbor Selection-based:** An example of this category is the Zone Routing Protocol (ZRP) (Hass & Pearlman, 2001);
- **Partitioning-based:** An example is the Core-Extraction Distributed Ad hoc Routing (CEDAR) protocol (Sivakumar et al., 1999).

Rajaraman (2002) has also classified routing protocols as:

- Flat routing protocols (e.g. DSDV, OLSR, DSR, AODV, TORA);
- Hierarchical routing protocols, e.g. the Hierarchical State Routing (HSR)(Iwata et al., 1999);
- Geographical routing protocols, e.g. the Greedy Perimeter Stateless Routing (GPSR)(Karp & Kung, 2000).

Alotaibi and Mukherjee (2012) have also offered a comprehensive review of routing-algorithm categories, such as Geographical, Geo-casting, Hierarchical, Multi-path, Power-aware, and Hybrid routing algorithms. It is noteworthy that naive routing protocols can be used effectively only for text or images. For audio/video transmission, special routing protocols must be proposed, as special attention must be given towards the live streaming. Igartua and Frias (2010) have presented a self-configured framework for video streaming services over wireless MANET, entitled as Adaptive-Multi-path Multimedia Dynamic Source Routing (A-MMDSR). This framework can self-configure according to the dynamics of the environment. In particular, the routing algorithm in A-MMDSR periodically updates a set of paths, classifies them according to a set of metrics and arranges a multi-path forwarding scheme. Chow and Ishii (2007) have used multi-point-to-point transmission together with Multiple Description Coding (MDC) (Goyal, 2001) results in enhancement of the quality of video streaming. They have also suggested an extension to DSR protocol that eventually results in load balancing and finding of maximally disjoint routes. Munoz et al. (2010) have presented a more attractive extension: Reliable Dynamic Source Routing for Video (RDSR-V) streaming, which is a QoS-aware reputation-based routing protocol for video-streaming applications over wireless MANETs. Hu and Johnson (2002) have presented a more specific demonstration of DSR protocol for live audio and video transfer over wireless MANET. Their work significantly improves the transmission of real-time media over multi-hop wireless MANET.

In wireless MANET, multiple paths for the same source and destination may be present, and thus handling of an interactive application becomes somewhat an easier task. This happens because data from source node A to destination node B will take some path, while reply from node B to node A can take some different path, so the efficiency of the link and ultimate throughput can be increased. As a node selects the type of service (e.g. video-on-demand), it declares specific bandwidth requirements. And depending upon bandwidth requirements, appropriate paths may be set. Using multi-path for video/audio transmission over wireless MANET seems to be a good option as the failure probability of a single path is always more as compared to multipath. It allows packets to take multiple paths as if we are doing loose source routing (Johnson, 1993), and thus overall link utilization can be improved. In addition, probability of packet loss can be minimized. But to implement this scheme successfully, receiver has to struggle in handling jitter for each packet or in handling out of order packets and in some cases some packets in between might get misplaced. As a result, if we are dealing with real-time video/audio streaming, then multi-path might not give the desired output. Obviously, routing in case of multi-path becomes more interesting. Mueller et al. (2004) have demonstrated various issues and challenges related to multi-path routing algorithm in wireless MANETs. However, they have left out with handling out of order packets (introduced at receiver due to different packet arrival rate).

Resource Reservation

Every flow needs certain and prerequisite resources in order desired QoS to be provided. So, resources can be reserved in advance, so that when and as demanded by flow it should be there. Reserving the path in advance also tells us that whether the required resources are available or not to fulfill the desired QoS parameters. This might so happen that resources are currently occupied by some other flows, so the current flow can't be served. In this case, protocol may assign some waiting time to the current request to avail that resources or if the current request is of higher priority, then the protocol will snatch out the resources from current flow and will make it available to the requested flow. The resource can be reserved either in hard state or soft state QoS:

- The hard state QoS reservation forces the resources to keep reserved along the path from source to destination, until the whole communication process gets completed. Hard state QoS reservation releases the resource, if and when the path in between brakes. Obviously, this type of reservation is problematic in wireless MANET, because the link breaks happen most often;
- In case of wireless MANET, soft state QoS reservation is much better choice as the topology changes very frequently, and doing hard state reservation might result in wastage most often.

RSVP

In wired networks, the topology is fixed and the resources required by the nodes can be reserved efficiently by using the RSVP (Braden et al., 1997). However, RSVP cannot be directly applied to the wireless MANET because:

- Wireless MANET nodes are mobile in nature, so we cannot be sure whether or not reserved resource will be available when a need arises;
- The bandwidth of network devices is very much limited. Consequently, handling the heavy amount of control information generated by RSVP becomes an overhead.

Talukdar et al. (2001) have argued that there is no provision of passive reservation in RSVP. Therefore, RSVP cannot use advanced reservation viz. a node cannot reserve resources where it will be in future.

MRSVP

This resource reservation protocol is useful for infrastructure-based cellular networks. It requires some kind of prediction i.e. it is presumed that the mobile node is aware of all the locations to those it is going to visit during the lifetime of the flow. MRSVP can reserve resources using two different ways (Talukdar et al., 2001):

- **Active Path:** In this case, data packets are currently using the path reserved (i.e. path is active);
- **Passive Path:** If the path reserved is not active yet and will only be useful in future.

However, MRSVP is not suitable for wireless MANETs. The uncontrolled mobility of network devices makes it almost impossible to predict the future locations of the node; and this is the key requirement for MRSVP to work. Suppose somehow we obtained all the future locations and we reserved the resource along the path, then it may possible that node holding that resource will move out of the range, when the actual need will arise.

Dynamic RSVP

In DRSVP, the QoS can be guaranteed even in a network whose bandwidths are dynamic in nature (Mirhakkak et al., 2000). The DRSVP protocol automatically divides the available bandwidth among all other applications so that varying link bandwidth can be handled efficiently. DRSVP protocol decides whether to or not to accept the connection. If certain QoS parameters (e.g. maximum packet size, peak rate, token bucket depth, average rate and the minimum polished unit) can be supported by the network, then reservation can be accepted, otherwise it will be rejected (Mirhakkak et al., 2000). The DRSVP gives range of values, which allow it to entertain multiple flows. However, this becomes much more complex to handle than simple RSVP, and nodes having limited processing capability in wireless MANET makes it more difficult to implement.

QOS ROUTING

A routing protocol finds the path that can provide the required resources to the flow, while a resource reservation protocol reserves this path prior to data transmission. In wireless MANETs, the routing protocol must be very adaptive to the route changes that occur. For this purpose, novel QoS routing protocols have been proposed and operate by taking into account different (or maybe multiple) QoS parameters. Throughput is the most extensively considerable QoS parameter.

Hereafter, we present routing protocols that guarantee throughput. Chen et al. (1997) have proposed the Clustering-based Channel Capacity Routing (CBCCR) protocol. This protocol extends the concept of DSDV protocol, specially developed for supporting multimedia over wireless MANETs. Sivakumar et al. (1999) have proposed Core Extraction Distributed Ad hoc Routing (CEDAR) protocol which depends on the "core" which is constructed. The "core" provides efficient and low overhead infrastructure such as to provide routing and broadcasts in wireless MANETs. Chen and Nahrstedt (1999) have proposed Ticket-Based distributed Probing (TBP) protocol that selects multiple paths without using flooding those are capable of satisfying the QoS parameters. Stine and Veciana (2004) have proposed Node State Routing Protocol (NSRP) that is based on location awareness and signal strength. Chen and Heinzelman (2005) have proposed Contention-Aware Ad hoc On-demand Distance Vector (CAAODV) routing protocol that contains admission control with feedback scheme. By disseminating bandwidth information using "Hello" messages, the bandwidth estimation is performed. Yang and Kravets (2005) have proposed Contention-aware Admission Control Protocol (CACP) which also thinks about the effect of the admission of new flows on the neighboring nodes along with local information. Gupta et al. (2005) have proposed Interference aware QoS Routing Protocol (IQRP). IQRP makes use of probe packets to compare different paths that are available. Ivascu et al. (2009) have proposed Quality-of-Service Mobile Routing Backbone over AODV (QMRB-AODV) that struggles to distribute traffic all over the network, so that bandwidth can be utilized efficiently. In addition, it reduces the number of control messages.

Next, we discuss some protocols that guarantee bandwidth. Lin and Liu (1999) have proposed the Channel Capacity-Based Routing (CCBR) protocol. By performing the calculation of bandwidth and slot reservation, the CCBR protocol guarantees bandwidth. Zhu and Corson (2002) have proposed on-demand QoS routing protocol based on AODV for TDMA-based MANETs (QoSR-Z), which is cross layer approach that negotiates information between Network and MAC layers. Liao et al. (2002) have proposed a TDMA-based Bandwidth Reservation Protocol (TBRP) for QoS routing for a MANET. Furthermore, it considers hidden and exposed terminal problem, while taking decision about route discovery. Jia et al. (2005) have proposed Ad-hoc Shortest-Widest Path (ASWP) routing protocol that is based on Bellman-Ford architecture and k-shortest path approach. ASWP attains performance close to the optimal possible. Guimarães et al. (2009) have proposed Bandwidth Reservation on multi-rate Ad-hoc Wireless Network (BRAWN) protocol that performs bandwidth allocation on per flow basis. BRAWN is inclined to select highest possible transmission rate in order to perform data transmission.

Now we present QoS routine protocols that aim to guarantee delay. Zhang and Mouftah (2005) have proposed On-Demand QoS Delay-Constrained Routing (ODCR) protocol, which is on-demand unicast routing protocol. It works towards reducing communication overhead. Liu et al. (2006) have proposed Cross-Layer Scheduling Protocol (CLSP). CLSP considers multiple connections with different QoS requirements and uses a cross-layer approach. Abdrabou and Zhuang (2006) have proposed a position-based Quality-of-Service Greedy Perimeter Stateless Routing (QoS-GPSR) protocol that performs temporary bandwidth reservation. QoS-GPSR makes use of position information in routing and bandwidth reservation and adopts a cross-layer approach. Tang and Zhang (2007) have proposed Amplify-and-Forward (AF) and Decode-and-Forward (DF) QoS routing protocol (AF-DF) that considers throughput along with delay as its QoS parameter. It is a cross-layer approach that works towards maximizing the relay network throughput along with considering delay constraint. Nikaein et al. (2001) have proposed a Hybrid Ad hoc Routing Protocol (HARP) protocol. HARP is hybrid in nature and combines reactive and proactive schemes. It is noteworthy that HARP considers Buffer space as its QoS parameter.

Sheng et al. (2003) have proposed the Delay-Sensitive Adaptive Routing Protocol (DSARP) which considers Delay along with Buffer space as its QoS parameter. DSARP is based on constraint condition: 'The shortest route and the lowest delay'. Wang and Kuo (2005) have proposed Application Aware QoS Routing (AAQR) protocol which is a QoS-aware routing protocol. It also considers jitter along with delay and throughput as its QoS parameters. To estimate the node state, it makes use of Real Time Control Protocol (RTCP). Badis and Agha (2005) have proposed QoS Optimized Link State Routing protocol (QoLSR) which considers MAC delay along with throughput as its QoS parameter. It also proposes refined and a more efficient heuristic for selecting MPR set with minimum size. Fan (2004) has proposed a Cross-Layer Multi-Constraint QoS Routing (CLMCQR) protocol, which also considers Packet Loss Rate (PLR) as its QoS parameter along with throughput and MAC delay. It negotiates information between Network layer and MAC layer in order to select an optimal route. Barolli et al. (2003) have proposed Genetic Algorithm based routing for Mobile

Ad-hoc Networks (GAMAN) which considers delay along with PLR as its QoS parameter. It is source initiated Genetic Algorithm (GA) based routing algorithm having good response time. Misra and Banerjee (2002) have proposed Maximum Residual Packet Capacity (MRPC) routing protocol, which considers energy along with PLR as its QoS parameters. It also considers the stuff that different links require different transmission powers instead of relying only on function of battery power for making routing decisions. Kim et al. (2004) have proposed Signal-to-Interference Ratio (SIR) and Channel Capacity-based Routing (SIRCCR) protocol, which considers SIR also along with throughput as its QoS parameters. It claims to reduce the probability of call denials.

Hereafter, we present some QoS routine protocols that consider Link stability as their QoS parameter. Shen et al. (2003) have proposed the Entropy-Based Routing (EBR) protocol, which is based on entropy (i.e. life of path). The QoS is guaranteed in wireless MANET by selecting path having longest-life i.e. calculated with the help of proposed entropy metric. Rubin and Liu (2003) have proposed a similar concept entitled as Link Stability-Based Routing (LSBR). Also, they have presented a number of models those can be used to predict the link stability. Sun et al. (2006) have presented a position-based routing protocol for wireless MANETs, called GvGrid. GvGrid takes into account Packet Arrival Ratio (PAR) as it's QoS parameter. It makes use of GPS in order to access the relative position of nodes, which might cause some delay.

Table 2 shows the comparison among these normal QoS routing protocols, while Table 3 shows the comparison among the discussed cross-layer based routing protocols.

RECENT ADVANCEMENTS IN QOS ROUTING

Many modifications have been made in the routing protocol to improve the performance of the network. Egilmez et al. (2012) have presented a Distributed QoS Routing (DQR) architecture for scalable video streaming. DQR architecture divides the video into different layers. As each layer will have different QoS requirements to be satisfied, DQR architecture forces different layers to take different paths. The DQR architecture works on Open-Flow network, but can be migrated easily to wireless MANET. Dai et al. (2012) have presented Correlation Aware QoS Routing (CAQR) algorithm for wireless sensor network. By using correlation-aware inter-node differential coding scheme, they achieved to reduce the traffic in the network. In particular, they proposed a load balancing scheme to distribute the traffic throughout the network. Finally, by integrating this correlation-aware technique to the routing framework, they accomplished low energy consumption system along with reduced traffic and load balanced system. The Light-Weight Trust-based QoS Routing (LW-TQR) algorithm has been proposed by Wang et al. (2014). This algorithm aims towards providing more secure, better packet delivery ratio and average end-to-end delay in the network. In this framework, malicious nodes are detected and isolated from the network. So, security does not get compromised enabling this mechanism best suited for the military-related application. In the case of stable links, the real-time application would perform better. Moussaoui et al. (2014) have proposed Link-State QoS Routing Protocol (LS-QRP) based on the link stability. LS-QRP protocol is best suited for the point-to-point voice call applications (e.g. Voice over MANET - VoMANET) or video streaming because it makes stable and sustainable links between each pair of nodes in the network. A stable link meets proper QoS requirements. Obaidat et al. (2013) have proposed QoS-aware Multipath Routing Protocol (QMRP). This protocol tries to reduce the delay such as to improve the reliability and QoS of the multimedia communication over wireless MANETs. QMRP passes the packets by using multiple links to the same destination in order to reduce delay. The same result in more reliable transmission as even though one link fails then it will not affect throughput badly. In order to achieve better quality, QMRP is a cross-layer approach that tries to make physical layer and network layer interact. The simulation study depicts that QMRP performs much better in most of the cases like end-to-end delay, packet delivery fraction and route discovery frequency, but fails in reducing the routing overhead in comparison to AODV. Alwan and Agarwal (2013) have proposed Multi-objective QoS Routing (MQoSR) protocol for wireless sensor

Table 2. A comparison of QoS routing protocols

Protocol	QoS Parameter	Features	Explanation
CBCCR	Throughput	Can inform source of bandwidth and QoS to any destination	Provides more effective call acceptance control.
CEDARP	Throughput	Depends on "core": self-organizing routing infrastructure.	Core provides an efficient and low overhead infrastructure
NSRP	Throughput	Based on location awareness and signal strength.	NSR protocol provides capability to predict connectivity.
IQRP	Throughput	Uses probe packets to compare different packets.	Uses local knowledge and state information.
CACP	Throughput	Scalable	Considers effect of admission of new flow on neighboring nodes
QMRB-AODV	Throughput	Makes use of mobile routing backbone	Lesser control messages and better utilization of bandwidth by distributing traffic
MRPC	Throughput, Energy	Power-aware routing algorithm.	Routing decisions are based on a function of battery power
SIRCCR	Throughput, SIR	Selects multiple routes.	Reduces the probability of call denials.
QoLSR	Throughput, MAC delay	Considers packet collision probability, nodes MAC queuing and service times	Uses new heuristics for selection of MPR's
AAQR	Throughput, Delay, Jitter	Node state estimated using RTCP	No need of any additional probing messages.
CCBR	Bandwidth	Performs bandwidth calculation and slot reservation.	DSDV + "resource reservation" with/without bandwidth calculation.
ASWP	Bandwidth	Based on adopting Bellman Ford algorithm and k-shortest path protocol	Algorithm is able to achieve performance close to optimum possible.
BRAWN	Bandwidth	Allocates bandwidth on per flow basis.	Selects highest possible transmission rate for transmitting data.
TBP	Delay	Multipath and distributive.	Selects multiple paths without flooding.
ODCR	Delay	On-demand and unicast.	Reduces communication overhead
GAMAN	Delay, PLR	Source based and based on genetic algorithm.	Robustness is primary concern.
DSARP	Delay, Buffer Space	Based on constrained condition: the shortest route and the lowest average delay.	Ensures that minimum packets get lost in the network
HARP	Buffer space	Hybrid: combines reactive and proactive schemes.	Performs two level routing, intra zone and inter zone.
EBR	Link stability	Entropy based: lifetime of path.	Selects path having longest life.
LSBR	Link stability	Based on link survival time.	Proposed different models to estimate link stability.
GvGrid	PAR	On-demand and makes use of GPS	Selects nodes that are likely to move in similar direction with similar speed

networks. In order to provide the QoS, two different kinds of metrics (i.e. Link-based-metric and Path-based-metric) are used. MQoSR uses heuristic neighbor selection mechanism with geographic routing algorithm in order to provide a routing solution.

Table 3. A comparison of cross-layer QoS routing protocols

Protocol	QoS Parameter	Features	Information Negotiation
QoSR-Z	Bandwidth	Distributed, based on AODV, can handle some degree of node mobility.	Between network and MAC layers.
TBRP	Bandwidth	TDMA based and solves hidden terminal and exposed terminal problems	Between network and MAC layers
CLSP	Delay	Allows multiple connections with different QoS requirements	Between physical and MAC layers
QoS-GPSR	Delay	Does temporary bandwidth reservation and provides per flow end-to-end guarantee.	Between network and MAC layers
AF-DF	Delay, Throughput	Aims at maximizing relay network throughput.	Between physical and data link layers.
CAAODV	Throughput	Combines admission control and feedback, estimates residual bandwidth available at each node.	Between network and application layers
CLMCQR	PLR, MAC delay, Throughput	Level of interference is calculated by observing MAC delay.	Between network and MAC layers

It can be useful to a wide variety of applications as this is a multi-criteria QoS routing algorithm. Rehman et al. (2015) have introduced the Forward-Link-Quality-Estimation Routing (FLQER) protocol that is originally designed for VANET's. FLQER includes an efficient technique to predict the forward link quality. So, that whenever we will get that link won't be useful in future, we can immediately switch to some alternate paths. FLQER protocol can be useful in real-time applications, as the link quality estimation algorithm can be migrated to wireless MANET. Cadger et al. (2015) have presented Geographic Predictive Routing (GPR) which can be an efficient protocol for video-streaming applications, especially in the highly mobile network. GPR focuses on location and mobility criteria in order to get improved performance. The advance concept of Artificial-Neural-Network is being used to correctly depict the future locations of neighbor nodes so that link-switching decision can be made. Huang (2015) has presented a special QoS routing algorithm, which does the load-balancing for multi-path video transmission over wireless MANET. The QoS routing algorithm can be used efficiently for video streaming applications. Brak et al. (2014) have introduced a novel and effective modification to existing Optimized Link State Routing (OLSR) protocol entitled as OLSR-VA to make OLSR aware of VoIP applications. Brak et al. based their protocol in the principle that effective adaptation of routing parameters can enhance VoIP quality. OLSR-VA constantly monitors traffic and detects the VoIP activity. After that routing parameters are adapted in order to meet the QoS requirement of VoIP application. This protocol is self-adapting routing protocol, which adapts its parameters to the VoIP load in the network. Sanchez-Iborra et al. (2015) have proposed a new routing protocol entitled as Better Approach To Mobile Ad-Hoc Networking (BATMAN). This protocol exclusively claims to provide QoS in providing VoIP and video traffic. By using both emulator and simulator, the authors evaluated the performance of the BATMAN. They concluded that BATMAN performs much better than OLSR. They have also suggested that performance can be further improved with an appropriate tuning of configuration interval. In addition, BATMAN is capable of adjusting the bit-rate of the video traffic according to the number of streams in the network for managing video traffic.

Table 4 shows a comparison among all these recent advancements in routing protocols.

ACS-Based QoS Routing Protocols

Recent literature has focused on achieving QoS using ACS (ANT-Colony) algorithm. An Ant-based multi-QoS routing metric, named as AntSens-Net, has been introduced by Cobo et al. (2010). AntSens-

Table 4. Recent advancements in routing protocols

Protocol	Features	Comments
DQR	Supports video streaming over large-scale multi-domain Open-Flow networks.	Divides the video into different layers and force different layers to take diverse paths.
CAQR	Deliver visual information under QoS constraints.	Also proposed correlation-aware inter-node differential coding scheme and a correlation-aware load balancing mechanism
LW-TQR	Estimate the trust degree between nodes.	Best suited for the military-related application
LS-QRP	Minimizes the recalculation of MPR and routing table	Guarantees packet loss and response time.
QMRP	Introduces new parameter projected-load	Cross-layer approach(negotiates information among physical, MAC and network layers).
MQoSR	Uses heuristic neighbor selection mechanism.	Uses link and path-based metrics for QoS provisioning
FLQER	Improves the selection of next relay node.	Achieves higher reach-ability compared to existing relay selection protocols
GPR	Bottom-up routing process.	Predicts future locations of nodes using Artificial Neural Network
QRVS	Depicts multi constrained QoS routing mechanisms in AOMDV.	Can be used efficiently for video streaming
OLSR-VA	Extension of OLSR protocol	Can be used efficiently for VoIP applications
BATMAN	Capable of adjusting bit-rate of video according to the number of streams in the network.	Supports both VoIP and video traffic

Net is based on traditional ant-based mechanism and also consider QoS. It builds some type of hierarchical structure on the network and then selects the paths in order to fulfill the QoS requirements for different types of traffic. It uses multi-path video packet scheduling, which results in minimum video distortion transmission. Wang Y. et al. (2014) have presented an Improved Ant-colony based Multi-constrained QoS Energy-saving Routing (IAMQER) algorithm. This algorithm is also capable of energy saving and throughput optimization for wireless MANETs. IAMQER manages the relationship between the network throughput and energy consumption by analyzing the local node parameters, such as node queue length, node residual energy, number of forwarding data packets etc. Simulation studies of IAMQER have proven that it also improves the packet delivery ratio, thus resulting in better quality and better user satisfaction. Rodriguez-Perez et al. (2015) have proposed an Ant Colonization routing algorithm to Minimize network Power Consumption (ACS-MPC). The algorithm works on the principle that in low load network conditions, we can aggregate the whole traffic in a minimal set of links, so that all other nodes (that are not part of link aggregation) can sleep for a moment saving energy. This algorithm minimizes the global energy consumption by designing their routing tables in a decentralized manner. Eiza et al. (2015) have proposed Situation-Aware Multi-constraint QoS (SAMQ) routing algorithm that is based on the ACS routing algorithm. SAMQ focuses on vehicular ad hoc networks (VANETs) and is best suited for the highly wireless MANET where the speed of the mobile node is high. In particular, SAMQ computes the possible routes between the communicating vehicles depending on the multiple QoS constraints those are granted between them. It responds in a proactive manner in order to handle the route failure. In addition, it benefits from the situational awareness (SA) model that provides a framework for improving QoS routing reliability in VANETs.

Table 5 shows a comparison among all these ACS based routing protocols.

Table 5. Recent advancements in ACS based routing protocols

Protocol	Features	Comments
AntSens-Net	It builds hierarchical structure on network.	It uses efficient multi-path video scheduling.
IAMQER	It is based on the analysis of local-node information.	It proposes path evaluation function.
ACS-MPC	It works on power conservation.	It aggregates and/or divides traffic all over network.
SAMQ	It selects best route from multiple computed routes.	It responds locally and proactively to link/route disconnections

NOVEL APPROACHES FOR MULTIMEDIA OVER WIRELESS AD HOC NETWORKS

An interesting cross-layer approach for real-time streaming on wireless MANET has been demonstrated by Kuo et al. (2013). This approach is titled Cross-Layer Overlay for Multimedia Environment on P2P-MANET (COME-P2P). COME-P2P is useful for real-time point-to-point applications (like VoMANET or video communication) as it is specific for peer-to-peer communication. It is a cross-layer approach and thus the lower layers detect the mobility of nodes and convey this information to upper layers, so that the upper layer can maintain the routing table. The main contribution of COME-P2P approach is to maintain the stability of the routing paths for live streaming via IPv6 routing. The simulation results have depicted that it reduces the signaling overhead for live-streaming.

Bellavista et al. (2013) have proposed a light-weighted and self-organizing middleware, named localized relay-based mobile multimedia (LEM). LEM is useful for multimedia delivery in MANET (especially which is dense in nature). However, LEM approach is designed for providing multimedia services in some geographically bounded area of interest. Consequently, LEM middleware can be useful for applications like localized-video-conferencing or localized-rescue-operation.

Diaz et al. (2014a) have proposed the Multimedia Wireless Ad-Hoc Cluster Architecture (MWAHCA) to create and manage the cluster-based wireless MANET to provide multimedia streaming over it. It claims to provide proper QoS for a cluster-based wireless MANET. It evaluates the capacity for each individual node and uses this information to meet different QoS parameters. The main advantage of MWAHCA is that it divides the network into different clusters, where each cluster will be dedicated towards specific traffic types. It makes use of suitable Multimedia Init Profiles (MIPs) to adapt the different physical network configurations. However, MWAHCA does not take into account load balancing and fault tolerance mechanisms. Diaz et al. (2014b) have proposed the fault tolerance mechanism to be used with MWAHCA in order to increase its reliability. For fault tolerance, they have used a temporary fast switching path to improve the QoS recovery transition. They made provision to run algorithm independently for each multimedia flow in the network. They have reduced the convergence time to control the QoS parameters and to keep them as low as possible, which eventually resulting in minimum packet loss.

Ahmad et al. (2015) have demonstrated an efficient approach for delay optimization using the Knapsack algorithm, designed to deal with the multimedia data. First, they have demonstrated that delay is dependent on the packet size and buffer size to a great extent by presenting the mathematical relation of delay, buffer size, and packet size. Afterwards, they have used Knapsack algorithm to maximize the "in-order packets in the buffer", while on the other hand to minimize the "out-of-order packets in the buffer" simultaneously. For doing the same, they have also estimated the proper packet size and buffer size. They have made a buffer to act as a leaky-bucket for packets. With the help of simulation, they have demonstrated that their approach can be useful for the multimedia transmission over MANET, especially when the size of the buffer is somewhat small, but the size of data is more. This is what will be the situation most of the time in wireless MANET.

Coll-Perales et al. (2015) have presented more interesting empirical models of the communications performance for the Multi-hop Cellular Network (MCN). MCN can be easily inherited to the wireless MANET, as it is dependent on the device-to-device (D2D) model. These models consider the impact of various parameters like: a number of hops, propagation conditions, distance etc. The authors have argued that this model can be very useful in case of design and demonstration, testing or optimization of novel communications and networking protocols designed to work with MCN. The models represent the MCN throughput experienced at the mobile destination node, as the function of multiple parameters like a number of hops, propagation condition, distance etc.

Ghazani (2015) have proposed a new Light Weight distributed QoS Algorithm (LWQA) for wide area ad hoc networks. It dynamically adjusts the Contention Window (CW) related to real-time flows using queue data structure and linear algebra. The algorithm distinguishes between the flows of the same type and can provide the different types of service for these similar flows. The main advantages of LWQA is that it doesn't need any type of resource reservation to ensure QoS. Unlike all other algorithms, flow in LWQA doesn't contend with other flows. Simulation studies have demonstrated that LWQA is capable of achieving the required quality.

Finally, Castellanos et al. (2016) have proposed a new QoS routing protocol based on AODV (AQA-AODV) that creates routes according to application QoS requirements. They have introduced link and path available bandwidth estimation mechanisms and an adaptive scheme that can provide feedback to the source node about the current network state, to allow the application to appropriately adjust the transmission rate. The authors proved that the combined use of AQA-AODV and the scalable video coding provides an efficient platform for supporting rate-adaptive video streaming.

The above mentioned approaches give much better results than earliest models in providing multimedia communication over MANETs. However, further improvements (e.g. support for end-to-end delay during the route discovery phase) must be proposed in order to enhance more their performance in MANETs. More experiments must be also performed using novel routing approaches with network-adaptive protocols for assessing the quality of experience (QoE) of the user.

CONCLUSION

MANET applications can be rapidly developed, if the technical issues concerning the provision of QoS will be resolved. Among these technical issues, the most important is QoS routing that includes the required routing mechanism and protocol as well as the required resource reservation protocol. Many intra-domain routing algorithms have been proposed which satisfy bandwidth, delay, and multiple constraints, while other multicast routing algorithms address the discovery of a tree covering source and multiple destination nodes subject to a set of constraints. Source, distributed and hierarchical routing algorithms have also been demonstrated in the literature.

This survey has provided an overview of some of the existing issues and challenges in providing multimedia communication over wireless MANETs. Especially, it has focused on the issues related with selecting proper QoS-based routing protocol, and it has enlisted some of the existing techniques resolving these issues. Also, it has discussed various QoS models, routing mechanisms and protocols used in order to provide efficient QoS routing over MANETs.

Most of the existing QoS models and frameworks are designed considering specific QoS routing protocols, which are working at their best to the some kind of applications and scenarios. Scalability and reliability of QoS for multimedia applications over wireless MANET will depend partially on QoS routing mechanisms operating on a full end-to-end basis. Obviously, other protocols and mechanisms, such as QoS PHY, QoS MAC, QoS signaling, and QoS admission control and scheduling will play their significant role to this issue, but studying them was not the goal of this survey.

Several combinations of QoS routing mechanisms are possible toward customized QoS routing solution for current multimedia application. In most cases, the nature of these QoS routing solutions will drive the combination of these mechanisms. We must design a generic QoS routing framework as it would be able to provide QoS routing to multimedia flows with divergent QoS requirements by having the scope for adaptation to various protocols/mechanisms, those can further help in achieving the desired QoS routing in MANETs. Such generic QoS routing framework should:

- Classify the traffic into real-time and non-real-time classes;
- Assign scalable priorities to the real-time traffic flows as they come with different bandwidth, throughput and delay requirements. Real-time flows must be treated differently according to their needs;
- Offer good bandwidth management based on an intelligent adaptation method that recognizes the priorities of the traffic.

Finally, the functionalities of this QoS framework (i.e. resource estimation, admission control, resource reservation and bandwidth adaptation) should be handled in a way that avoids the waste of resources and interference with other on-going flows.

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