A Comprehensive Survey on Various QoS Routing Protocols in MANETs

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Abstract

The Mobile Ad Hoc Network (MANET) is a collection of self-organized mobile nodes that can form a dynamic infrastructure and establish wireless communication among them. The MANETs have gained popularity in many applications like civil and military surveillance due to their inherent characteristics, such as self-organized capability and ease of deployment. In recent years, the MANETs also have to support many real-time multimedia-based applications which require strict Quality of Services (QoS) like delay and reliable data delivery. This paper presents a common overview of MANET characteristics, applications, and QoS requirements. Further, it comprehensively reviews different QoS routing protocols with their advantages and disadvantages. Moreover, this paper discusses the issues in conventional works and the possible future work extensions.

Keywords: Mobile Ad Hoc Networks, Routing Types, Quality of Service (QoS) routing protocols.

1. Introduction

A Mobile Ad Hoc Network (MANET) is a wireless multi-hop network without any infrastructure, and there is no need to plan for installing any base stations [1]. The nodes in MANET move independently of one another, forming a dynamic network topology. The mobile nodes' transmission range limits due to the battery power constraints, channel fading, and bandwidth. In MANET, each node can act as a source and destination [2]. On occasion, the intermediate nodes can act as a router. In MANET, the data packets are transmitted in a stored and forward manner between the two communicating nodes. The nodes can make direct communication with each other through a single hop or multi-hop within a communication range [3]. In MANET, the addition and deletion of nodes affect the routing hops. In case the nodes in MANET are out of communication range, the router is required for communication. The data packet sends from source node to destination node in a multi-hop fashion is called routing.

1.1 Characteristics of MANET

The inherent MANET characteristics are described as follows.

- **Dynamic topologies and Channel capacity:** In MANET, the mobile nodes are move free ata different speed. So it leads to unpredictable topology changes in the network. The mobile nodes may create or break links between nodes at anytime due to node mobility, and it reduces the channel capacity.
- **Rapidly Deployable:**It is unnecessary to provide the infrastructure support to setup MANET so that the deployment and routing process in MANET is relatively easy than infrastructure-based networks.
- **Self Structure and Self Organizing:** As MANET supports node mobility and new nodes acceptance, it is easy to organize and maintain the network topology.
- **Low Transmission Power and Coverage Extension:**The source node cannot communicate directly with the destination, located in a long distance. So, the source node transmits the data packet in a multi-hop communication with low transmission power. Using the multi-hop routing, the MANET extensively makes longer the range of the wireless node.
- **Security Threats:** In a wireless network, the communication between two nodes is unpredictable due to the dynamic environment. The threats easily affect the wireless network compared to a wired network. The security level is significantly less in a wireless network according to the features of spoofing, eavesdropping, and denial of service attacks.

1.2 Applications of MANET

Due to the ease of deployment and wireless communication, the MANETs are employed in many application areas that are as follows.

- **Collaborative Work:** People want to work in a collaborative computingenvironment outside of the office environment to exchange their project information.

- **Bluetooth and Personal Area Network (PAN):** A PAN is a short-range local network, provides an online connection to a given person. Bluetooth is a technique used in a short distance range to transmit the data between two users, such as mobile phones and laptops.
- **Military Applications:** MANET is a self-structured wireless network used at any commonplace. According to this characteristic of MANET is used in the military to maintain the information among soldiers.
- **Day to Day Applications:** MANET is used for day-to-day applications like e-mail, File Transfer Protocol (FTP), and multimedia applications due to self-structured and self-organized characteristics.

2. QoS Routing in MANET and Challenges

QoS routing defines the provision of a guaranteed level of wireless communication in the network.In MANET, the provision of QoS routing takes an important role in real-time communications like video and audio [4]. The QoS provisioning in MANET is highly difficult due to mobile nodes and battery power limitations.

- **Unpredictable Link Failure and Mobility:** Wireless network topology changes are unpredictable due to highly mobile nodes. The signal fading, multi-hop, interference, and intrinsic data packet collision make challenges in signal propagation over wireless networks, and it is difficult to measure the bandwidth and delay of a wireless link.
- **Capacity Constraints:** Generally, wireless networks have limited bandwidth and less expensive. Each mobile node equipped with a single interface can make wireless communication with only one node in the communication range at a time. Thus, it limits the channel capacity.
- **Channel Access Delay:** The channel access control depends on the distributed mechanism because there is no base station or centralized controller for communication. The distribution of control packets to control the channel access incurs high delay, and it is important to reduce the channel access delay for achieving QoS provision.

- **Route Maintenance:** In MANET, the mobile nodes maintain route information. The network topology is unpredictable, and it makes challenges to QoS in the wireless network compared to the infrastructure network. The QoS in wireless communication needs to reduce the delay and stale routes in the network.
- **QoS Provisioning Problem in Multilayer:** In MANET, the QoS provision in multilayer is a major problem. In an infrastructure-based network, the transport layer and routing layer only need to contribute to QoS provision, while in a wireless network, all layers need to contribute to QoS provision. The physical layer should be able to adapt to the changes in a wireless network rapidly. The Medium Access Control layer (MAC) needs to provide QoS for reliable data communication, guaranteed channel access, and data packet loss reduction. The network layer needs to find efficient data transmission paths in a dynamic network topology for QoS provisioning. In MANET, the transport layer needs to ensure the packet loss, delay, and delay jitter combined with recurrent link failures. The application layer ensures QoS to quickly adapt the wireless communication with minimum delay, minimum data packet loss, and out-of-sequential packet delivery in order.

3. Classification of QoS Routing in MANET

Several QoS routing protocols are surveyed in [5] [6] [7]. QoS routing in MANET is classified based on the network topology, geographical information, layer interaction, channel allocation, and evolutionary algorithm-based. Figure 1 shows the classification of QoS routing protocols in MANET.

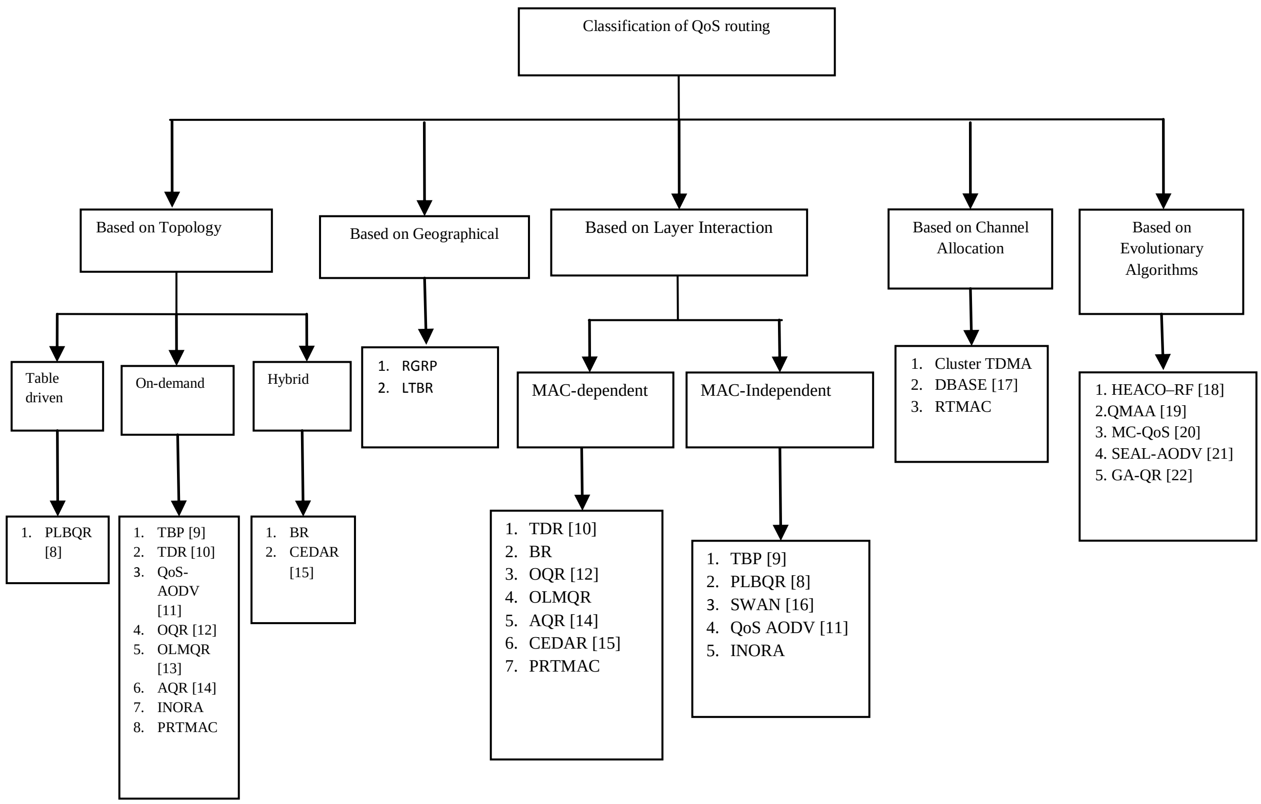

Figure1: Classification of MANET QoS Routing Protocols

3.1.1 Topology based QoS Routing

The topology-based QoS routing protocols employ the topological information in QoS route selection. Further, it is classified into table-driven, on-demand, and hybrid. In table-driven protocol, each node maintains the routing information to the entire network topology. In on-demand protocol, the communication route is established between two nodes at the time of communication. The hybrid routing protocol has both the characteristics of table-driven and on-demand.

Table Driven QoS Routing Protocol: In table-driven protocol, the node maintains the routing tables to the entire network topology. In table-driven, the path overhead is high due to the maintenance of routes to each node in the network. The routing information is exchanged among the neighboring nodes periodically. When communication occurs between two distant nodes, the sender node obtains the route information immediately from the routing table. The immediate route selection minimizes the delay in the network. However, frequent route failure leads to store stale information and transmission failure.

The Predictive Location-Based QoS Routing (PLBQR) protocol [8] employs a location prediction scheme and update mechanism to overcome the routing issues related to the stale route information. In the update mechanism, each node disseminates the location and resource information to its neighbors. It does not allocate the resources to the end-to-end communication path, but it performs the admission control with the support of delay prediction mechanism efficiently. It follows two different update mechanisms according to the changes in network topology. Initially, it disseminates the location information periodically, but in the second approach, the location update interval is varied based on the node mobility parameters such as mobility speed and direction. By using the depth-first search and reserved resource per hop, the next-hop node is selected for the data transmission. However, inaccurate location prediction due to unpredictable node mobility leads to QoS violation.

On-demand QoS Routing Protocol: In an on-demand routing protocol, the node does not maintain the route information to the entire network topology [23]. There are two states to design the on-demand routing protocols, such as route discovery and route maintenance. In the route discovery process, the route is established between two nodes, only when the communication occurs between them and the routes are maintained until it breaks. Thus, it reduces the routing overhead than table-driven protocol. Some of the on-demand QoS routing protocols are Trigger-based (on-demand) distributed QoS routing (TDR) protocol, QoS AODV, On-demand QoS Routing protocol (OQR), On-demand Link-state Multi-path QoS Routing (OLMQR) protocol, Asynchronous QoS Routing (AQR), INtelligent Optimization self Regulated Adjustment (INORA), Proactive Real Time MAC protocol (PRTMAC).

The on-demand-based AODV-BR [24] exploits mesh topology for providing multiple alternative routes to the destination without using additional control messages. It builds communication paths between source and destination on-demand using control packets. Based on the flooding procedure, it determines the communication routes, and it eliminates the duplicate packets using the sequence number. In the route reply phase, it creates mesh topology and informs alternative routes to the source node. Each node receives the RREP packets maintain the alternative routes in a separate table. In case the main route fails to transmit the packet due to mobility, the alternative route is started to transmit the packets. To reduce the routing overhead, it removes the route when it is not used for a long time. This scheme can be implemented in any on-demand routing protocol to improve the routing performance. It reacts fast under dynamic network topology, but alternative path storage increases the routing overhead.

Hybrid QoS Routing Protocol: In hybrid protocol, both the table-driven and on-demand routing characteristics are involved. It limits the proactive routing approach to the local topology, and route discovery on demand improves the hybrid routing performance, and it minimizes the routing overhead in the network. Several hybrid QoS routing protocols have been proposed,such as Bandwidth Routing protocol (BR) and Core Extraction Distributed Ad hoc Routing (CEDAR).

The table-driven and on-demand routing protocols advertise all available routes in the network, but it is not suitable for the large-scale network. Either minimum delay or high bandwidth path is not sufficient to provide better routing performance, and it is necessary to consider a path that satisfies multiple constraints in wireless communication. Thus, the Multi Constraint QoS (MCQoS) [25] combines the path-vector routing that disseminates the path information into the network with a path discovery scheme in an on-demand routing scheme. The path-vector routing computes the routing quality metrics for each available path. Only the dissemination of best path routing information within the local topology greatly reduces the routing overhead. It employs the distributed algorithm to adapt to the dynamic changes in network topology. Each upstream node transmits the data packet to the downstream node ensures multiple link quality metric increases the routing performance. However, the dissemination of QoS requirements to its downstream node increases the path discovery delay.

3.1.2 Geographic based QoS Routing

In geographical routing, each node maintains the location of its neighboring nodes for data transmission. The geographical routing differs from the topology-based routing by using physical location information, and it eliminates the storage of end-to-end route information. The most famous geographical routing is greedy forwarding, and it selects a node that is closer to the destination. Several techniques have been proposed to satisfy the different application requirements, such as bandwidth, delay, and delay jitter for QoS routing. Some of the existing geographic-based QoS routing protocols are Reliable Geographic Routing Protocol (RGRP) and Location - aided Ticket Based Routing (LTBR).

There is a need to consider several QoS metrics into routing [26]. It selects the next hop to reach the destination based on the QoS metric or hop count. However, the selection of shortest paths is not optimal always due to the dynamism in network capacity. It is necessary to select a route that provides the desired bandwidth level for the entire data flow. In geographical routing, the route discovery phase for determining the end-to-end route and the entire route information storageisunnecessary. The location information is used to determine the quality metrics, and it utilizes both the localized and location information for routing decisions.

The QoS-GPSR routing protocol is the extension of GPSR protocol for QoS provisioning [27]. It controls the call admissions by using the cross-layer approach, and it reserves the bandwidth temporarily for available communication routes. The QoS-GPSR protocol includes three routing phases such as path discovery, admission control, and resource reservation, and route repair. In the route discovery phase, it discovers the next hop based on its proximity to the destination with the knowledge of packet error rate. Each node broadcasts the hello packet for exchanging its channel idle time and available bandwidth information. Each node takes the admission control decision based on the available bandwidth information provided by the MAC layer. For admission control, it employs admission requests and admission refuse packets, and a node that receives the admission request is allowed to access the channel if it satisfies the bandwidth requirement. Otherwise, it sendsan admission refuse message to the requester. Thus the new data flow does not affect the QoS provisioning of existing data flows.

3.1.3 QoS Routing based on Layer Interaction

Cross layer-based QoS approach defines the interaction between MAC layer and network layer to the provision of QoS routing. The cross-layer QoS routing approach is divided into MAC-dependent and MAC- independent. In the MAC-dependent approach, the network layer depends on the MAC layer for providing QoS in the network. On the other hand, in MAC- independent QoS approach, the network layer does not require the MAC layer support in the provision of QoS.

MAC- Dependent QoS routing: Several MAC-dependent QoS routing protocols have been proposed in wireless communication. For example, Trigger-based (on-demand) distributed QoS routing (TDR) protocol, Bandwidth Routing protocol (BR), On-demand QoS Routing protocol (OQR), On-demand Link-state Multi-path QoS Routing (OLMQR) protocol, Asynchronous QoS Routing (AQR), Core Extraction Distributed Ad hoc routing (CEDAR), Proactive Real Time MAC protocol (PRTMAC).

To provide an efficient QoS provisioning, Distributed Admission Control for MANET Environments (DACME) [36] architecture combines the probe-based admission control and dynamic source routing. To satisfy the QoS requirements of applications, the admission control on channel access is performed using a probing mechanism. It uses probe packets for measuring link quality metrics instead of measuring the end-to-end path quality. In each probe, the sender node generates and transmits a set of data packets to the destination. At the end of the probe, the destination measures the path quality using link-layer feedback and informs the sender node via reply packets. After receiving the reply packet, the sender node selects another path if it is not desired for QoS provisioning. Instead of disseminating measured link quality metrics into the network, the probing mechanism directly measures the network capacity. The probe measurement provides flexible QoS architecture, and it reduces the traffic due to congestion. The communication delay is high when a frequent link failure occurs due to mobile nodes. The DACME avoids reservation of resources, and so it is suitable for more applications under dynamic network topology.

MAC-Independent QoS Routing: In MAC-independent QoS routing, the network layer is not depending on the MAC layer for QoS provisioning. Some of the MAC-independent QoS routing protocols are Predictive Location-Based QoS Routing Protocol (PLBQR), Quality of Service Ad hoc On-demand Distance Vector (QoS AODV), INtelligent Optimization self Regulated Adjustment (INORA), and Stateless Wireless Ad Hoc Networks (SWAN).

3.1.4 QoS Routing based on Channel Allocation

An efficient channel allocation is important to achieve QoS routing. The QoS provision is achieved not only in the network layer, and it is necessary to allocate the channel for data forwarding among contending nodes in the MAC layer. Based on the channel allocation, several QoS routing protocols have been proposed in MANET. For example, cluster TDMA, Distributed Bandwidth Allocation/Sharing/ Extension (DBASE) protocol, and Real Time MAC (RTMAC).

Cluster TDMA: In cluster TDMA, the cluster formation and cluster head selection are made in a distributed manner. The network nodes are divided into different groups, and the group members elect the cluster head, which acts as a local coordinator. TDMA approach divides the time into several slots for channel access control. The local coordinator controls the transmission power by maintaining the list of power gain of group members. Moreover, the gain list maintenance is used to free slot scheduling and verifying packet drop due to reserved slot failure.

DBASE: The Distributed Bandwidth Allocation/Sharing/Extension (DBASE) protocol attains efficient channel access in an ordered manner by employing the contention-based process. The DBASE approach divides a data frame into three classes based on its priority. The priority-based data forwarding reduces the queuing delay efficiently and improves the routing performance.

3.1.5 QoS Routing Based on Evolutionary Algorithms

The QoS assured MANET applications demand guaranteed data delivery with different QoS constraints such as delay, bandwidth, loss ratio, and delay jitter. The evolutionary algorithm-based QoS routing methods receive high attention in recent years, as they employ computational strategies designed based on natural processes. Some of the evolutionary algorithms are Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), cuckoo search, swarm intelligence algorithm, and genetic algorithm.

HEACO–RF [18]: It is a concurrent heuristic ACO and reliable fuzzy QoS routing protocol proposed for MANETs. For efficient QoS route selection, the HEACO-RF utilizes two phases ACO based route identification and fuzzy logic-based reliable route selection. The deposit of entire candidate routes in between a source and destination are discovered using the modified ACO in the initial phase. The HEACO-RF considers the heuristic and reliability fitness function during route identification. Further, in the second phase, the HEACO-RF uses the fuzzy logic-based link stability, remaining energy, and loss rate metrics for selecting the reliable routes by the ant agents of ACO.

QMAA [19]: It is a QoS mobility-aware ACO routing protocol that utilizes energy metrics and signal strength measurements to find the distance between a pair of source and destination. Further, the QMAA selects the reliable best routing paths among the available routes using the ACO method and maximizes the QoS efficiency of the MANET routing.

MC-QoS [20]: The MC-QoS is the multi-constraint QoS routing method in which the evolutionary algorithm like genetic is used to select a multi-constraint QoS route. The genetic algorithm is a lightweight feasible solution that develops QoS routes based on a cost function. Also, the MC-QoS do not necessitate any hard evolutionary operators and validations, resulting in quick and efficient solution detection within a short time.

SEAL-AODV [21]: In this protocol, the hunting behavior seals-inspired swarm intelligence is used to select efficient routing paths. The SEAL-AODV chooses the routing paths based on multiple metrics such as hop count, the remaining energy level of nodes, and routing load. Moreover, the SEAL-AODV enhances the network throughput and packet delivery reliability with minimum end-to-end delay by employing multiple QoS metrics in route estimation.

GA–QR [22]:A genetic algorithm-based clustering QoS routing protocol proposed for MANET. The clustering of GA-QR is designed based on preference under undisputed constraints. Further, it produces prolonged optimal communication routes with high convergence and neglecting the effects of unstable clusters and frequent route disconnections.

4.Comparative Analysis of MANET QoS Routing Protocols

QoS routing protocol	DACME [28] [2009]	AODV-BR [24] [2008]	BMR [29] [2011]	DACP [30] [2011]	MCQoS [25] [2009]
Author	C. T. Calafate, et al.	Sung-Ju Lee and Mario Gerla	Wenjing YANG, et al.	JooSang Youn, et al.	Amit Mondal, et al.
Objective	To provide QoS provisioning by cooperating different layers	Toimprove on-demand routing, create a mesh and use multiple alternative routes	To propose disjoint parallel paths based on the available bandwidth	To provide QoS assurance using distributed admission control	To provide scalable flow route maintenance using path vector protocol
Type of metric used	Bandwidth and delay jitter	-------	Bandwidth	Bandwidth	Bandwidth
Routing type	MAC-dependent	On-demand	On-demand	On-demand	Hybrid
Advantages	Probing measurement	React fast under dynamic	Improved network	Minimized packet drop	High utilization of network

	provides flexible QoS architecture	network topology	throughput	due to collision	resources
Disadvantages	Probing packets incur high communication delay	Alternative path storage increases the routing overhead	Path discovery delay is increased when a high link failure occurs	High delay due to the 2-hop information identification	Dissemination of QoS requirements to its downstream node increase the path discovery delay
Solved issues	Reducing the traffic due to congestion	Transmission failure due to node mobility	Two parallel paths routing reduces the path overhead	Routing overhead reduction	Minimized communication delay
Unsolved issues	High mobility leads to frequent transmission failure	Duplicate transmission	Less path availability under sparse network	High back-off delay	Availability of efficient paths that satisfies multiple QoS constraints is less
Result	Fast response to the link failure providing better performance	Achieving reliable packet delivery in the face of node movements and route breaks	Efficient throughput under high traffic networks	Accurate estimation scheme for available resources	Scalable QoS flow route management

QoS routing	AAC [31]	PRTMAC [32]	QoS-GPSR [27]	StAC [31]	AQR [14]

protocol	[2007]	[2012]	[2006]	[2007]	[2003]
Author	R.Renesse, et al.	V. Vivek, et al.	Atef Abdrabou and Weihua Zhuang	L.Hanzo and R.Tafazolli	V. Vidhyashankar, B.S. Manoj
Objective	To provide efficient routing under high traffic and high mobility scenarios	To propose a tightly coupled solution for efficient bandwidth utilization	By exploiting position information utilize the advantages of UWB at the network layer	To reduce back off time by focusing colliding nodes	To propose an efficient slot allocation strategy
Type of metric used	Bandwidth	Delay and Throughput	Bandwidth	Bandwidth	Bandwidth
Routing type	MAC-dependent	MAC-dependent	Geographical	MAC-dependent	Channel allocation
Advantages	Reducing QoS violation	Support real-time traffic	Better performance under high traffic network	Minimized delay and packet loss	Provision of end to end resource reservation in asynchronous networks
Disadvantages	Session pausing increases the communication delay	Need a high range of control channel	Link failure reduces the routing performance	High admission time range	High configuration time
Solved issues	Packet drop due to channel collision	Reducing hidden terminal problem	Reduced packet drop due to channel collision	Packet drop due to channel collision	Using sequence number avoids routing loops
Unsolved	Communication	Not considering	Communication	High delay	Bandwidth hole

issues	delay	the power resources	hole	due to the re-initiated session	issues
Result	Bandwidth aware routing provides efficient channel access	Support for real-time applications	Efficiently utilizes the network radio resources	Better results while increasing the data flow rate	Support for delay constrained applications

Table 1: Comparative Analysis of MANET QoS Routing Protocols

5. Conclusion

In this paper, an overview of MANET with its challenges and applications is described. Further, it explains the significance of QoS routing in MANET and the QoS challenges. Consequently, the QoS routing protocols are categorized into five categories that are network topology, geographical information, layer interaction, channel allocation, and evolutionary algorithm-based. Further, each type is explained with some existing works. Finally, the major advantages and limitations of the existing works are explained comparatively. In the future, it is essential to extend the evolutionary algorithms based on MANET QoS routing protocols for realistic MANET multimedia applications with multiple constraints.

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