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Comparative Review of new QoS-Aware Clustering Protocols for Efficient Routing in Mobile Ad-Hoc Networks

Gatete Marcel[1], Dr. A. Kovalan[2]

[1]School of Computer Sciences & Applications, Periyar Maniammai University, Thanjavur, Tamil Nadu, India
[2]Former Associate Professor, Department of Mathematics and Computer Applications, Division of Software Engineering, Periyar Maniammai University, Thanjavur, Tamil Nadu, India

ABSTRACT

Due to the infracrtureless nature of MANETs, some of their fundamental characteristics such as wireless medium, dynamic topology, collision and interference events, decentralized management, and distributed cooperation between nodes always influence its overall performance as various problems such as the Quality of Service provision's degradation, higher error rates, various constraints related to bandwidth, power and applications-related issues are frequently associated with them. To contain all those constraints, various algorithms and protocols have been developed mainly aiming at satisfying the users and applications' requirements in providing high QoS in order to achieve the overall network's performance. Clustering is one approach toward dealing with those MANET's routing-related problems, but due to its unstable nature, it is sometimes difficult for protocols specialized in clustering techniques to divide the network into clusters in conjunction with their Cluster-Head selection criterion. Various clustering mechanism have been proposed in the literature such as **QAMACF** (QoS-Aware transmission for Multimedia applications using Ant Colony with Fuzzy optimization), a protocol implemented based on Ant Colony Optimization and Fuzzy Logic techniques, **GDAQM** (Genetic with DPD for Attaining high QoS in MANETs), a very efficient and robust algorithm which is a combination of both Genetic and MDPD-k scheduling algorithms, **MARMAQS** (Multi-Algorithm Routing Mechanism for Acquiring high Quality of Service in MANET), a routing mechanism very effective in achieving high QoS in term of highly increased transmission's reliability, network's lifetime, packet delivery ratio, throughput, and decreased both end-to-end delay's ratio and routing overhead, **FSR-CAES** (Full-Featured Secure Routing Clustering Algorithm with Energy-Aware and Scheduling capabilities for highly increasing QoS in MANET), an efficient clustering technique which is a combination of numerous algorithms, each one containing one of the previously mentioned problems. All those QoS routing algorithms share almost the same goal; achieving high QoS especially in transmitting multimedia data over MANETs, each one having its own features, enhancements, and achievements. The clustering scheme they use achieves high scalability in the presence of large networks with speedy nodes. As the comparative analysis and evaluation of these protocols has never been conducted; this paper aims to provide a systematic analysis of each QoS protocol by presenting each algorithm's detailed features, their comparative evaluation using various prominent QoS provision techniques is then provided.

Keywords : MANETs, QoS-Aware Routing, Clustering, Multimedia Applications, Comparison.

I. INTRODUCTION

Mobile Ad Hoc Networks (MANETs) are of a great popularity as the wireless communication using mobile devices is of various advantages compared to wired networks, especially for real-time applications. Being infrastructureless, MANETs face various challenges inhibiting the routing protocols to achieve their expected goals. Due to this misbehavior, it is sometimes difficult to achieve high Quality of Service for these types of wireless networks especially for multimedia data transmission such as video, audio, image, photo, etc. This often results in QoS degradation which further causes the reduction of the whole network's performance.

To address this, various routing protocols aiming at providing efficient routing in MANETs have been proposed in the literature [1], but none of them is able to fully provide high QoS especially in transmitting data packets of different types. One of the negative issues prohibiting an increase in OoS provision in this type of ad hoc networks is the network partitioning problem; this issue arises in the fact that MANET's topology is dynamic and composed of mobile nodes which frequently moves out of the range while others unexpectedly join the network and moving from a place to another randomly, thus resulting in a hard-to-manage network with various shambles.

Clustering is one approach toward minimizing those problems as it helps in providing solutions to resource management-related difficulties while achieving the process of partitioning the network into small groups, each one playing a major role as a disjointed cluster [2].

Some more problems shouldn't be neglected by the protocol designers; these are related to the lifetime of nodes as the whole network's performance gradually degrades whenever some nodes are unexpectedly shutdown or restarted due to low battery power; a negative issue which should be taken into consideration while designing a robust routing protocol. The problems inherent to the security breaches incurred in the network is another negative issue frequently arising in MANETs as various intruders may act as normal and authentic nodes and steal or damage some packets passing through them, or cause other network misuses. The fairness during packets transmission should also be taken into consideration using efficient packet scheduling algorithms; this technique accelerates the packet transmission rate and avoids very much some problems associated with the packet routing processes such as collision, delay, routing overhead, and interference. It also alleviate the problems related to packets queuing operations.

Designing and implementing a multi-algorithm QoS-aware protocol capable of transmitting multimedia data and aiming at eliminating those previously mentioned negative issues is challenging but was possible in [2][3] [4] [5]. Our contribution in this paper is to conduct a comparative survey of these multi-algorithm protocols under various angles of evaluation using different routing metrics and parameters, a conclusion is then made.

The remaining parts of this paper are organized as follows: in Section II, the literature survey is discussed. Section III provides the comparison of QoS-aware routing protocols for multimedia applications, and the conclusion is presented in section IV.

II. METHODS AND MATERIAL

Literature Survey

2.1 Clustering

Clustering [5] is one approach toward improving the network management by following some basic rules consisting of partitioning it into different subclasses each one playing the role of a small and manageable cluster composed of a group of nodes according to the geographical areas they are currently located.

Upon completing the network partitioning operations, each cluster's members elect a special node, a Cluster-Head which has the most important role of locally coordinating other cluster's nodes by performing various intra- and inter-cluster operations. This type of node has to bear a high processing speed and energy compared to other mobiles nodes, members of the same cluster.

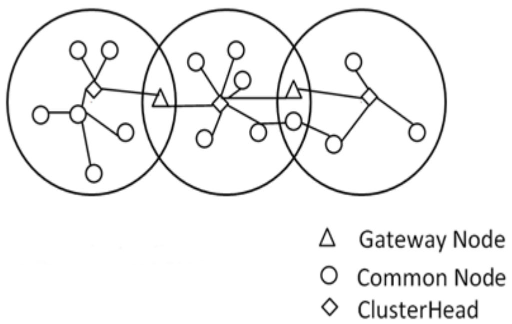

Figure 1. Cluster Architecture

Protocols which are efficient in partitioning the network into clusters i.e. Cluster-based Routing Protocols (CBRP) [5] are often used for increasing the performance of MANETs especially for routing-related issues. These types of protocols are provided with the following features:

- They are efficient in performing fully scattered operations.
- They are able to reduce the flooding traffics.
- This kind of algorithms locally repair the broken routes.
- They mitigate the frequent topological changes in MANETs caused by speedy mobile nodes' behaviors.
- They can stabilize the end-to-end communication paths and maximize the route's lifetime.
- They also improve the network's scalability such that the routing overhead does not become remarkable in large-scale networks.

More advantages are available with this technique, for example, a Cluster-Head is able to record the available paths between different clusters; this is more advantageous than performing the same operation between nodes resulting in both network's capacity and routes' lifetime increase at the same time decreasing the routing overhead's ratio.

In spite of relying on inter-node communication, all of the cluster's member communicate with the Cluster-Head which in turn, may communicate with its mates, Cluster-Heads located in the neighbourhood through the gateway node, this decreases very much the unnecessary traffic flows.

The following are different types of mobile nodes, members of a cluster:

2.1.1. Cluster-Head

It is a node elected by the other nodes in order to perform intra- and inter-cluster communications, it is a special node as it is a good coordinator which performs the resource management operations for the entire cluster, thus, working as its base station.

2.1.2. Gateway Node

A gateway node is another important node situated in between two or more clusters and perform inter-cluster communications as it talks to the Cluster-Head of one cluster and relays the information to the gateway node of another cluster which in turn, forwards the information to its Cluster-Head. Doing so, it acts as a distributed or common access point between two Cluster-Heads of different clusters. This kind of node can be of two types:

a) Ordinary or normal gateway node

This kind of node is located in between two Cluster-Heads at the one-hop neighborhood of each and acts as an intercessor for them during their communication.

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b) Distributed gateway node

To be a distributed gateway, a node has to be located in the one-hop neighborhood of a Cluster-Head and connected to another node, a direct neighbor of another Cluster-Head so that the two clusters are communicating through those two gateway nodes.

2.1.3. Ordinary node

These are normal nodes with a direct connection to the Cluster-Head i.e. they are members of the cluster and take part in both the cluster and topology formation processes. These nodes can be either elected as Cluster-Head or gateways according to the selection criteria and requirements.

2.1.4. Cluster control architecture

Two types of cluster control architectures exist, the one-hop and d-hop; their difference exists in the diameter of the cluster wherein one-hop control architecture, every ordinary node is allowed to stay at one-hop distance of its Cluster-Head while in d-hop, the distribution of an ordinary node has to be grater or equal to one-hop with a maximum of d-hop distance from the local coordinator.

2.1.5. Structure of a cluster

Flat structure and hierarchical structures are the two forms of a cluster. In the flat structure, each and every node has an equal responsibility to perform a task. One problem here, is the routing overhead incurred in the network due to the flooding of data packets in large networks, this is not the case for small networks as it works very fine with them. With the hierarchical structure, the difference is that nodes are assigned different tasks and divided to act efficiently, here, the gateway node is responsible for intra- and inter-cluster communication while the Cluster-Head is dedicated to the central coordination operations.

2.2 Energy

Energy model [3] is another important feature to be taken into consideration while designing a robust routing protocol. It measures the level of the energy of each node in the network which helps in predicting its lifetime. A node has an initial energy *initialEnergy_* at the beginning of the simulation or during the topology creation and it is passed as an input parameter.

As the node receives or sends a data packet, it loses some energy which causes the value of *initialEnergy_* to proportionally decrease, the variable *energy_* contains the level of each node's energy at a specified time during the simulation. The energy consumed at any point of time can be then calculated by subtracting the *initialEnergy_* from the *energy_* variable.

When the current power's level of any node becomes zero, it can no more receive nor send packets. The overall energy level of the network can be estimated by summing up all current energy levels of all nodes available in the network. When it is low, the network's lifetime is decreased, causing the whole MANET to be unexpectedly shutdown. The network performance is very much affected by such events. Power-aware routing protocols are designed in such a way to contain this misbehavior by regularly taking into account each node and link's lifetime, thus increasing the whole network's lifetime.

2.3 malicious Node Detection

A malicious node is any type of intruder or unreliable node which participates in the overall operations of MANETs and my steal, damage, or launch gray hole attacks in the network or may perform some network misuse operations. These type of nodes cause the security breach in the network and should be regularly detected and prohibited to join the network. Cooperative Bait Detection Scheme (CBDS) [6] mainly aims at detecting and preventing malicious nodes from launching gray hole/collaborative black hole attacks in MANETs, for example, to deal with the malicious nodes' problem in [5], a cryptography-based secure technique was used. With this technique, the source node chooses an adjacent node and uses it as a bait destination address thanks to which the malicious node will be detected and caught when it sends back a suspicious RREP message to the sender. The reverse tracing mechanism is then used to both detect and disallow any malicious node from participating in the routing operations. This scheme combines both proactive detection from the source node and a reactive response at the subsequent steps in order to reduce the resource wastage. With this scenario, the source node is able to identify all nodes located at the selected path toward the destination. But it is not always the case, as sometimes for the source node, it may not be always necessary to be able to identify which intermediate node has the information to the destination, has an RREP message, or is the malicious one.

In this case, the source node may send its packets along the chosen fake shortest path which then results in a black hole attack events' occurrence. To solve this issue, CBDS algorithm is enhanced by extending it with an additional feature i.e. the function with a HELLO message which is efficient in helping each node to identifying adjacent nodes located in one hop by proactively sending a bait message having the bait address to entice the malicious node, a reverse tracing program is then used to detect their exact locations. Here, the destination addresses are used as the bait addresses.

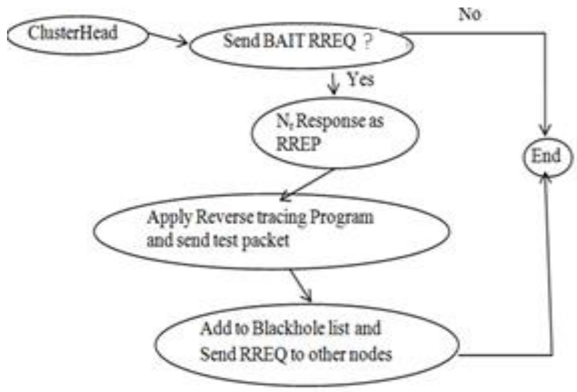

Figure 2. Malicious node detection in a cluster

2.4 Routing

The route discovery process [5] is necessary for the first time when a sender node needs to initiate the transmission process of a packet and selects the best alternative path when the current route to the destination fails or breaks. For both cases, the selected paths must be able to extend the route's overall lifetime based on the distance between the neighboring nodes and their respective velocities.

During this process, the sender initiates the route discovery process by broadcasting the RREQ. The Entry Expiration Time; a part of the RREQ packet allows maintaining the route for some period of time. When a route breakage occurs, the source node updates its routing table, and resends the RREQ for initiating the recovery process.

During the routing process, the clustering algorithm calculates the residual energy of each and every node by using the one that was used in Cluster-Head election process. The Cluster-Head updates its table with the new data obtained. This information concerns the hops between nodes, the available paths, the distance between them, the energy, etc. It is then used to select the best path to route packets trough toward the destination, the best path means the link with lesser hop counts, shorter distance to the destination, and with higher residual energy. With this technique, the transmission is very much enhanced, thus, resulting in the overall network performance.

2.5 Scheduling

Packet scheduling mechanisms [7] are very prominent algorithms in MANETs which ensure that the provision of QoS is guaranteed. These types of algorithms manage the queuing dynamics in the various situation in Internet and multimedia applications. These guarantee are sometimes in the form of delay and jitter, fairness and rate among various packet transmission sessions. The main objective of these algorithms is to provide a fairness scheme efficient in determining the order with which packets are transmitted in the network. The rate of the data transmission, the queue management, and the packet scheduling technique are all here considered. The fairness in the transport layer flow is analyzed.

A suitable scheduling algorithm is used for processing the queued packet; the design aspect of the scheduling algorithm plays an important role in determining an end-to-end bandwidth of the flow of the respective packet which is equally shared among all the competing flows. It does not only provide the per node fairness in rate but also achieve per-flow fairness in rate based on the transport protocol [5]. The following are different packet scheduling algorithms:

2.5.1. First-In-First-Out (FIFO) Scheduling Algorithm

With FIFO queuing algorithm, there is a single queue where packets are placed, with this scheme, the first coming packet is the first processed and transmitted. This mechanism is the most used queuing algorithm.

Advantages

- ✓ This queuing policy requires a very low computational load.
- ✓ The behavior of a FIFO queue is predictable – the maximum delay is calculated by the maximum depth of the Queue

Disadvantages

- ✓ It is not easy to provide different services to dissimilar packet traffic classes as long as all packets are stored into a single queue. Another issue arises when the entire buffer is occupied by a burst of flow prohibiting other flows to be served until the buffer is freed.

2.5.2. Priority Queuing Algorithm

This method is efficient for differentiated service classes as it sets priorities to various incoming packets while placing them in the queue. The packets with high priority are processed first while the ones with the low priority are served last.

Advantages

- ✓ This algorithm supports differentiated service classes and requires more elaborate queue scheduling mechanism.

Disadvantages

- ✓ There is unfair between packets with low-priority and the ones with the high-priority when there is an excessive high-priority flow as the packets with lower priority are not processed.

2.5.3. Weighted Fair Queuing (WFQ) Algorithm

This algorithm uses a Processor Sharing System (PS) to support flows with different bandwidth where it assigns each queue different weights relating to the allocated output port's bandwidth. The process is as follows:

All the incoming packets are stored in a queue for their respective flows and additionally stamped with a finish-time, the WFQ scheduler selects different packets with the smallest finish-time. The chosen packets will be transmitted next on the output port.

Benefits

- ✓ This type of algorithm protects each and every service class by providing a guarantee of the lowest level of the bandwidth of the output port, this is done independently to the activities of the other classes.

Drawback

- ✓ The problem with this scheme is that this kind of user-defined classes is not able to help in queuing the traffic and WFQ can never provide some definite bandwidth guarantees to a traffic flow.

2.5.4. Class-Based Weighted Fair Queuing (CBWFQ) Algorithm

CBWFQ provides some extended features to its original Weighted Fair Queuing (WFQ) functionalities and it is efficient in affording the support for different user-defined traffic classes. It describes different traffic classes based on match criteria such as protocols, access control lists, and input interfaces.

The traffic for a class is made by packets bearing the match criteria for a class. A queue is formed for each class and a traffic belonging to the said class is directed to its corresponding queue. In order to successfully ensure that the class queue is fairly serviced, CBWFQ uses the weights assigned to the queued packets [7].

Benefits

- ✓ The bandwidth to be assigned to each traffic class is exactly mentioned. As it allows the access control lists and protocols to define traffic classification, it is able to regularly provide coarser granularity.

Drawbacks

- ✓ One major problem is that there is exist no rigorous priority-queue for real-time traffic, VoIP, for example, to alleviate latency.

2.5.5. Low Latency Queuing (LLQ) Algorithm

This kind of algorithm is efficient in facilitating the single priority queue's usage where some individual classes of traffic can be stored.
The rigorous priority queuing mechanism with LLQ algorithm often allows delay-sensitive traffic, a voice, for example, to be firstly processed prior to any packet type existing in another queue. [8]

2.6 Multimedia Application

Multimedia applications [9] as the name suggests are those types of networks in which different kind of information can be relayed from one end to another. The data transmitted can be of any type such as audio, video, image, photo, text, etc. Multimedia applications exhibit some special features compared to ordinal data transmission operations which do not require so manyf techniques to take care of the information relay from source to destination. The video streaming is an example of such applications which is characterized by three main characteristics:

a) High-bandwidth requirements
b) Delay-constraint applications with
c) Tolerance to small packet losses (usually less than 1%).

One major challenge concerns the guarantee provision about which level of QoS one can provide to the end-users, this is one of the reasons why rigorous protocols are required in order to achieve high QoS provision in MANETs for this type of applications. To achieve this, nowadays, new routing protocols have been designed and implemented aiming at increasing the transmission rates of the existing wireless media.

The IEEE 802.11e for example which has been designed provided with QoS-aware features is implemented on MAC chipsets of various vendors. These achievements have been of a great importance as the protocols designers were able to create a wireless environment in which multimedia data are transmitted at higher bit rates at a longer distance while meeting the QoS criteria posed by applications with delay constraints and jitter.

2.6.1. Multimedia Transmission in MANETs

Since the times when the bandwidth of wireless channels and radio have been increased proportional to the augmentation of the computational power of mobile devices, multimedia data transmission operations has been very appealing. Even if the enhancements in multimedia data transmission have been successful, MANETs are still facing various challenges due to the topological dynamicity, transmission errors, node and link breakage and failure, the problem of energy constraints, network misuses by malicious nodes, network partitioning related problems, multicasting storms, multi-path and multi-hop routing, queuing scheme, etc. Three attributes characterize multimedia applications namely the demand for high data transmission rate (high-bandwidth-consuming applications), the sensitiveness to packet delays (latency and jitter), and the tolerance to packet losses (packet-loss tolerant applications). Technical issues and challenges arise from the previous properties which should be addressed and some additional mechanism should be provided aiming at improving multimedia data transmission in MANETs.

Such mechanisms may include:

- Priority of multimedia packets against other ordinary data packets.
- Implementation of congestion, interference, and flow control mechanisms for the multimedia applications.
- Enhancements of the routing operations with additional wireless medium-related metrics in order to improve the multimedia transmission's performance.

2.7 Multicast Features

Multicasting [13] is the transmission of data packets to a group of zero or more nodes identified by a single destination node i.e. the packets have to pass from source to destination traversing a group of nodes acting as intermediate hosts. The rules are as follows, there is a regular dynamicity for the member of the group changes meaning that a host can join or leave the network at any time without restriction. Nodes, members of the group can be located anywhere in the allowed group's vicinity and can be any number. The member of the group can be shared with other groups i.e. it can participate in a different group at the same time and it is not necessary for it to be the member of the group in order a packet is sent to it.

Multicast routing in MANETs poses various challenges due to inherent properties of the network such as wireless links, decentralized management, infrastructureless nature, node mobility, low reliability, and scarce resources, etc.

Currently, two types of multicast routing protocols exist in the literature for wireless networks namely tree-based and mesh-based multicasting routing protocols. In tree-based multicasting algorithms, for dynamic networks, a frequent reconfiguration is needed, thus, resulting in instability of the network.

Here, a tree-like data forwarding path is constructed which is rooted at the source of the multicast session. The multicast tree is composed of a unique path from the multicast source to each of the multicast receivers. Two example of such protocols is Multicast extension for Ad-Hoc On-Demand Distance Vector (MAODV) and Adaptive Demand- Driven Multicast Routing protocol (ADMR). Mesh-based multicasting routing protocols are those algorithms where different paths may exist between source and destination nodes which are intended to enrich the connectivity among group members for better resilience against topology changes.

On-Demand Multicast Routing Protocol (ODMRP) and Core-Assisted Mesh Protocol (CAMP), are the examples of this type of algorithms. The multicast routing protocols are of a great importance in the wireless network as for example emergency searches, rescue situations, military battlefields, web-based learning, video conference, and interactive multimedia games require this type of protocols while rapidly and urgently sharing information, as they provide rapidly deployable and quick reconfiguration networks.

2.8 Qos-Aware Routing Protocols Classification

QoS-aware routing algorithms in MANETs are classified differently, they are firstly classified by the network topology (flat, hierarchical, and hybrid), secondly by using different methods while solving the QoS-related issues (ticket-based probing, predictive, and more node's state information). The third classification is about the route discovery methodology, with which those protocols are classified as proactive, reactive, and hybrid. Moreover, another classification concerns the interaction with the MAC layer where they are categorized as independent or dependent while taking into account the QoS requirements. The later classification concerns the delay, bandwidth, security, energy, etc.

III. RESULTS AND DISCUSSION

COMPARISON OF QOS-AWARE ROUTING PROTOCOLS

3.1. New QoS-aware routing protocols for multimedia transmission

We next conduct a comparative study of newly designed robust QoS-aware routing mechanisms able to increase the overall performance of MANETs.

3.1.1. QAMACF: QoS

Aware transmission for **M**ultimedia applications using **A**nt **C**olony with **F**uzzy optimization [2]

QAMACF is implemented based on Ant Colony Optimization and Fuzzy Logic techniques, this protocol is a combination of multiple prominent techniques, and it is efficient in routing ordinal and multimedia data packets even in highly dynamic MANETs as opposed to the conventional routing protocols.

3.1.2. GDAQM

Genetic with **D**PD for **A**ttaining high **Q**oS in **M**ANETs [3] GDAQM is a very efficient and robust algorithm which is a combination of both Genetic and MDPD-k scheduling algorithms. The Genetic Algorithm which is an energy-efficient mechanism mainly aims at finding out an optimal path which is then selected by considering multiple QoS constraints, it is efficient in solving QoS-multicast related routing problems, and the MDPD-k is used for packet scheduling purposes.

3.1.3. MARMAQS

Multi-Algorithm Routing Mechanism for Acquiring high Quality of Service in MANET [4]

This routing mechanism is very efficient in achieving high QoS in term of highly increased transmission's reliability, network's lifetime, packet delivery ratio, throughput, and decreased both end-to-end delay's ratio and routing overhead. It is a compound protocol consisting of various QoS related techniques namely Lifetime Remainder Routing mechanism, packet scheduling scheme, and the intrusion detection algorithm.

3.1.4. FSR-CAES

Full-Featured Secure Routing Clustering Algorithm with Energy-Aware and Scheduling capabilities for highly QoS in MANET [5]

This protocol is an efficient clustering technique which is a combination of numerous algorithms, each one containing one of the problems causing MANET's overall performance by degrading its Quality of Service. Those problems are related to routing, power, scheduling, network partition and intrusion or network misuse, etc. It increases very much the MANETs' overall performance.

3.2. Comparison of QoS-aware routing protocols for multimedia applications

Table 1 provides the comparative outcomes of the new QoS-aware routing protocols obtained using prominent techniques which have been popular thanks to their regular contribution in increasing the QoS of MANETS; QoS Metrics, Multicast Features, Multimedia applications, Energy-Aware Routing, Intrusion detection, Clustering technique, Packet Scheduling. As we can see, all protocols almost provide the same enhancements with a minor difference as each one does not include all of the features; one can find some features in one protocol which have not been considered in the other protocol. A full-featured protocol would be more productive.

Table 1. Comparison of QoS-aware routing protocol for multimedia applications

Routing algorithms	**QoS Metrics**	**Multicast Features**	**Multimedia applications**	**Energy-Aware Routing**	**Intrusion detection**	**Clustering technique**	**Packet Scheduling**
QAMACF	Yes	Yes	Yes	Yes	No	Yes	Yes
GDAQM	Yes	Yes	Yes	Yes	No	Yes	Yes
MARMAQS	Yes	No	Yes	Yes	Yes	No	Yes
FSR-CAES	Yes	No	Yes	Yes	Yes	Yes	Yes

IV. CONCLUSION

In this paper, we have conducted a comparative review of new QoS-Aware clustering protocols for efficient routing in Mobile Ad-Hoc Networks. Increasing the Quality of Service in MANETs is the most prominent features which every protocol designer should take into consideration while implementing a robust routing protocol otherwise the QoS provision would be compromised. Even if it is not easy but providing QoS guarantees has become an essential feature for the operation of multimedia applications. We presented a survey of four QoS-aware routing protocols for MANETs namely QAMACF, GDAQM, MARMAQS, FSR-CAES. Those protocols share the same goal of providing high QoS in MANET but they have different features which make a protocol better or not compared to another. We compared these routing protocols in terms of various QoS techniques such as QoS Metrics, Multicast features, Multimedia Applications, Energy-Aware Routing, Intrusion detection, Clustering techniques, and Packet Scheduling. A detailed and comprehensive comparison table is also provided for better understanding of QoS provision in MANETs for transmitting multimedia data. We recommend future research in this field to further enhance those new QoS-aware protocols with some additional features or design new more robust protocols each one provided with all of the seven features; this will increase very much the QoS guarantee resulting in efficient transmission of data for multimedia applications in MANETs.

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