Comparative Study of New QoS-Aware Routing Schemes for Multimedia Applications in MANET

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Abstract: **Due to the complexity of real-time multimedia applications in MANET, various problems inherent to QoS provision inhibit the successful transmission of multimedia data. A major problem is related to the unpartitioned network which makes the network hard-manageable. The energy constraints are challenges faced as some nodes are dead due to their low battery power. Storm problems are related to the broadcasting nature of some routing protocols. Other major problems relate to the fairness and security issues often neglected during data transmission. To address those problems, various robust QoS routing, multi-algorithm mechanisms have recently been proposed, each one being a mixture of important QoS provision techniques namely Ant Colony with Fuzzy Optimization Techniques, Genetic Algorithms, Multicast Techniques, Power-Aware Routing Schemes, Clustering Mechanisms, Intrusion Detection Techniques, and Packet Scheduling Schemes. QAMACF (QoS-Aware transmission for Multimedia applications using Ant Colony with Fuzzy optimization) is a prominent QoS protocol which is a combination of multicast techniques and ant colony with fuzzy optimization mechanisms. GDAQM (Genetic with DPD for Attaining high QoS in MANETs) is a made of both Genetic and MDPD-k scheduling algorithms. MARMAQS (Multi-Algorithm Routing Mechanism for Acquiring high Quality of Service in MANET) consists of QoS techniques namely lifetime prediction routing, packet scheduling, and the intrusion detection schemes. FSR-CAES (Full-Featured Secure Routing Clustering Algorithm with Energy-Aware and Scheduling capabilities for highly increasing QoS in MANET) is composed of numerous algorithms, each one containing one of the previously mentioned problems. In this study, using the NS-2 simulator, a comparative evaluation of the above-mentioned protocols is conducted, each scheme performed well for some experimentations and outperformed during others, hence, it was proved these QoS protocols are well suited for real-time multimedia applications.**

Keywords: *Comparison, MANETs, Multimedia Applications, QoS Protocols.*

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 multimedia applications. Being infrastructureless wireless networks, MANETs face various challenges preventing the QoS routing protocols to attain their expected QoS- provisioning 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, animated video, audio, image, photo, etc. This often results in QoS degradation which further causes the reduction of the whole network performance.

To address this, various routing protocols aiming at providing efficient routing in MANETs have been proposed in the literature (Kaur, 2015). However, none of them is able to provide high QoS especially in transmitting data packets of different types. One of the negative issues prohibiting an increase in QoS provision in this type of ad hoc network is the network partitioning problem; this issue arises due to the fact that MANET topology is dynamic and composed of mobile nodes which frequently move out of the range while others unexpectedly joining the network and moving from one place to another randomly, thus, resulting in a hard-to-manage network with various shambles. Clustering is used to minimize such problems by dealing with the resource management-related problems by partitioning the network into small manageable and independent groups of nodes, each being a disjoint cluster.

Some other problems related to the lifetime of nodes should not be neglected by the protocol designers as the whole network performance gradually degrades whenever some nodes are unexpectedly shut down or restarted due to low battery power.

Another problem concerns different types of network intruders which usually act as authentic and normal nodes and cause security breaches in MANET such as stealing or damaging some packets passing through the network or cause other network misuses. The fairness during packet transmission should also be taken into consideration using efficient packet scheduling algorithms which accelerate the packet transmission rate and avoids problems associated with the packet routing processes such as collision, delay, routing overhead, and interference. They also alleviate various problems relating to packet queuing operations.

Those previously mentioned challenges can be eliminated by a multi-algorithm QoS-routing protocol capable of transmitting different types of data. Designing and implementing such kinds of a protocol is sometimes challenging. In the research works conducted by (Marcel and Vetrivelan, 2015; Marcel and Vetrivelan, 2016; Marcel and Kovalan, 2016), to provide a high Quality of Service in MANET, various QoS mechanisms have been proposed namely QAMACF (QoS-Aware transmission for Multimedia applications using Ant Colony with Fuzzy optimization), GDAQM (Genetic with DPD for Attaining high QoS in MANETs), MARMAQS (Multi-Algorithm Routing Mechanism for Acquiring high Quality of Service in MANET), and FSR-CAES (Full-Featured Secure Routing Clustering Algorithm with Energy-Aware and Scheduling capabilities for highly increasing QoS in MANET). All those newly designed QoS-routing protocols mainly aim at providing high QoS in MANET during multimedia data transmission, each one has its own enhancements and features.

This research study aims to provide a comparative evaluation of those protocols using various prominent QoS provisioning techniques i.e. power-aware routing algorithms, clustering mechanisms, multicasting features, packet scheduling techniques, multipath routing mechanism, and intrusion detection schemes. Different QoS evaluating parameters are also used; such metrics are the packet delivery ratio, end-to-end delay, throughput, routing overhead, energy, route reliability, normalized routing load, and packet loss ratio.

The remaining part of this paper is organized as follows: in Section II, the literature survey is discussed. The comparison of new QoS routing protocols for multimedia applications is provided in Section III. Results are discussed in section IV, and the conclusion is presented in Section V.

II. LITERATURE SURVEY

2.1. Clustering

Clustering is a network management operation which consists of partitioning the network into different small subclasses or clusters, each one composed by a number of nodes located in the same geographical areas.

Once the network clustering operations are over, nodes, members of each cluster elect a special node, a Cluster-Head. This node plays a major role in locally coordinating other cluster members by carrying out different intra- and inter-cluster relevant operations. Compared to other nodes of the same cluster, a Cluster-Head node has to bear both high processing speed and energy.

Protocols which are efficient in partitioning the network into clusters i.e. Cluster-Based Routing Protocols (CBRP) are often used for increasing the performance of MANETs especially in fighting various routing-related issues (Marcel and Kovalan, 2016).

2.2. Energy

The energy model 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. Either at the beginning of the simulation or during the network topology creation, a node bears an initial energy termed as *initialEnergy_* which is then passed as an input parameter. This variable's value decreases whenever a node either sends or receives a data packet as some energy is lost as long as one of those events occurs. At a specific time during the simulation, the variable *energy_* contains the relevant level of each node's energy. So, the energy consumed at that time is then calculated by subtracting the *initialEnergy_* from the *energy_* variable.

When the current power 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 lifetime is decreased, causing the whole MANET to be unexpectedly shut down. 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 lifetime, thus increasing the whole network lifetime (Marcel and Vetrivelan, 2015).

2.3. Malicious Node Detection

A malicious node is any network intruder which disguises itself and act as a normal node and may participate in the overall operations of MANETs. Such nodes may launch gray hole attacks in the network, damage or steal various packets passing through the network. To avoid such network misuses, these kinds of nodes should be regularly detected and prevented from joining the network.

Cooperative Bait Detection Scheme (CBDS) discussed by Jian-Ming et al. (2015) mainly aims at detecting and preventing malicious nodes from launching gray hole/collaborative black hole attacks in MANET. Some more research studies have been conducted, for example, to deal with the malicious nodes problem, Marcel and Kovalan (2016) used a cryptography-based secure technique.

2.4. Routing

The route discovery process 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 overall lifetime based on the distance between the neighboring nodes and their respective velocities (Marcel and Kovalan, 2016).

2.5. Packets Scheduling

Semeria (2001) stated that packet scheduling mechanisms are very prominent algorithms in MANETs which ensure that the provision of QoS is guaranteed. These types of algorithms manage the queuing dynamics in various situations in Internet and multimedia applications. Such guarantees are usually provided in the form delay and jitter, rate and fairness among various data packet transmission sessions. The main objective of these algorithms is to provide a fairness scheme efficient in determining the order in which packets are transmitted in the network. The rate of data transmission, queue management, and packet scheduling techniques are all here considered. In such situations, the fairness in the transport layer flow has to be analyzed.

A suitable scheduling algorithm is always used for processing the queued packets; 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 provides both per-node fairness and per-flow fairness in rate based on the transport protocol in use (Marcel and Kovalan, 2016).

2.6. Multimedia Applications

Multimedia applications 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. Transmitting multimedia data differ from ordinal data transmission as multimedia applications exhibit some distinctive features. The later type of transmission does not need special techniques to take care of information relay from one end to another (Yasin et al. (2013).

2.7. Multicast Features

Jain and Agrawal (2014) discussed multicasting and stated that this technique consists of transmitting 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 vicinity and can be of any number. A 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.

III. 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: **Q**oS-**A**ware transmission for **M**ultimedia applications using **A**nt **C**olony with **F**uzzy optimization (Marcel and Vetrivelan, 2015)

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: **G**enetic with **D**PD for **A**ttaining high **Q**oS in **M**ANETs (Marcel and Vetrivelan, 2015)

GDAQM is an efficient QoS-routing protocol 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 capable of solving multicast-related routing issues, and the MDPD-k is used for packet scheduling purposes.

3.1.3 MARMAQS: Multi-**A**lgorithm **R**outing **M**echanism for **A**cquiring high **Q**uality of **S**ervice in MANET (Marcel and Vetrivelan, 2016)

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

3.1.4. FSR-CAES: **F**ull-Featured **S**ecure **R**outing **C**lustering **A**lgorithm with **E**nergy-**A**ware and **S**cheduling capabilities for highly increasing QoS in MANET (Marcel and Kovalan, 2016)

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

Table 1: Comparison of QoS-aware routing protocols 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. RESULTS AND DISCUSSION

4.1 Simulation environment

The comparative experiments are conducted using the NS-2 simulator. The simulation environment is created with the NS-2.35 version on Ubuntu 14.10 platform to study the performance of the new QoS routing protocols. While oTcl is used as the front-end language, the C++ is used on the back-end side.

The maximum number of nodes is set to 20 mobile nodes, each one with the transmission range of 250m. The nodes randomly move from one place to another within the simulation area whose topology size is set to 1500m * 1500m. The Constant Bit Rate (CBR) is used for the appropriate traffic management in MANETs during the packet transmission process as well as for TCP traffics, and the nominal bit-rate is set to 2 Mb/s. Each packet size is 512 bytes, and the network interface queue size for routing data packets is set to 40 packets for all the four scenarios. The IEEE 802.11 for wireless LANs is used at the MAC layer with Two-Ray Ground propagation model. A random waypoint model is used to model movements of nodes which move with a speed uniformly distributed in the range between 1 and 30m/s. Both omnidirectional antenna and error-free wireless channel models are used.

Table 2: Simulation parameters and values

Simulation Parameters	Values
Simulator	Network Simulator 2
Topology Size	1500m*1500m
Number of Networks & their Size	5, 10, 15, 20
Interface Type	Phy/WirelessPhy
Queue Length	40 Nodes
Transmission Range	250m
Channel	Wireless Channel
MAC Type	IEEE 802.11
Queue Type	Queue/DropTail/PriQueue
Size of Packet	512
Nominal Bit Rate	2mbps
Antenna Type	Omni Antenna
Propagation Type	TwoRayGround
Nodes Mobility Speed	1…30m/s
Traffic	CBR

4.2 Routing Load

As observed in Figure 1, the four protocols which have recently been proposed namely QAMACF, GDAQM, MARMAQS, and FSR-CAES are compared using the routing load as an evaluating parameter metric. All the protocols always perform well as their normalized routing load is not affected significantly when the number of nodes is increased. A slight augmentation of the routing load occurs almost in the same fashion as the network size grow. When the number of nodes is set to 20, QAMACF's routing load gradually increases and attains as high as 40 but immediately dropping to 6, when the number of nodes is 10.

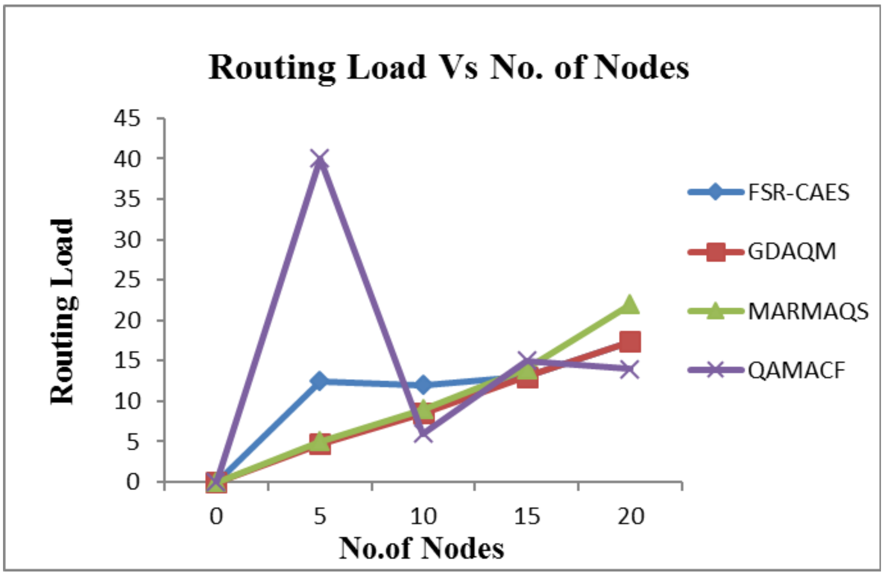

Figure 1: Comparative results of the new schemes using routing load

4.3 Throughput

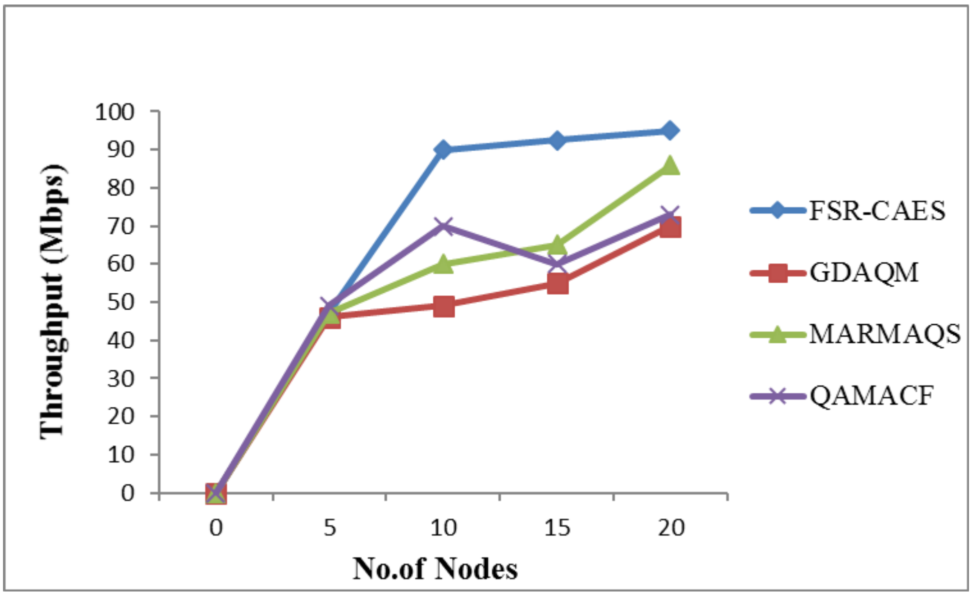

Figure 2: Comparative results of the new schemes using Throughput

In Figure 2, the outcomes of the comparative evaluations of FSR-CAES, GDAQM, MARMAQS, and QAMACF are presented. FSR-CAES slightly outperforms other routing protocols as its throughput almost and progressively increases with the increase in the number of nodes; this is due to the fact that it partitioned the network into various clusters, each headed by a cluster head which controlled the whole cluster resulting in higher levels of availability, reliability, and stability, thereby maximizing the throughput of the network. An overall observation for all the protocols is that their throughputs gradually increases when the network size changes which means that the network size does not affect the throughput of the protocols very much.

4.4 Reliability

As seen in Figure 3, MARMAQS is exhibiting an excellent behavior as it maintains a higher reliability than FSR-CAES, GDAQM, and QAMACF. FSR-CAS does not perform very well as its routing reliability is maintained at lower levels for the overall simulation time. When the number of nodes ranges between 0 node and 5 nodes, the routing reliability ratios of GDAQM, MARMAQS, and QAMACF are almost the same and start to differ slightly as the number of nodes is increased. One interesting revelation about all the protocols is that they exhibit good behavior as their route reliability ratios continue increasing even when the number of nodes changes; this is due to the fact that those protocols select reliable routes during the packet transmission processes.

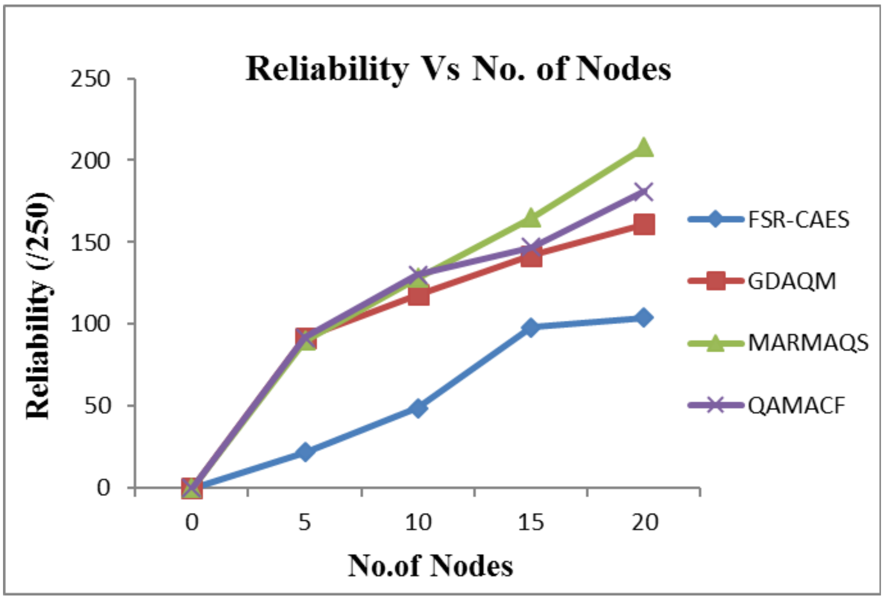

Figure 3: Comparative results of the new schemes using reliability

4.5 Packet Delivery Ratio (PDR)

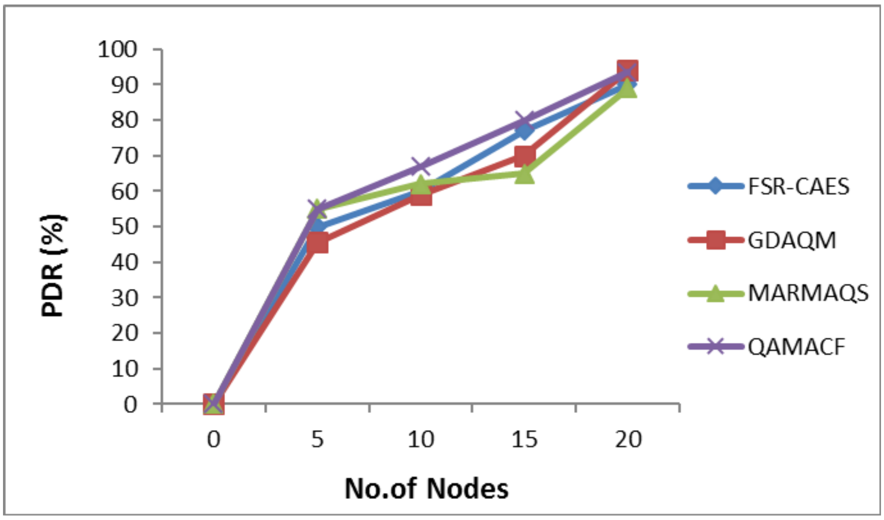

Figure 4: Comparative results of the new schemes using PDR

The routing protocol in MANETs must ensure that the packet delivery ratio is maintained at a high level. In figure 4, one can observe an interesting case, where all the four protocols perform very well as their PDRs are almost identical for all network sizes. QAMACF's PDR remains slightly higher with a minor difference to other protocols' during the overall simulation time. The four protocols are successfully capable of transferring a large number of packets to the destination which means a small number of packets have been dropped during their transmission process. Another observation is about the PDR which almost and progressively increases proportionally to the number of nodes.

4.6 Packet Loss

In Figure 5, the comparative analysis of the new schemes is presented by exhibiting the packets lost during their transmission. This is another interesting case as all the four protocols minimize the packets lost during multimedia data transfer and their packet loss ratios neither increase nor decrease very much. FSR-CAES outperforms other protocols as its packet loss ratio is lower for the overall simulation time. When the number of nodes is set to 20, the packet loss of FSR-CAES begins to go down and to null.

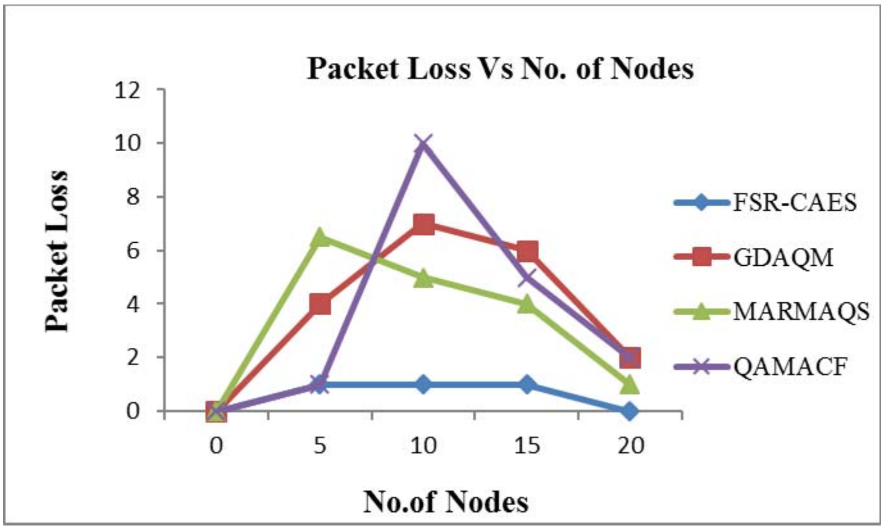

Figure 5: Comparative results of the new schemes using packet loss

4.7 Overhead

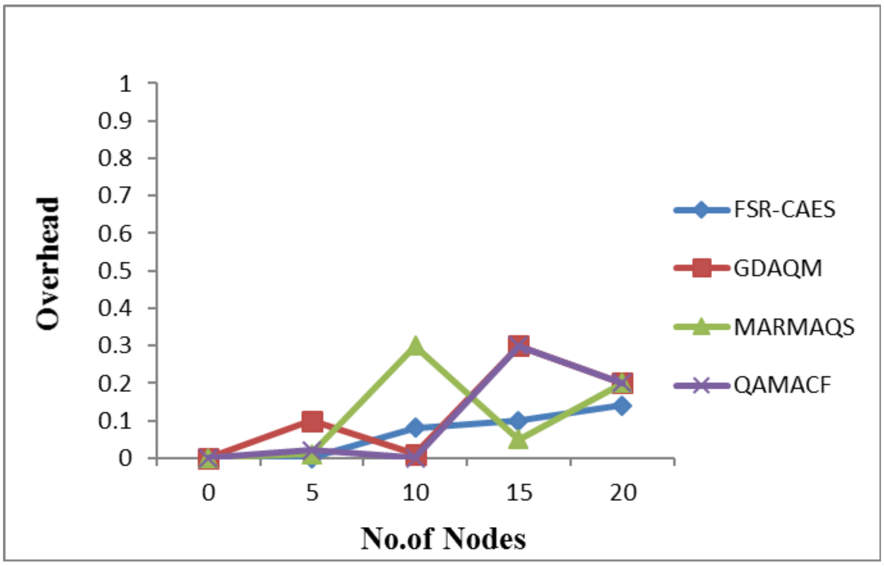

Figure 6: Comparative results of the new schemes using routing overhead

Figure 6 presents the comparative results of the new protocols using the routing overhead as an evaluating parameter. FSR-CAES incurs low overhead compared to the other three protocols. The outperformance of FSR-CAES in minimizing the overhead is possible due to the clustering technique which lowered the amount of routing overhead incurred in the network. GDAQM, MARMAQS, and QAMACF perform well and almost in the same fashion, their routing overheads shapes are in crisscross patterns.

4.8 Energy

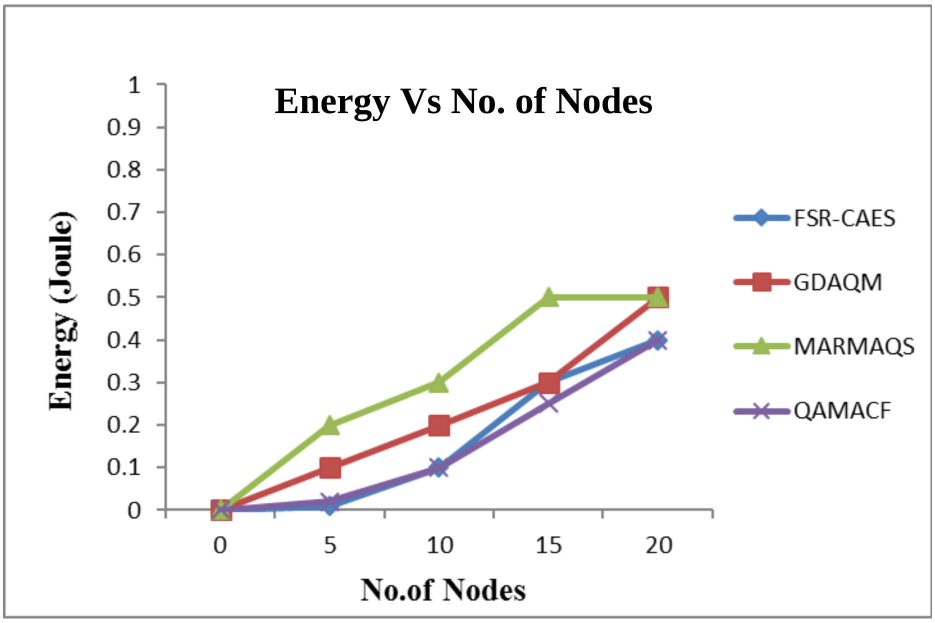

Figure7: Comparative results of the new schemes using energy

In MANET, all nodes such as source, destination, and intermediate nodes situated along a specific path should have high energy all the time for their uninterrupted services. If the energy is lower for any node in the network, for example, an intermediate node, the node will be shut down sooner resulting in the path break which may cause path fails and packets will be immediately lost. This will affect the whole network and degrade its performance. In Figure 7, FSR-CAES and QAMACF manage well the energy consumption during multimedia data transmission processes. MARMAQS and GDAQM work mediumly as an average energy was consumed by the nodes. As an overall observation for all protocols when the number of nodes is increased, the energies consumed during packet transmission operations slightly increase too.

4.9 Delay

Higher throughput and less value of delay will improve the performance of the network for the overall network lifetime but it is a challenging task in MANET. However, as implicated in Figure 8, the newly designed routing protocol, FSR-CAES is exhibiting an excellent behavior as it maintains a steady end-to-end delay ratio lower than the other protocols for the overall simulation time. GDAQM, MARMAQS, and QAMACF are also performing well. For QAMACF, when the number of nodes is set to 10, its delay ratio attains 50 and decreases for the remaining simulation time.

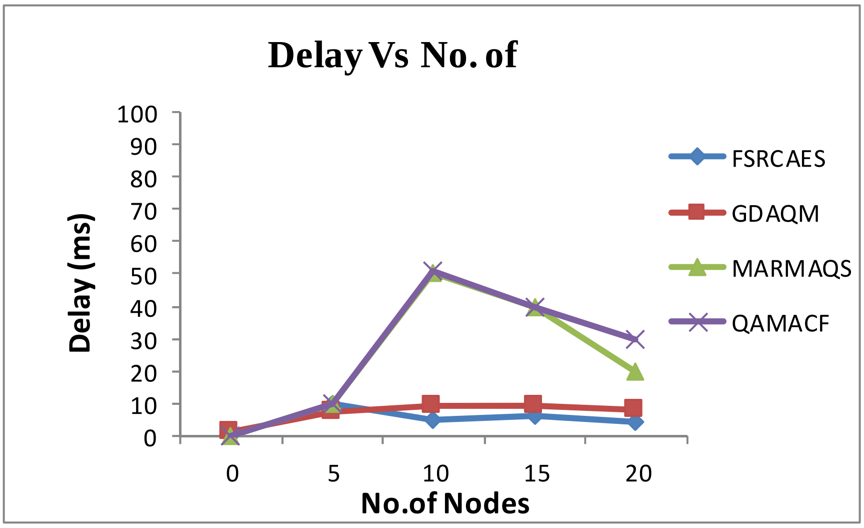

Figure 8: Comparative results of the new schemes using Delay

V. CONCLUSION

In this study, a comparative analysis of the newly designed QoS-Aware routing protocols for efficient routing in Mobile Ad hoc Networks was conducted. Increasing the Quality of Service in MANETs is the most prominent feature which every protocol designer should take into consideration while implementing a robust routing protocol otherwise the QoS provision would be hard to achieve. Even if it is not easy, providing QoS guarantees has become an essential feature for the operation of multimedia applications. A comparative study of the new QoS-aware routing protocols for MANETs namely QAMACF, GDAQM, MARMAQS, and FSR-CAES is presented in this study. These 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. Those routing protocols were compared in terms of packet delivery ratio, end-to-end delay, throughput, routing overhead, energy, route reliability, normalized routing load, and packet loss ratio.

The performance evaluation with throughput revealed that FSR-CAES outperformed other protocols as its throughput progressively increased for the overall simulation time. Concerning the route reliability parameter, GDAQM, MARMAQS, and QAMACF exhibited a better behavior rather than FCR-CAES whose reliability never attained the others', while for both PDR and routing load, all the four protocols performed almost in the same way as their normalized routing load ratios were lower and their PDR ratios were high even when the number of nodes was set to 20. Regarding the packet loss, all the protocols performed well as the lost packets were minimized; the same did not always apply to QAMACF as when the network topology was made of 15 nodes, the ratio of lost packets started increasing and never got down for the remaining simulation time. For the overhead, all the four protocols performed well as their overhead ratios were maintained at lower levels (less than 3). Regarding the energy parameter metric, it was revealed that the energy consumed augmented proportionally to the increasing number of nodes but all the new schemes managed well the power consumed by nodes as the energy level of all the protocols did not attain a high level during the simulation time. Concerning the end-to-end delay, FSR-CAES outperformed other protocols as it maintained the end-to-end delay ratio lower while other protocols performed mediumly.

As an overall observation, the new schemes performed well as each simulation results revealed that no protocol was performing worse even if some were performing normally in some cases and outperformed better in others. Hence, it is confirmed that the new schemes are well suited for high QoS provision for multimedia applications in MANET.

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