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MARMAQS: A NEW EFFICIENT MULTI-ALGORITHM ROUTING MECHANISM FOR ACQUIRING HIGH QUALITY OF SERVICE IN MANET

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Abstract

Mobile Ad hoc Network (MANET) is nowadays leading other types of wireless networks as it entirely consists of mobile nodes communicating without requiring any central management scheme to control the information exchanges between nodes, this is one of its features that are the main reason this type of wireless network is highly demanded in different environments requiring an immediate attention such as emergency situations for example in case of medical communication, commercial sector, military battlefields, etc. Due to this infracrtureless nature of MANET, some of its fundamental characteristics such as wireless medium, dynamic topology, collision and interference events, and distributed cooperation between nodes always influence its overall performance as various problems namely Quality of Service provision's degradation, higher error rates, various constraints related to bandwidth, power, and applications are frequently associated with them. To contain all those negative issues, 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 but none of them provides an adequate solution. To successfully solve those problems, in this paper we propose a new routing scheme; MARMAQS: Multi-Algorithm Routing Mechanism for Acquiring high Quality of Service in MANET. 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. The proposed scheme is a compound protocol consisting of various QoS related techniques namely Lifetime Remainder Routing mechanism, packet scheduling scheme, and the intrusion detection algorithm. The routing algorithm concerns all processes related to the best route selection and takes into the account both the node and link's lifetime prediction mechanisms, the packet scheduling mechanism; Urgency based Packet Scheduling (UPS) is efficient in performing the packets scheduling operations and is a robust algorithm able to highly reduce the congestion events in the network, finally, the intrusion detection mechanism is able to detect security breaches in the network. To prove the robustness of our proposed mechanism, we conduct an experimental evaluation comparing it with three popular QoS-based schemes available in MANETs namely Particle Swarm Optimization (PSO) based node and link lifetime prediction (PNLP), Improved Routing Security (IRS), and Lifetime Prediction Routing in Mobile Ad Hoc Networks (LPR). The evaluation is conducted using four prominent MANET's QoS evaluating parameters; end-to-end delay, packet delivery ratio, throughput, route reliability, and routing overhead. The experiments are carried out using the NS-2 simulator; the outcomes revealed that our proposed mechanism highly outperforms the existing ones for all the studied scenarios.

Index terms: *MANET, Quality of Service, Routing, Security, and Scheduling Algorithms*

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I. Introduction

MANET is a collection of mobile nodes interconnected by auto-configured wireless links [30]; mobile nodes can be any wireless terminals such as cell phones, personal digital assistant (PDAs), tablets, portable gaming devices, etc. The network is decentralized meaning that no central manager such as a router, access point, or any network management-capable device is available responsible for controlling the whole network for example for topology's formation operations, packets transmission, and any other networks' operations; this leads to frequent

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network topology changes with highly mobile nodes. Various problems arise such as limited bandwidth, routing overhead, hidden terminal problems, battery and application-related constraints, dynamic route changes, resource constraints, nodes' cooperation related problems, etc. [1][2][3]. Different applications for emergency communications such as military battlefields, commercial sector, tragic events requiring an immediate attention such as floods and earthquakes, local level access to conference room/ classroom, and Personal Area Networks (PAN) use MANET as their preferred wireless network. As previously mentioned, MANET is a self-configuring network, so the autoconfiguration operations are required for achieving the topology's formation processes in this type of wireless network; IPV6 which is a stateless protocol is used for this end, as it defines a novel mechanism for the purpose of achieving the nodes' autoconfiguration's processes in wired networks. The same approach applies to distributed wireless networks especially for large scale Mobile Ad hoc Networks by using the hierarchical approach [4]. A Cryptographic mechanism is used during information sharing and exchanges operations between two or many communicating nodes [5]. In MANETs nodes sometimes exhibits some misbehavior and selfishness characteristics which in turn frequently causes long nodes' inactivities; as a solution to this problem, a generic mechanism based on reputation to enforce cooperation among the nodes of a MANET to prevent selfish behavior was proposed in [6]. Nowadays MANETs are used for identifying and collecting information about the victim's location and his/her personal information from the disaster covered area using GPS technologies [7].

Figure 1: MANET's Architecture

Figure 1 displays the basic architecture of a MANET, where mobile nodes (mobile phones and tablets) are wirelessly interconnected. Here, the multi-hop routing, dynamic topology, and distributed organization; prominent features of a MANET are presented. Those features affect very much the Quality of Service's provision in MANETs which is a very important factor to be highly taken into account while designing a robust routing protocol as the performance of MANETs increases proportionally to the high provision of QoS. It is necessary while transmitting ordinary packets but highly required for achieving successful multimedia data transmission (video, audio, image, pictures, etc.) as they pose various transmission challenges. Different QoS parameter metrics have been proposed by various researchers for this end, in this paper, we consider only the prominent ones namely lifetime, reliability, delay, throughput, packet delivery ratio, and routing overhead. For example, the communication between two nodes can be interrupted or broken due to dynamic topological changes in the network, thus affecting the performance of the whole network's operations by decreasing the packet's transmission reliability. Our proposed algorithm is a mixture of various techniques which takes into account all those previously mentioned issues. To increase, for example, the network's lifetime, the nodes' energy consumption's rate was reduced in [8], here every node's and link's lifetimes were predicted, and this technique is incorporated in our proposed algorithm under the name of Lifetime Remainder Routing mechanism. For security reasons, only the identified reliable nodes (having

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the higher rate of reliability) are used for packet transmission purposes. The next process concerns the packet scheduling mechanisms where a scheduling algorithm is used to avoid the routing overhead and network congestion events, minimized end-to-end delay, etc., the last process concerns the security provision mechanism which ensures the reliability of nodes which packets will pass through to reach the destination; an intrusion detection system is incorporated in our proposed algorithm for this end. Combining various QoS provision related techniques in one protocol enabled us to develop a very robust algorithm efficient in providing high QoS in MANETs.

The main contributions of our paper are as follows:

- Propose a robust Lifetime Remainder Routing mechanism which successfully performs the best path selection processes for achieving efficient packet transmission operations.
- Develop an Urgency-based Packet scheduling algorithm for packet scheduling purposes in order to decrease the routing overhead and packet overflow during the transmission processes in the whole network.
- Introduce an intrusion monitoring system which improves the MANET's reliability by preventing unreliable nodes from participating in data packet's transmission operations, thus increasing the security.
- Achieving a high QoS in term of highly increased transmission's reliability, packet delivery ratio, throughput, and decreased end-to-end delay's ratio, routing overhead resulting in the highly increased whole network's routing performance.

The remaining parts of this paper are organized as follows: in Section 2, the related work is discussed. Section 3 provides the problem definition. The proposed routing mechanism, its pseudocode, and the mathematical analysis are described in Section 4 while Section 5 provides the experiments conducted evaluating the existing algorithms with the proposed scheme and their relevant experimental results. Finally, Section 6 concludes our work and references are presented in Section 7.

II. RELATED WORK

Researchers in [9] discussed a MANET with two important constraints namely buffer's size and packet's lifetime; they explored their impacts on the global network's lifetime. This study used the embedded Markov chain theory to develop a complete theoretical framework and the packet's end-to-end delay was studied based on M/G/1/K queuing theory for revealing how both buffer size and packet's lifetime impact the network's throughput, delay, and packet's loss ratio's performance in the network.

Authors in [10] estimated the residual link's lifetime in Mobile Ad Hoc Networks (MANETs) based on the distances between the nodes connected by the said link. They proposed an algorithm called mobile-projected trajectory (MPT) algorithm that was used for estimating the relative link between two nodes based on a relevant trajectory. To detect the changes in velocity, the MPT was provided with velocity change detection (VCD) test that was referred to as MPT-VCD algorithm. The outcomes of their researches revealed that RLL was robust in term of piecewise-linear trajectory and multiple velocity changes. They further proposed that the incorporation of the MPT-VCD scheme into multi-path routing algorithms would be studied in the future for further enhancements.

Shivashankar et al. [11] presented a robust power-aware algorithm; EPAR (Efficient Power-Aware Routing protocol) which increases the network's lifetime in MANETs. This protocol identifies the capacity of each participating node with the help of both the residual energy and the expected energy spent during the packet forwarding processes on specific links. The study evaluated three MANET's routing protocols namely EPAR, MTPR, and DSR varying the network's scale. The simulation results revealed that EPAR reduced very much both the mean delay and the energy consumed during high load networks' operations.

Authors in [12], proposed a new cross-layer distributed energy-adaptive location-based CMAC protocol which they called DEL-CMAC for MANETs. The main objective of this protocol was to improve the performance of MANET based on the network's lifetime and energy's efficiency. An innovative network allocation vector setting was provided for dealing with the varying transmitting power of the source and relaying terminals. Here the energy consumption was based on both transceiver circuitry and transmit amplifier. A distributed utility-based relay selection strategy was incorporated that selects the best relay based on both location's information and residual energy.

Yu-Chee et al. in [13] presented a formal model to predict the lifetime of a routing path based on the random-walk model. They finally stated that the result found in their research can be used in both measuring the scalability of a MANET and evaluating routing paths during the route selection processes.

In paper [14], authors considered the problems of maximizing the lifetime of MANETs with routing features such as multicast connection, Omni-directional antennas usage, and having fewer energy resources. They then proposed two distributed multicast algorithms namely basic energy-efficient multicast (BEEM) and distributed maximum lifetime multicast (DMLM) aiming at maximizing the network's lifetime where nodes freely and randomly move in the network. These algorithms explore various operations in the network aiming at taking the advantage of the power saving options offered by the wireless multicast property in mobile networks. Through simulation studies, DMLM algorithm outperformed for all the cases studied changing the nodes' mobility speed.

Researchers in [15], considering current traffic conditions in the network have proposed a metric called 'the drain rate' aiming at forecasting the lifetime of nodes. Combined with the remaining battery's power value, nodes were selected to be part of an active route, they then defined two route selection approaches in MANET namely Minimum Drain Rate (MDR) and the Conditional Minimum Drain which provided excellent results compared to the existing algorithms.

Chih-Min Chao et al. [16] presented a new MAC protocol for power saving options in MANET (Single Hop). They stated that protocols' quorum-based sleep/wake-up mechanism conserves the energy by allowing the host to sleep for more than one beacon interval when some transmission operations are being performed. The main idea of this system was to extend the sleep duration of the host in order to conserve each node's power, thus allowing the extension of MANET's lifetime. The outcomes results showed that their expected goal was reached with this proposed algorithm and they are planning to extend this protocol and use it with multi-hop MANETs while keeping the end-to-end delay' ratio tolerable.

In paper [17], authors suggested a new communication mechanism which they called RandomCast. This scheme saves the energy by reducing redundant rebroadcasts for a broadcast packet; it is used by the sender to specify the desired level of the overhearing that makes a prudent balance between both the energy and routing performance. The simulation results confirmed that the proposed algorithm is highly energy-efficient compared to conventional 802.11 as well as 802.11 PSM-based schemes, in terms of total energy consumption, energy goodput, and energy balance. The researchers plan to incorporate the concept of Random-Cast within the other routing protocols.

To address the drawbacks of traditional routing protocols in MANET, authors in [18] were motivated in designing a new protocol based on Grover's searching algorithm. With this scheme, each node maintains a node vector function, and all nodes can obtain a node's probability vector using Grover's algorithm, and then select an optimal route according to the node's probability. Compared to DSR, the proposed protocol was very efficient in reducing both the number of routing hops and network delay, thus, increasing the whole network's lifetime and performance.

In [19], communication methods that use data packets sent over the Internet Protocol; two dynamic Internet gateway protocols which transmit packets within an autonomous system namely Enhanced Interior Gateway Routing Protocol (EIGRP) and Routing Information Protocols (RIP) were studied in this paper. Authors stated that an advanced distance vector routing protocol is required, so they proposed an improved distance-vector routing protocol mechanism for reliable network transmission in LANs (Local Area Networks) where various enhancements and changes were provided as packets from RIP were able to be transformed into EIGRP when RIP reached its allowable maximum hop counts.

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Suraj Pandey et al. [20] proposed a particle swarm optimization based heuristics that schedules applications for the cloud resources that takes computation and data transmission cost. In their paper, they compared the cost savings when using PSO and existing 'Best Resource Selection' (BRS) algorithm. Simulation results showed that PSO outperformed BRS in achieving three times cost saving and in providing good distribution of workload onto resources.

Jaspher W.Kathrine et al. [21] discussed various packet scheduling algorithms for different wireless networks. Their study clearly explains about the advantages and disadvantages of every packet scheduling mechanism for each type of wireless network. They stated that different packet scheduling techniques do not take into account the security issues, so they proposed a new algorithm; Security-Aware Packet Scheduling Algorithm in Real-Time Wireless Networks for the packet scheduling which considers both security and packet scheduling schemes.

In paper [22], authors proposed a routing algorithm which is efficient in providing the lifetime prediction processes in order to maximize the network's lifetime. Thanks to the routing solution that maximizes the variance of the remaining energies for nodes in the network, it improves the lifetime of the whole network by about 20-30% even if it introduces some additional traffic in the network. This algorithm was compared in performance with the dynamic source routing (DSR), the proposed scheme was always outperforming.

In [23], G. Arulkumaran et al. presented a mechanism for improving the security during routing processes in MANETs. This technique was able to efficiently find malicious nodes in the network as it aims at selecting better routes and detecting various security attacks and threats. This paper mainly aimed at reducing the ratio of lost messages, thus increasing the data packet transmission's reliability this resulted in both high throughput gain and route's reliability with a minimum collision attack's rate.

Vinod Kone et al., in [24] presented a new mechanism aiming at improving the packet delivery ratio of ODMRP protocol using simulations through GloMoSim 2.0 simulator. This algorithm selects packets and caches with the Forwarding Group members; this resulted in enhancing the distribution process in sharing retransmission responsibilities between intermediate nodes. Here, some acknowledgement packets in the format of bitmap images are piggybacked on the Join Reply packets. There was no increase in the control overhead with this technique and the provision of reliable multicast was achieved thanks to the peripheral buffer-based approach which was introduced for this end.

Authors in [25] proposed a delay scheduling algorithm aiming at transmitting delay-sensitive data packets over a multi-hop MANET. Considering the end-to-end delay requirements, they calculated three types of urgencies namely first packet urgency, node urgency, and route urgency. Those metrics were very important in achieving QoS improvements. In short, this algorithm was able to maximize the number of arriving packets at the destination by improving the throughput of the network.

In paper [26], authors proposed an algorithm; Particle Swarm Optimization (PSO)-based lifetime prediction algorithm for route recovery in MANET. Using network parameters such as node's mobility and energy drain rate, they were able to predict the lifetime of both links and nodes in MANET; they used the fuzzified and fuzzy rules for this end. Thanks to this technique, every node's status was verified before transmitting any packet through it. There was an exchange of responsibilities for data packet's transmission purpose from a weak node to the strong one; this highly decreased both the packet drop and communication overhead's rates.

Efficient Power Aware Routing (EPAR) protocol, an improvement to DSR protocol, for maximizing the network's lifetime was proposed in [27]. This paper evaluated three power-aware Ad hoc routing protocols (DSR, MTPR, and EPAR) taking into consideration the network's lifetime and packet delivery ratio as parameter metrics. In the proposed trust management scheme, the trust model has two components: trust from direct observation and trust from indirect observation. Simulation results revealed that for large-network size, EPAR was outperforming in term of throughput as it could initially choose which path has the maximum Lifetime.

Namrata Awasthi et al. [28] proposed a new routing mechanism capable of providing better security options for a specific MANET especially in a company environments, offices, or private networks. The scheme was called Improved Secured Routing for AODV (IRS). The simulations outcomes revealed that the proposed algorithm provided an improved packet delivery ratio and throughput, minimized end-to-end delay, and the reduced packet's drop rate for Ad hoc On-Demand Distance Vector (AODV) routing protocol. This achievement was possible thanks to the fact that attacks were being avoided proactively by including changes in the basic implementation of AODV routing protocol. Authors finally stated that in the future their research can be improved by providing a dynamic interface for changing the key pattern specified so that the network can be safeguarded against human errors.

Authors in [29] made a primary contribution on scheduling algorithms that categorizes and prioritizes the real-time traffic with the intention of improving the performance of the real-time applications. Five types of scheduling algorithms have been analyzed using the OPNET simulator. The simulation outcomes showed that when comparing LLQ algorithm to the other scheduling algorithms, the delay was minimized and throughput maximized for real-time applications. Authors finally stated that the proposed algorithm can be also implemented using the OPNET modeler.

II.PROBLEM DEFINITION

A Mobile Ad-hoc Network (MANET) is an infrastructureless wireless network meaning that the topology is dynamically created without any central authority such as a router, access point, etc. Being a wireless network, the lack of any management scheme, its dynamic topology; MANET faces various challenges the main ones concerns the network's overall lifetime as its mobile nodes are battery-powered and constrained by limited battery power's lifetime; this issue makes a node's active state short due to unrealistic shutdown or restart. This tragic event affects very much the reliable data transmission's operations from one end to another, thus, resulting in the Quality of Service's degradation in the whole network [30]. Another major problem associated with nodes is in the situations where they fall out of the radio frequency ranges resulting in unexpected route breaks which in turn cause various problems such as packet drop, increased end-to-end delay's ratio, etc. Another major problem faced in MANETs is associated with packet's priorities arrangement before their transmission processes start, some poor protocols do not have those scheduling features required to avoid both the congestion and routing overhead events during their transfer processes. The serious problem which sometimes is not taken into consideration by various researchers is the security issues where packets face security breaches in the network caused by some intruders or some malicious nodes. To solve those previously mentioned negative issues, we propose a new routing mechanism; MARMAQS: Multi-Algorithm Routing Mechanism for Acquiring high Quality of Service in MANET, an algorithm which is a combination of various techniques each one designed to contain its corresponding problem, thus, our proposed scheme highly increases the QoS's ratio in the whole network.

IV. PROPOSED WORK

4.1. OVERVIEW

The proposed algorithm mainly aims at improving the provision of QoS in MANETs; this is achieved by enhancing various QOS parameters namely the increased lifetime, throughput, Packet Delivery Ratio (PDR), and reliability but minimizing both the end-to-end delay and routing overhead. Concerning the lifetime parameter metric, we consider both the link and node's lifetime by extending each node's battery power, which then reduces packet drop's ratio which should be caused by both the link's failure and breaks due to the death of any participating node caused by the lack of energy or the one having been fallen out of the communication range. This is one of the improvements required to attain a high network's performance.

The proposed scheme is a complex protocol consisting of Routing, Packet scheduling, and Intrusion monitoring mechanisms. Routing is related to the packet transmission processes consisting of route discovery, route selection, transmission process, and route maintenance while the packet scheduling techniques are used to schedule the packets aiming at avoiding both the congestion and routing overhead while the transmission is in progress,

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finally the intrusion monitoring process deals with the problem related to the packet loss in the network caused by various security breaches. The mixture of those various techniques makes our proposed scheme very robust as it achieves a high QoS's provision in MANETS. The following sections describe those techniques incorporated in our proposed scheme.

4.2. ROUTING

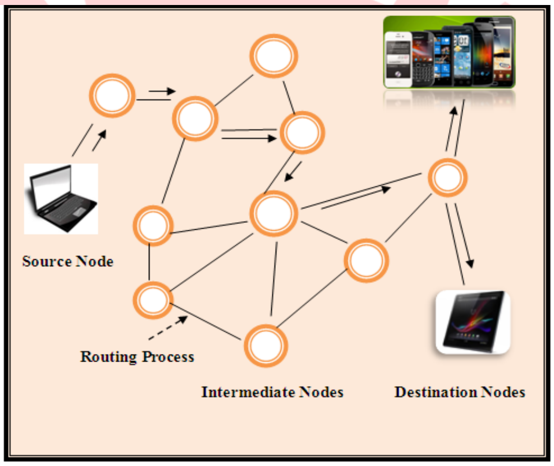

Figure 2: Routing and network topology structure with the proposed scheme

As we can see on Figure 2, the network is composed by a dynamic topology consisting of various types of wireless devices i.e. laptops, tablets, and mobile phones. Finding an appropriate route aiming at establishing a communication channel between nodes while exchanging messages is the main goal of deploying a MANET; upon obtaining the best route; information is then relayed from one end to another traversing various intermediate nodes and links, hence, multi-hop and multi-path routing. In this paper, we introduce a new mechanism; Lifetime Remainder Routing capable of highly achieving routing processes thanks to its ability to take into account both the node and link's lifetime prediction mechanisms; features required to predict the future transmission's success as they help in avoiding various problems related to routing such as increased packet drop and end-to-end delay, and both the decreased transmission reliability and packet delivery ratio, etc. [8].
The link's lifetime is defined as follows:

$$LLT_i = \min(LC_i, N_{i-1}, N_i) \quad (1)$$

While the lifetime of a node located along a given path is defined by:

$$T_{N_i} = \frac{e_i^{NT}}{EV_i^N}, \mathrm{t} \in [\mathrm{NT}, (\mathrm{N}+1)\mathrm{T}] \quad (2)$$

Where, LLT_i represents the lifetime of a link, LC_i a connection between two nodes N_{i-1} *and* N_i. T_{N_i} represents the lifetime of a node, EV_i^N is the energy depletion at N[th] period of time and e_i^{NT} represents the residual energy's value. Upon determining the lifetime of both nodes and their relevant connecting links, the root nodes' values in the routing table are accordingly updated. Using the hop-count methods, we then calculate the best paths to route packets through, and finally, packet transmission processes take place using the selected best routes.

Figure 3 exhibits the Lifetime Remainder Routing mechanism's full processes:

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Pseudocode 1: Lifetime Remainder Routing

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Inputs: Every node's Lifetime (T_{N_i}), every link's Lifetime (LLT_i), RT, Req (S-id, D-id, BC-id, Hp), and Rep (S-id, D-id, Hp, T_{N_i})

Output: Packet transmission using the selected best path

Begin

Step 1: S_n Req

Step 2: if (D_n →Rep)

Update RT

Step 3: Choose P

Step 4: P must have fewer Hp

Step 5: P € LLT_i && T_{N_i}

Step 6: if **(**LLT_i && T_{N_i} is high for P)

Transmit I → D_n

Rep from S_n

else

Select another P, P € LLT_i

Transmit I → D_n

Rep from S_n

End

===

Figure 3: Lifetime Remainder Routing algorithm

The pseudocode on Figure 3explains all about the full routing process of our proposed scheme. S_n is the source node, D_n is the destination node, S-id is the source node's id, D-id is the destination node's id, Hp is the hop count, P is the path from a given sender node to a respective receiver node, RT is the routing table, Req is the initial request packet, Rep is the reply packet from the destination node, BC-id is the broadcast id for every Req, and I is the information to be transmitted to the destination node. Nodes are initially supplied with higher energy and their lifetime is calculated in eqn(2). We first transmit a Req (S-id, D-id, BC-id, Hp) to the neighboring nodes. Each one then checks for the conditions included in the transmitted information in the packet, when it satisfy those conditions, it then sends a reply packet in the form of Rep (S-id, D-id, Hp, T_{N_i}) to the sender node. All replies from all neighbor nodes are processed and the routing table (RT) is then updated as shown in Table 1. The selected best path must satisfy the following two conditions: having a lesser number of hops and both higher link and nodes' lifetimes otherwise an alternative path from the RT satisfying those conditions is chosen instead. This technique is very successful in avoiding the excessive packet loss ratio during the packet's transmission processes even if some additional problems may arise such as the overhead incurred in the network and congestion events due to the simultaneous transmission processes, for this, a scheduling scheme is required to contain those negative issues, thus, we propose a new packet scheduling algorithm in section 4.3.

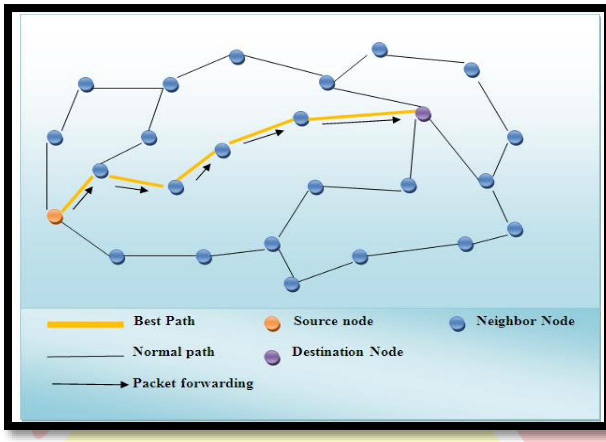

Figure 4: Lifetime Remainder Routing scheme

Table 1: Routing Table

Lifetime(j)	Nodes	1	2	3	. . .	N
1000	1	0	1	1	. . .	6
1000	2	1	0	2	. . .	4
1000	3	1	2	0	. . .	7
1000	.	.	.	.	.	.
1000	.	.	.	.	.	.
1000	.	.	.	.	.	.
1000	N	6	4	7	. . .	0

4.3. PACKET SCHEDULING

Packet scheduling is another important mechanism that enhances the Quality of Service (QoS)'s provision in MANETs, with this techniques priorities are always assigned to traffic flows. In this paper, we introduce a new scheduling algorithm; the Urgency-based Packet Scheduling (UPS), with which the link and node's lifetime parameter values derived from eqn. (1) and eqn. (2) are used for both packet scheduling and transmission purposes. We first prepare a route which will be used for transmitting the packet whose both link and node's lifetimes are very high. We prioritize packet during the transmission processes using packet urgency and node urgency parameters. The packet urgency can be calculated as follows,

$$\mathrm{U_{pack}}(\mathrm{t}) = F_{ur}\left(\frac{d_{res}(t)}{D_{mx}}\right) \text{ ------------------------------------ (3)}$$

Where $d_{res}(t) = D_{mx} - d_{acc}^{i}$ (t)

D_{mx} is the maximum tolerable end-to-end delay which is the cumulative delay the from source node to the i^th^ node, $d_{res}(t)$ is the residual delay that satisfies the end-to-end delay requirement over the remaining hops. When a packet has smaller $d_{res}(t)$, then it is immediately transmitted to the destination node (high priority). The node's urgency is calculated as follows,

$$\mathrm{U_{node}}(\mathrm{t}) = \sum_{j \epsilon R} \mathrm{U_{node(j)}}(\mathrm{t}) \text{--------------------- (4)}$$

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This packet scheduling algorithm; Urgency based Packet Scheduling (UPS) associated with this process is shown in both figure 5 and 6.

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Pseudocode 2: Urgency-based Packet Scheduling algorithm

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Inputs: P = {1, 2, 3 … n}, Priority = {'A', 'B', 'C'}, Nodes = {n_1, n_2, n_3 …}
Output: Packet transmission
Begin
Step 1: S_n P to D_n
Step 2: Calculate $U_{pack}(t)$ ¥ P
Step 3: Calculate $U_{node}(t)$ ¥ Nodes
Step 4: If ($U_{pack}(t)$ && $U_{node}(t)$ is higher)
    $U_{pack}(t)$ && $U_{node}(t)$== 'A'
    Transmit p→D_n
  Else if (($U_{pack}(t)$ is higher) && ($U_{node}(t)$ is lower))
      $U_{pack}(t)$ && $U_{node}(t)$== 'B'
      Transmit p→D_n
  Else if (($U_{pack}(t)$ is lower) && ($U_{node}(t)$ is lower))
    $U_{pack}(t)$ && $U_{node}(t)$== 'C'
    Transmit p→D_n
  End if
  End if
  End if
End

==

Figure 5: Urgency-based Packet scheduling algorithm

Figure 5 depicts the process of the proposed packet scheduling algorithm. In this figure, 1, 2, 3 … n represent each packet's number, 'A', 'B', 'C' are their transmission priorities while n_1, n_2, n_3… represent the nodes' numbers through which packets are transmitted within the network. Here, $U_{pack}(t)$ is the calculated urgency of packets to be transmitted and $U_{node}(t)$ is the urgency of node calculated for all the ones whose packets' urgency is high. In this paper, when both packet and node's urgencies are high at a given time they are then given the first priority 'A' during the packets' transmission processes. When the urgency of a packet is high while the node's is low at a specific time then their transmission's priority is set to the second level 'B'. Finally, when the urgencies of both packet and node are low at a given time, the third priority 'C' is then given to them.

Upon completing both the packet's and the nodes' urgency calculations, the transmission process then takes place with the first priority given to an urgent packet from eqn. (3), which has to pass at the urgent node from eqn. (4) and having a higher lifetime from eqn. (2) through a link whose lifetime is high from eqn. (1) and having fewer hop counts. This scheduling scheme combined with the Lifetime Remainder Routing algorithm avoids very much the delay incurred during the sensitive data's transmission processes resulting in minimized packets drop's ratio caused by both routing overhead and some congestion events.

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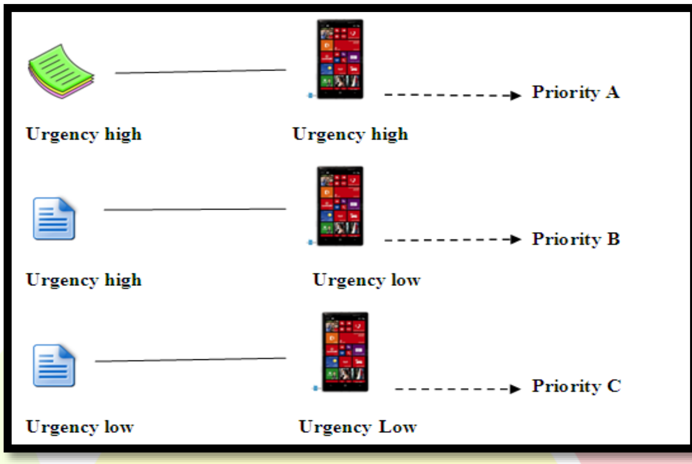

Figure 6: Urgency-based Packet Scheduling (UPS) scheme

4.4. Intrusion Monitoring

Intrusion detection and monitoring system is a security management scheme for both wired and wireless networks. It can be either a device or software application which monitors the network's activities aiming at finding malicious or policy violation events and then produces electronic reports to the management agents. The main process involves the information gathering and analyzing operations from several areas in the network which identify security breaches involving both the intrusions and network's misuse. In this paper, we increase the reliability of a network using the same approach by analyzing the behavior of every node available in the network in order to achieve highly reliable end-to-end transmission resulting in a significant increase in the Quality of Service in MANETs.

Due to the lack of any central manager in MANETs, every node here will act as a network's monitoring agent, it verifies the behavior of neighboring nodes before forwarding data packets to them using the watchdog technique, the monitoring operation is performed for the next hopping within the network. The outcomes of the monitoring processes are kept at each node if any malicious node is found along the path toward the destination; the monitoring nodes then send an alarm signal to the sender instructing it to choose an alternate path.

V. Experimental Evaluation

This section describes various approaches used in our performance evaluation to prove how our proposed scheme outperforms in successfully providing high QoS in MANETs. These are Particle Swarm Optimization (PSO) based node and link lifetime prediction (PNLP), Improved Routing Security (IRS), and Lifetime Prediction Routing in Mobile Ad Hoc Networks (LPR).

PNLP [26]

With this mechanism, both node's and link's lifetimes are predicted using parameters such as relative mobility of nodes, energy drain rate, etc. The fuzzy and fuzzified rules have been used to make relevant decisions based on each node's status; the resulted information is then shared among all participating nodes in the network. The checking process then follows consisting of verifying the status of each node before the transmission process begins, the handover between a weak node and a strong one can occur during the route recovery process.

IRS [28]

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IRS is a security protocol which has been proposed for Mobile Ad Hoc Networks, it successfully provides the routing protocol's security by allotting a Pattern Key to every node and each one wishing to communicate first checks for both the identity and validity of its partner before the communication starts. For the communication to take place the pattern key of both the sender and receiver are to be mixed to create another encryption key and will be then used for both encryption and decryption processes. This scheme very much enhanced the performance of MANETs.

LPR [22]

LPR is reactive routing protocol that has the ability to predict the battery's lifetime based on its past activity using a Simple Moving Average (SMA) predictor, it also accounts for the rate of the energy discharge. This is a dynamic distributed load balancing approach that avoids power-congested nodes and chooses paths that are lightly loaded i.e. whose lifetime is maximized, this helps LPR achieve minimum variance in energy levels of different nodes in the network. This routing protocol is very efficient in extending the service life of a MANET consisting of a dynamic topology. It achieves this by performing local decisions with minimum overhead. This results in a clear increase of the overall network's lifetime.

5.1. Simulation Setup and Results

We next describe the materials and methodology we used to compare our proposed scheme and the already existing ones.

5.1.1. Simulation environment

A detailed simulation model based on NS-2 is used to model the four protocols namely our proposed scheme; MARMAQS and the existing ones namely PNLP, LPR, IRS. IEEE 802.11 for wireless LANs is used at the MAC layer with radio propagation model of Two-Ray Ground. 201 packets are maintained in the queue. The network consists of 30 nodes within an area of 1500X1500 with the maximum simulation time of 100 seconds. A random-way point model is used to model the node's movements which move at the speed ranging between 1 and 20 m/s.

5.1.2. Simulation parameter values

The following table depicts the parameter metrics used to compare our proposed scheme; MARMAQS with the existing ones.

Table 2: Simulation Parameters

Parameters	Values
Number of nodes	30
Interface type	Phy/WirelessPhy
Channel	Wireless Channel
Mac type	Mac/802_11
Queue type	Queue/DropTail/PriQueue
Queue length	201 Packets
Antenna type	Omni Antenna
Propagation type	Two-Ray Ground

Size of packet	256-1280
Mechanism	MARMAQS
Traffic	CBR
Simulation area	1500M*1500M
Node mobility speed	1…20 m/s

5.2. PERFORMANCE EVALUATION METRICS

Our proposed algorithm is compared with the existing ones using the following metrics:

- End-to-End Delay
- Packet Delivery Ratio (PDR)
- Throughput
- Route Reliability
- Routing Overhead

5.3. COMPARATIVE ANALYSIS

We present the performance of our proposed scheme with the existing ones in the form of both tables and figures; the comparative study in term of End-to-End Delay is depicted in Table 3 and Figure 7, while the outcomes of the performance evaluation with PDR are presented in Table 4 and Figure 8, Table 5 and Figure 9 exhibit the performance our compared protocols in term of Throughput, the comparison using the Route's Reliability is shown in both Table 6 and Figure 10, and finally, Table 7 and Figure 11 contain the comparative results using the Routing Overhead parameter.

5.3.1. END-TO-END DELAY

End-to-end delay ratio is the average time necessary for a packet to reach the destination. It may be caused by many factors such as route discovery cycle and queuing process used during the data packet transmission operations. Only data packets that have been successfully delivered to the destination are counted. The performance of the protocol is determined by the value of the end-to-end delay; the lower ratio means the higher is the performance of the protocol.

$$\text{End-to-End Delay} = \frac{\sum(Arrival\ time - Send\ time)}{\sum Number\ of\ connections}$$

Table 3: Performance evaluation using End-to-End Delay

Node's Mobility (m/s)	MARMAQS	PNLP
10	6	15
20	6.2	16
30	7	18
40	8	19
50	9	20

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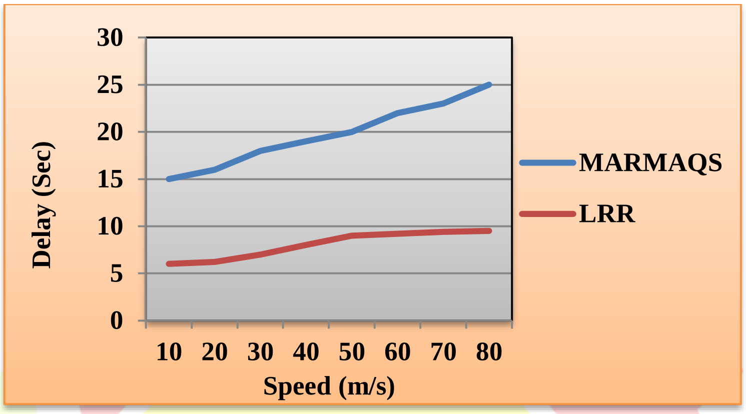

Figure 7: Performance evaluation using End-to-End Delay

As seen in both Table 3 and Figure 7, the performance of our proposed algorithm; MARMAQS is compared to the PNLP's, the outcomes reveal that MARMAQS outperforms PNLP in term of end-to-end delay as for all the cases studied varying the nodes' speed, our proposed scheme maintains a lower delay's ratio, this is due to the fact that our proposed scheme select the best path with minimum hop counts resulting in short delay for a packet to reach the destination. One interesting observation is that both protocols delay's ratios almost continually increase as we augment each node's speed, the main reason for this behavior is that for example the destination node may be moving fast and go far away from the source node resulting in an increase of the incurred delay in the network; it will take some more time for packet to reach the destination as some additional hops may appear in the network.

5.3.2. Packet Delivery Ratio (PDR)

Packet delivery ratio is the fraction of the number of delivered data packets to the destination. This fraction illustrates the level of the packet delivery. The greater value of packet delivery ratio means the higher performance of the protocol.

$$\text{PDR} = \frac{\sum Number\ of\ data\ packet\ received}{\sum Number\ of\ data\ packet\ sent}$$

Table 4: Performance evaluation with Packet Delivery Ratio

Node's Mobility (m/s)	MARMAQS	PNLP
10	0.8	0.7
20	0.7	0.6
30	0.6	0.5
40	0.6	0.4
50	0.5	0.3

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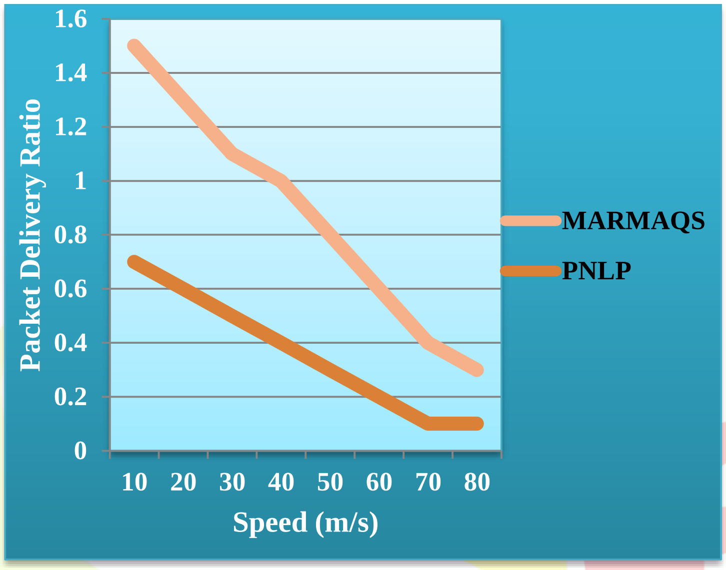

Figure 8: Performance evaluation using Packet Delivery Ratio

Table 4 and Figure 8 depict the outcomes of our simulation where MARMAQS was again compared with PNLP but this time in terms of Packet Delivery Ratio. The PDR of our proposed scheme remains higher than the PNLP's for the overall of simulation time for small, medium, and high node's mobility speed. The PDR for both protocols almost progressively decreases as nodes' mobility speed increases, the main cause of this problem is the fact that the fraction of dropped packets increases caused by many factors such as congestion in the network with highly speedy nodes, or by frequent route failures and breaks which then results in minimized number of received packets at the receiver

5.3.3. THROUGHPUT

Throughput or network throughput is the rate of successful message delivery over a communication channel. In ns-2, it is defined as the total number of packets delivered over the total simulation time.

Table 5: Simulation experiments using Throughput

Number of Nodes	MARMAQS	IRS
10	9	6
20	7	5
30	6.9	5.5
40	6.5	3.9
50	5.4	3.6

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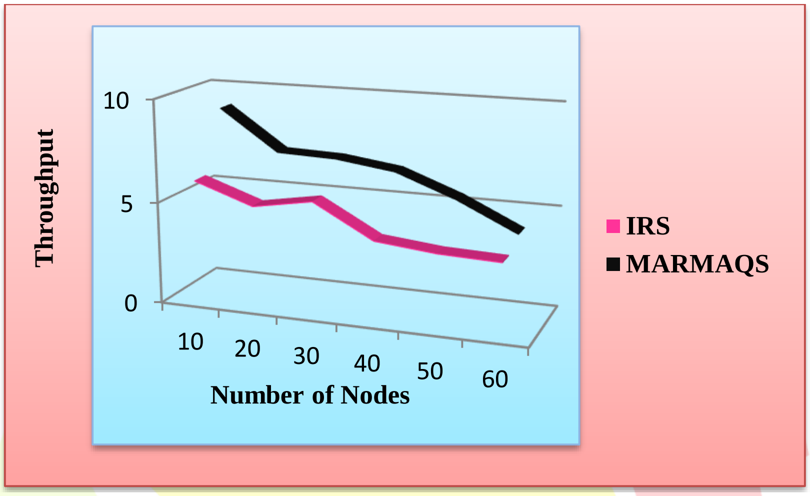

Figure 9: Performance evaluation using Throughput

As long as the throughput; the network performance evaluation parameter is concerned while MARMAQS is being compared in performance to IRS, our proposed scheme always exhibits a better behavior as it increases the throughput in the network maintaining it higher than the IRS's for small, medium, and larger number of mobile nodes as presented in Figure 9 and table 5. As the number of nodes increases the throughput for both protocols almost decreases due to the higher number of nodes which leads to the increasing number of hops resulting in a long transmission delay as the packets have to traverse various links and hop to reach the destination, this further results in a drop of throughput ratio followed by the prolonged total transmission time.

5.3.4. Route Reliability

For achieving a high QoS provision's rate, evaluating route reliability is another approach to be taken into consideration for this end. An intrusion detection system is for example used for testing the reliability of each path to pass packets through by gathering various information and identifying some security breaches involving both intrusions and the network's misuse. A node along the path toward the destination node is identified as reliable as long as it does not exhibit any security breach to the network otherwise, it is classified as an intruder (unreliable) and an alternative path is then chosen. Routing reliability's ratio may differ for various routing protocols.

Table 6: Simulation Results with Route Reliability

Number of Nodes	MARMAQS	IRS
20	9	7
40	8	6
60	7	5
80	6	4
100	5	3

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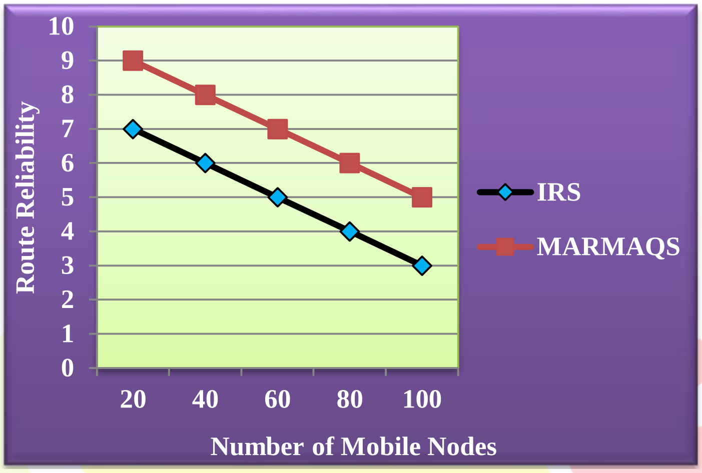

Figure 10: Performance evaluation with Route Reliability

As depicted on both Figure 10 and Table 6, as long as the Route Reliability network parameter is evaluated varying the number of mobile nodes, the proposed algorithm's route reliability is maintained to a higher level when compared to the existing IRS's during the overall simulation time even when the number of nodes is increased making our protocol a better one. This best efficiency of our proposed algorithm is provided thanks its intrusion detection mechanism which select the best paths by avoiding the unreliable ones but the performance of both protocols degrades as we increase the number of nodes, the main cause of this misbehavior is that when the number of nodes augments, the number of unreliable ones proportional increases which further results in the overall routes' unreliability.

5.3.5. ROUTING OVERHEAD

Mobile nodes often change their location within the network resulting in the generation of some stale routes in the routing table which further leads to unnecessary routing overhead whose ratio should be minimized.

Table 7: Experimental results using the Routing Overhead

Node's Velocity (m/s)	MARMAQS	LPR
5	50	62
10	53	64
15	55	66
20	60	70
25	65	80

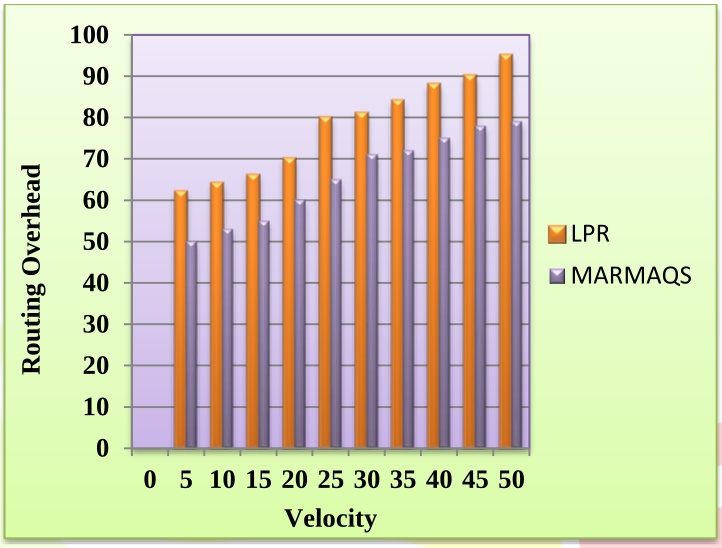

Figure 11: Performance evaluation using Routing Overhead

Figure 11 and Table 7 present the outcome of our performance evaluation using the routing overhead parameter with varying the velocity of nodes. The results reveal that our proposed scheme incurs lower overhead in the network even when the node's velocity is augmented; this is possible thanks to the security features incorporated in our proposed algorithm. One interesting observation for both protocols is that the overhead ratio always depends on the dynamicity of nodes' velocity as both the overhead and nodes' velocities augment in the same fashion.

VI. Conclusion

MANET being a decentralized wireless network, providing high QoS (Quality of Service) in this type of network is still challenging especially for multimedia applications. Several routing protocols have been designed mainly aiming at providing high QoS but researchers have faced various challenges such as Quality of Service provision's degradation caused by higher error rates and various constraints related to bandwidth, power, and applications. To provide a very prominent solution to those negative issues, we have proposed a new routing mechanism; MARMAQS: Multi-Algorithm Routing Mechanism for Acquiring high Quality of Service in MANET. This scheme is a mixture of three important QoS provision techniques namely node and link's lifetime prediction scheme, packet scheduling algorithm, and intrusion monitoring mechanism. The first technique; the Lifetime Remainder Routing protocol consists of route discovery, route selection, transmission process, and route maintenance operations, the second one; Urgency based Packet Scheduling (UPS) algorithm which performs the packet scheduling operations by arranging them in an ordered manner before the transmission process starts uses the priority of both the packets and nodes based on the urgency calculation mechanism. While the latter one efficiently provides a security mechanism as it detects malicious nodes and avoids packet transmission at such mobile nodes. For the performance evaluation, we have considered five different QoS parameters metric namely End-to-End Delay, Packet Delivery Ratio, Reliability, Routing Overhead, and Throughput; metrics used to evaluate the performance our proposed scheme; MARMAQS in comparison with the existing ones namely LPR, IRS, and PNLP varying the number of both nodes and nodes' mobility speed. For all the studied cases, the simulation results confirmed that our proposed scheme (MARMAQS) outperforms the existing mechanisms as it provides a higher rate in term of PDR, Route Reliability, and Throughput with minimized Routing Overhead and End-to-end delay's ratios. This achievement was possible thanks to the fact that our proposed scheme is a mixture of various robust QOS routing algorithms.

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