**Misan Journal of Engineering Sciences** ISSN: 2957-4242
Vol. 5, No. 1, 28 June 2026 ISSN-E: 2957-4250

# AI Proactive Agent of IoT-MANET for QoS Provision

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(Received 8 May, Revised 11 May, Accepted 4 June)

**Abstract:** Mobile ad hoc networks (MANETs) is one of vast array of wireless technologies in the internet of things IoT. The merging of IoT and ad hoc networking offers a strong boost to applications within smart cities, healthcare monitoring, as well as disaster management and industrial automation. With improvements in IoT data rates, network capacity, latency, routing protocols, power efficiency along with Quality of Service (QoS), Next Generation Networks (NGNs) and IoT-based Mobile Ad Hoc Networks (IoT-MANETs) are envisioned as end-to-end solutions to existing networking challenges that will yield required Network QoS (NQoS). The rise of using IoT-MANETs for many applications, leads to the QoS supporting. In this study, we proposed network cross-layers design of IoT-MANET QoS management and AI proactive agent machine model accordingly aims to achieve QoS levels and management by meet the NQoS. The results of the system model is that the QoS levels can be changed dynamically between QoS ranking points depending on the input NQoS parameters of the IoT-MANET.

**Keywords:** Internet of Things (IoT); Routing; Quality of Services (QoS); Mobile ad hoc Network (MANET); Artificial Intelligent (AI)

## 1. Introduction

MANET is an autonomous system of mobile routers connected by wireless links – the union of which forms a time-varying topology. It is comprised of two or more mobile devices—like computers, routers, or terminals—linked together in peer-to-peer configuration over cellular or multi-hop paths. In such a configuration, each node functions as a router and continues forwarding data packet to other nodes for the sake of communication that exists on the nodes [1]. MANETs are gaining more importance because of their flexibility and ability to function without fixed infrastructure. Though MANETs provide high flexibility, due to the random movement of nodes and frequent disconnection, it suffers from low throughput and high end-to-end delay. As multimedia applications come to underlie more uses of MANETs, the need for QoS support in voice, video and data transmission has become an essential requirement [2].

Wireless sensor networks (WSNs) and wireless sensor and actuator networks (WSANs) are critical for the evolution of Internet of Things (IoT) systems because they allow computational technologies to exchange information with the physical world. WSANs are used to connect the physical environment with computational units by monitoring environmental variables such as temperature, pressure, sound and light. The IoT data, collected by such devices, is then wirelessly transmitted to a processing unit for evaluation, and control signals are forwarded back to the actuators in this WSAN so the environment can then be adjusted depending on circumstances. WSNs and WSANs find applications for such a diversity, from environmental monitoring to tracking and localization, industrial automation as well as smart grids and healthcare. Non-terrestrial networks are typically in ad-hoc setup where communication is done using multi-hop and routing capabilities are required at each intermediate node. It is an intentional design that they function as a low-power and lossy networks (LLNs), enforced by certain networking standards like

DOI: https://doi.org/10.61263/mjes.v5i1.305
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MANET, IEEE 802.15.4, ZigBee, Bluetooth, WirelessHART and ISA-100.11a [3], [4]. Most TCP/IP protocol stack implementations for MANETs suggested with: 1st layer: physical layer, 2nd layer: MAC layer, 3rd-layer network layers, 4th-layer Transport Protocol and application layer in the last the fifth.

There are several challenges in the MANET structure when deployed in resource management to satisfy the requirements of QoS for some common applications. The key challenge in deploying MANET is to meet QoS requirements [5], [6]. QoS perspective in the field of Next Generation Network (NGN) is focused on achieving a significantly higher physical layer throughput with link data rates and MAC layer PDUs delay [7]. Different design philosophies form the basis of MANET routing protocols, and they are proposed to fulfil QoS requirements [2]. A notable NQoS variable is power consumption, as there is a vital issue regarding IoT related to energy conservation and power saving, as all devices have a limited amount of energy [4].

The following studies present a complete perspective with background on prior research in this paper: Agrawal et al. 2023 [8], Ogaili et al. 2022 [9], Khalaf et al. 2018 [7], Ivanov et al. 2024 [10], Tahaei et al. 2020 [4], Abdalla Etorban 2012 [2] and El-Din Mohamed et al. n.d. [6]. The listed previous studies show that there are several issues that need to be solved in particular ways. In IoT-MANET, there are common challenges to improve routing protocol selection, power consumption and hop count. NQoS parameter, namely, throughput, E2E delay, node speed and others are major issues that the next generation network is currently facing. The change in topology due to the mobile nodes results in frequent link breakages and leaving behind unstable routes that result is lossy packets, more delays and lower throughput. Inconsistent bandwidth and instable link quality adds to the complexity of communication, where interference and noise lead to a congestion, jitter, and thus unpredictable performance. Battery-powered IoT and MANET nodes experience depletion under high communication loads, hence adding complexity to the problem of energy constraints in these networks leads to reduced lifetime and reliability. Altogether, these challenges highlight the difficulty of ensuring reliable, efficient, and secure communication in IoT–MANET environments.

Our contribution in this paper is to design AI proactive agent machine of IoT-MANET for NQoS provision model that measures the existence QoS parameters. By integrating QoS parameters with a fuzzy logic inference system, the work presents an intelligent mechanism for dynamic QoS ranking. By performing the previous objectives, the proposed model will maintain the QoE status at user satisfaction. In this paper, we proposed a suitable system by using an AI approach in order to achieve the following aims:

- Offering a network, cross-layered design of IoT-MANET QoS management.
- Designing an AI approach system to perform IoT-MANET QoS ranking.
- Dynamically improve IoT-MANET routing protocols selection.
- Optimize NQoS variables by using proactive QoS machine management.
- Achieve self-power consumption enhancement to control the energy of IoT-MANET.

The rest of the study is organized as follows. Section 1 includes the introduction. Section 2 presents MANET features and routing protocol. Section 3 illustrates IoT-MANET structure. Section 4 proposes design of NQoS management for IoT-MANET. Section 5 explains the proposed system model. Section 6 describes the data collection of network layers from IoT-MANET. Section 7 presents the performance evaluation and results. Section 8 shows the discussion of the system performance and results. Finally, section 9 offers the conclusion.

## 2. Mobile Ad Hoc Networks (MANETs)

### 2.1 MANET features

MANET is a collection of mobile nodes that communicate and cooperate without the dependence on any pre-existing infrastructure. These networking tools procreate dynamically with the objective of increasing interactive features between devices without relying on static structures [11]. MANETs send data over several hops between nodes. MANET nodes must together work as routers and hosts [12]. Fig. 1 ( Fig.1 on the next page) shows several features of MANET.

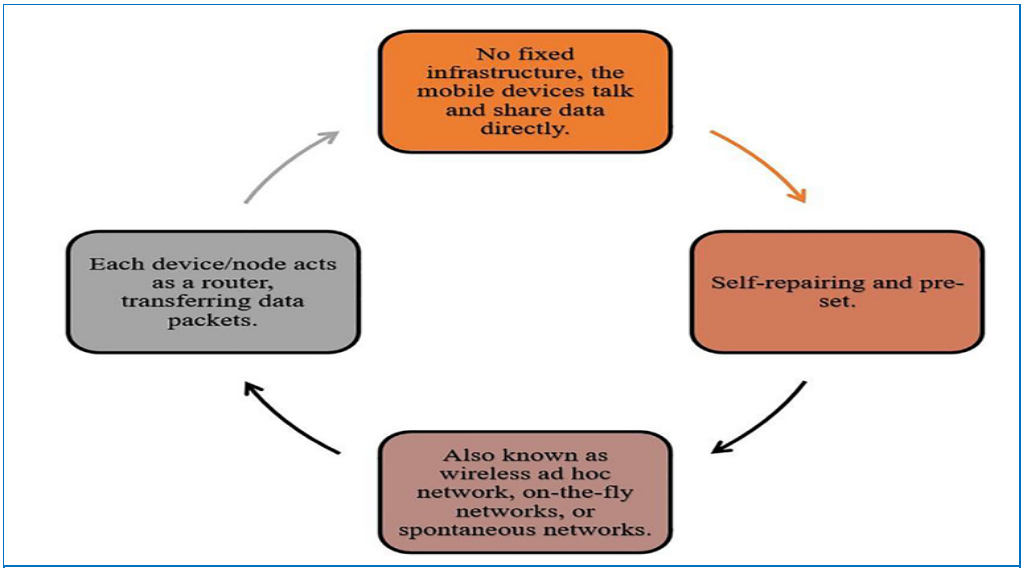



Fig. 1. Features of MANETs [8].

### 2.2 MANET routing protocols

Network Protocols are fundamental for routing, transferring data and communication in resources. As demonstrated in Fig. 2, MANET is formed by autonomous mobile node that communicate via wireless links with limited bandwidth. The topology of the network can change rapidly and in ways that cannot be easily predicted, because these nodes are mobile. Nodes in a decentralized environment have to exert effort to coordinate exchanging routing messages — which is particularly difficult when the topology is mutable.

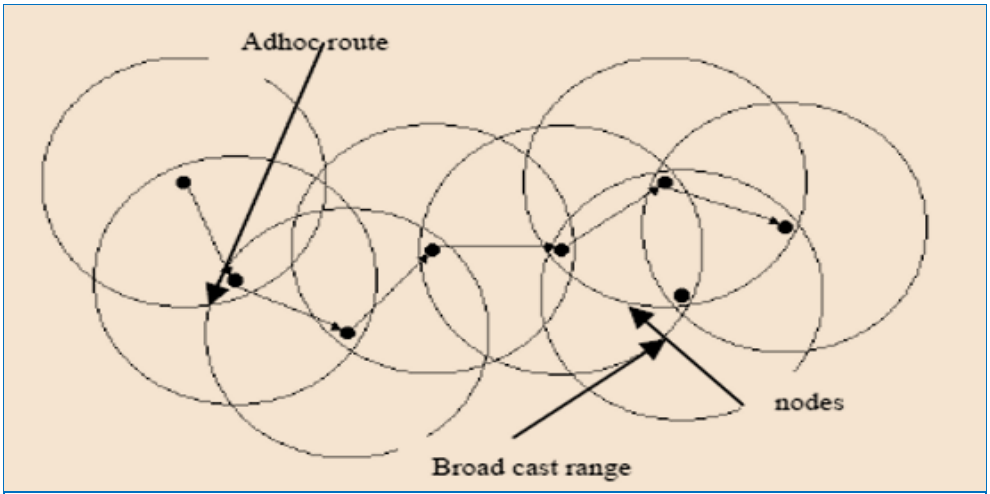



Fig. 2. MANET mobility [9].

In this study, we will be dealing with the following three protocol:

1. Ad hoc on Demand Distance Vector Routing Protocol (AODV): is an on-demand routing protocol for ad-hoc networks discovers route. It works on mainly four types of control messages: Traffic alerts for network activity, Route Request (RREQ) - to start path discovery, Route Reply (RREP)-to confirm and establish the discovered path, and finally Road Error (RERR) messages which notifies nodes of when a route is no longer valid [12].
2. Dynamic Source Routing (DSR): is a simple but effective routing method for ad hoc networks that can become rather ineffective in multi-hop scenarios. DSR is very reactive in nature which means that it only sets up the routes when necessary during data transmission. Using its routing

mechanism, it routes packets from one node to another, so we provide communication for many hops over the network [13], [14].

3. Destination Sequenced Distance Vector (DSDV): is an improvement on the traditional Routing Information Protocol (RIP) that is now specially designed for ad hoc networks, as a proactive and table-driven routing protocol. Each node maintains its own routing table for broadcasting packets within the entire network in this scheme. It is this forward exchange of routing information that maintains the interconnectivity between distinct nodes in the network [15].

## 3. Mobile Ad Hoc network and IoT

IoT defines a system consisting of digitally identifiable devices and objects that communicate with each other without human intervention, over the internet via wireless networks. These devices are commonly referred to as sensory things; therefore, the sensor and actuator capability is built on top of these "things." IoT systems have to deal with a lot of challenges in order to work correctly such as heterogeneity of devices, energy efficiency due to mostly being wireless communication, managing data from millions of sensors and decision-making agents, interoperability between all types of devices and technologies used by IoT devices for communication plus various security problems [16]. Wireless Sensors and Ad Hoc Networks are the technologies that lay the groundwork for connectivity by allowing IoT devices to communicate, share data, and function seamlessly in various environments [17]. Fig. 3 present Mobile Ad-Hoc Network and IoT structure.

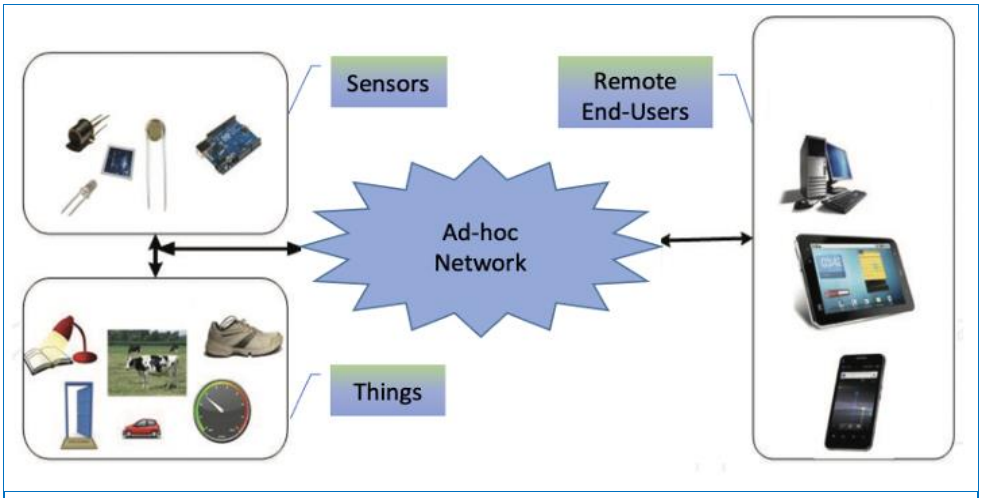



Fig. 3. IoT-MANET structure [18].

## 4. Proposed design of NQoS for IoT-MANET

In the context of IoT applications, especially those deemed mission-critical, the network infrastructure is the backbone of the environment. Adequate measures should be in place at all levels of IoT architecture to accomplish robust QoS [19]. As MANETs are ad hoc in nature, devoid of any fixed physical infrastructure, they encounter a number of challenges related to resource allocation and management. These challenges complicate strict QoS enforcement, which is crucial for enabling reliable operation in dynamic and decentralized settings [20]. The proposed design aims to optimize the QoS variables that effect the network, such as: Hop count (The hop count is the number of hops (intermediate connections) a packet passes through, thus affecting the end-to-end latency within network [2]), Routing protocol, number of retransmissions (The chances of successfully delivering packets decreases with the number of retransmission attempts because once the maximum threshold is reached, any new packet will be dropped [21]), Adaptive Modulation & Coding (AMC) (Through the Orthogonal Frequency Division Multiplexing (OFDM). It implements the 802.11a to provide improved transmission rates [22]) and transmission power. This enhancement depending on the status of the NQoS parameters like: E2E delay, Node Speed, power

consumption and throughput. See Fig. 4 ( Fig.1 on the next page) that presents proposed cross-layers management of IoT-MANET QoS design in order to meet NQoS.

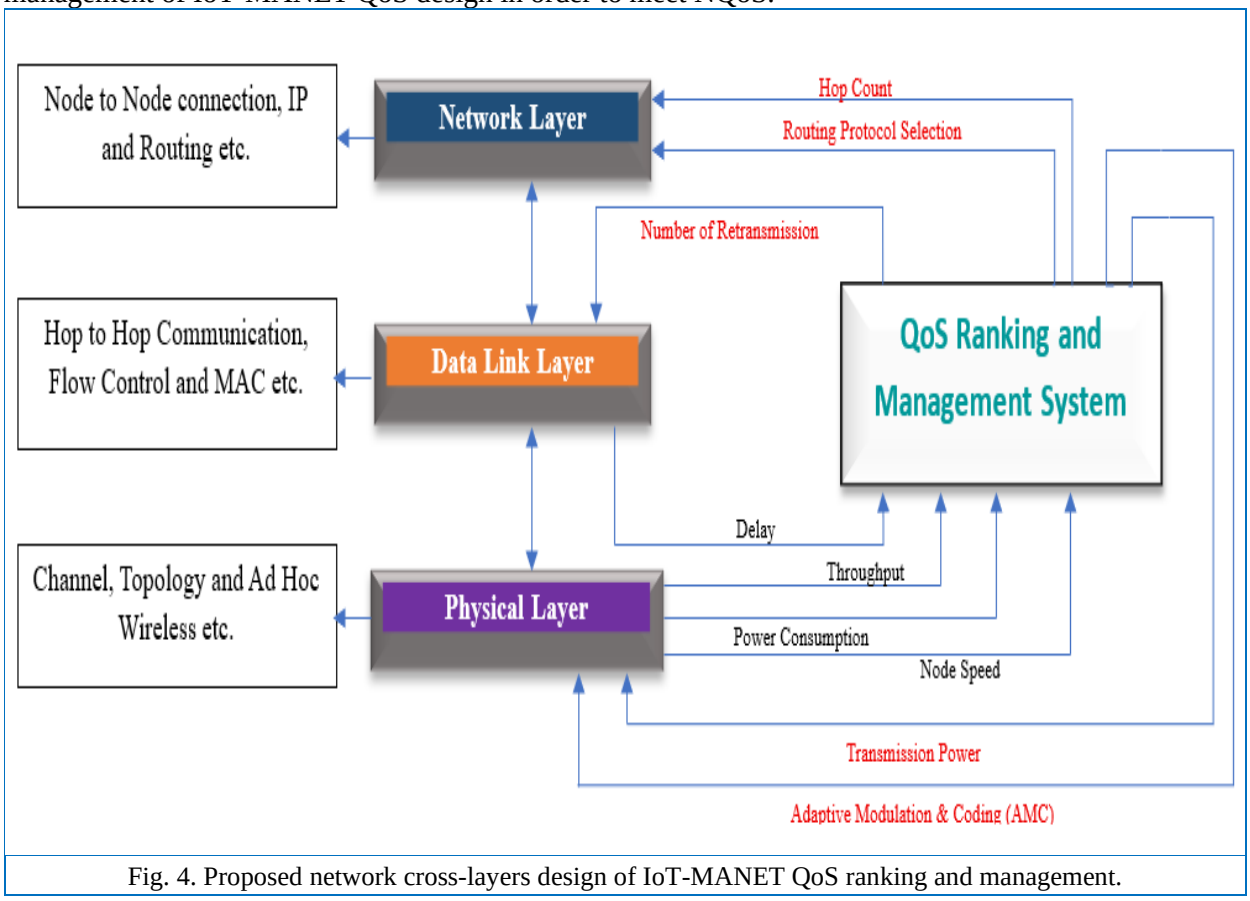



Fig. 4. Proposed network cross-layers design of IoT-MANET QoS ranking and management.

## 5. System model

The system model primarily relies on the fuzzy logic system approach because uncertainty is the measurement of imprecision which may classify a class of data to meet human needs for some control parameter. In addition, it is an effective tool used in the decision-making process where uncertainty and complexity are involved. Fig. 5 ( Fig.5 on the next page) shows the flow chart of our system model. This process starts by collecting relevant parameters from the network layers. The fuzzy control system uses these parameters to produce the respective QoS levels. After that the system evaluates and sets QoS for MANET. It generates suitable QoS report to enhance MANET QoS management through the IoT technologies based on this evaluation.

Fuzzy logic control system generally consists of the following three stages: fuzzification, fuzzy inference and defuzzification. During the fuzzification step, three main activities take place: (1) each input variable value is determined, (2) these values are mapped to the corresponding universe of discourse, and (3) the numerical inputs are transformed into linguistic terms referring to fuzzy sets. “Fuzzy” is a technique that creates human-like models, which are called fuzzy concepts, using fuzzy inference. Fuzzy inference utilizes fuzzy implication and inference rules to identify appropriate fuzzy control actions. Finally, during the defuzzification stage, the fuzzy output is converted back into a crisp value over an appropriate universe of discourse. This generates the definite; no fuzzy action to be performed from fuzzy reasoning. Fuzzy logic has membership functions that allow for transforming input variables into fuzzy sets. Some common types are triangular, trapezoidal and Gaussian functions, each affecting the system's sensitivity to anomalies. The Mamdani and Sugeno models are models that are most commonly utilized in the interference process. The Mamdani model is known for its intuitive and human-interpretable characteristics, whereas the Sugeno model is more computationally efficient (ready to use in real-time applications). These inference

mechanisms are based on rules, where fuzzy logical operators are used (e.g., minimum / AND and maximum / OR) and implication functions (such as the Mamdani implication rule to evaluate and quantify degree of abnormality [23].

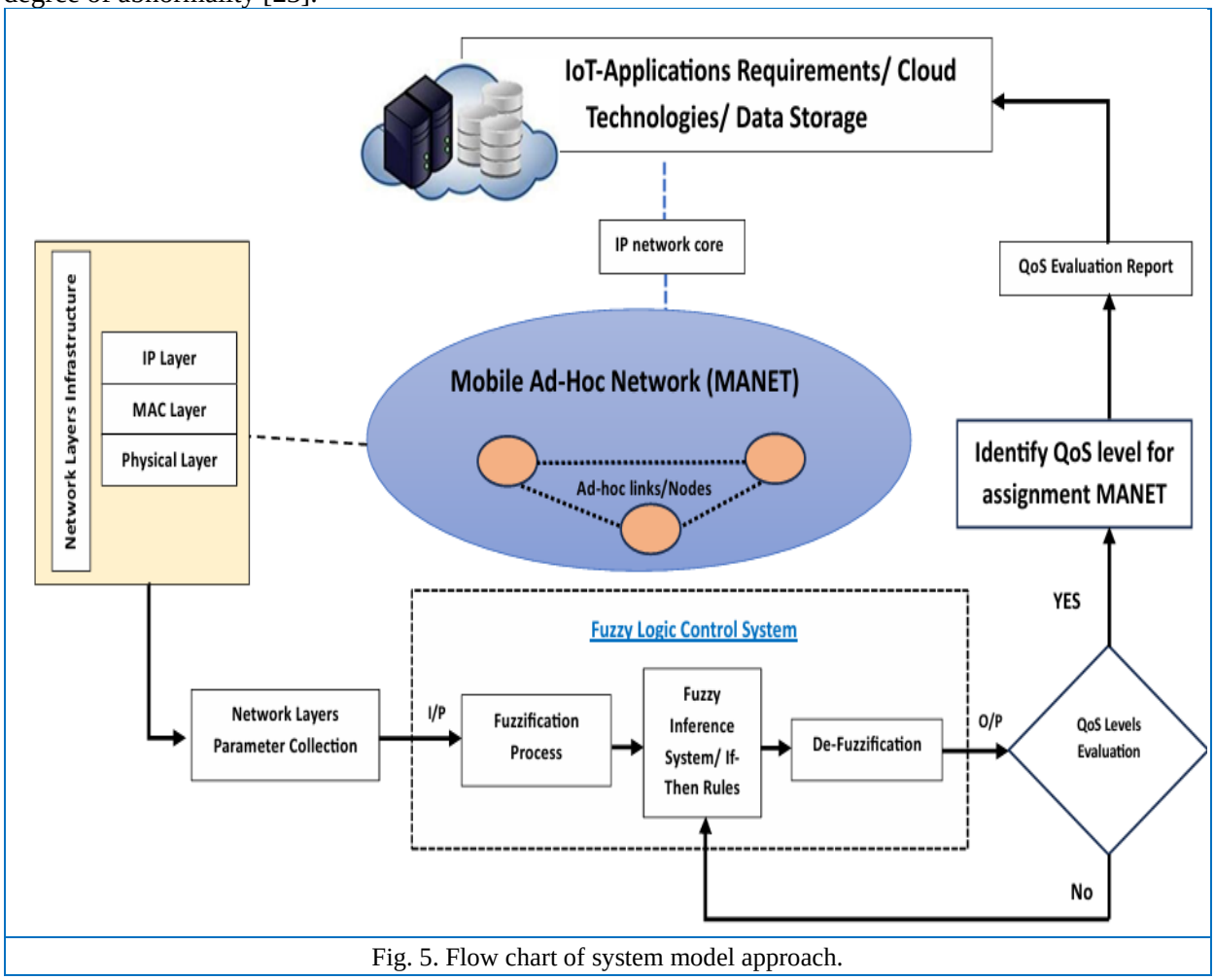



Fig. 5. Flow chart of system model approach.

## 6. Data collection of IoT-MANET layers

In the system model, the following QoS parameter of IoT-MANET NQoS will be collected:

1. Node speed (m/s): Represents how quickly nodes move within the network, influencing the stability and duration of connection sessions [24]. The collected values of this parameter are from 0 m/s to 100 m/s.
2. Transmission Power (mW): Since MANETs operate under limited energy resources, optimizing transmission power is crucial to reduce energy consumption and improve efficiency across layers [25]. The collected values of this parameter are from 0 mW to 1500 mW. This is because minimizing energy consumption at each node has the potential to extend network life time. Average energy consumption can be determined in this way:

$$\text{AvgEngConsumption} = \frac{(Initial\ Energy - End\ Energy)}{N} \quad (1)$$

Where N is the total number of nodes in the network.

3. Throughput is a performance metric that measures the amount of data successfully transmitted over the network within a given time frame [26]. The collected values of this parameter are from 0 to 1.

$$Throughput = \frac{Number\ of\ Delivered\ Packets}{Time} \quad (2)$$

4. Network E2E delay Defined as the time difference between when the sender hands a packet to RTP and when the receiver retrieves it from RTP. RTP (Real-Time Protocol) is commonly used for transmitting audio and video data over IP networks [27]. The collected values of this parameter are from 0 ms to 2.5 ms. E2E delay can be find as follow:

$$E2E\ Delay = N\ (Transmission\ Delay + Propagation\ Delay + Processing\ Delay) \quad (3)$$

Where N is the total number of transmissions.

## 7. Proposed model performance evaluation and results

The performance evaluation has been studied using a MATLAB-2021b simulator. The model's performance has been analyzed by using a Fuzzy logic approach and a Mamdani inference process. The collected parameter of NQoS is applied as an input for the fuzzy control system and the output is the QoS level that required to improve the network of IoT-MANET. The proposed fuzzy logic machine is shown in Fig. 6.

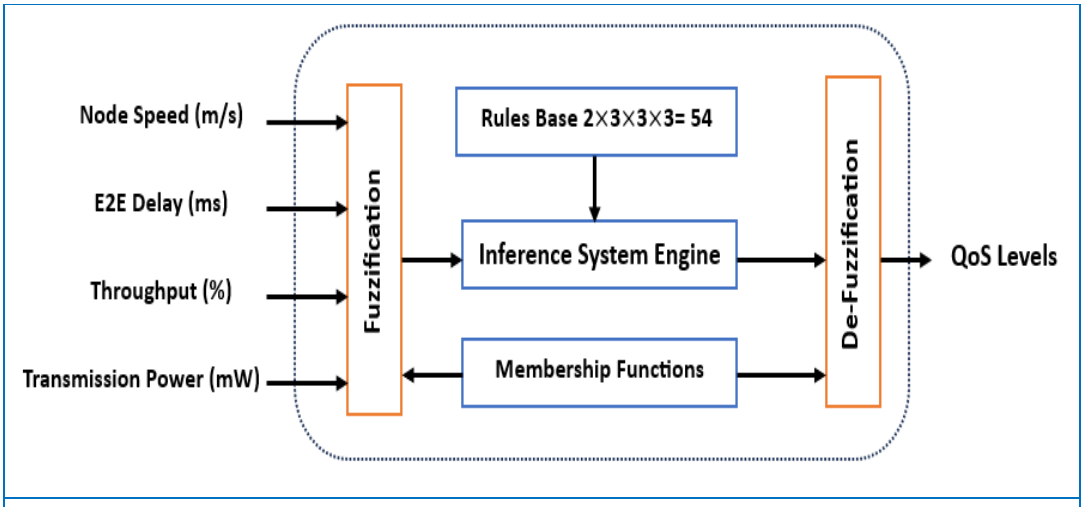



Fig. 6. Proposed proactive fuzzy agent machine.

In this study, we used the Mamdani model for inference and the triangular member function (MF) with AND (minimum) operator and trapezoidal MF. A triangular MF μ(x) curve depends on three parameters a1, a2 and a3. MF $\mu(x)$ is defined as:

$$\mu(x) = \begin{cases} 0 & if\ x < 0 \\ \frac{(x-a1)}{(a2-a1)} & if\ a1 \le x < a2 \\ \frac{(a3-x)}{(a3-a2)} & if\ a2 \le x\ < a3 \\ 0 & if\ x\ > a3 \end{cases} \quad (4)$$

where a2 is the peak location, while a1 and a3 define end points of the triangle.

A trapezoidal MF $\mu(x)$ is defined as:

$$\mu(x) = \begin{cases} 0 & if\ x < a \\ \frac{(x-a)}{(b-a)} & if\ a \le x \le b \\ 1 & if\ b\ \le x\ \le c \\ \frac{(d-x)}{(d-c\ )} & if\ c \le x \le d \\ 0 & if\ x > d \end{cases} \quad (5)$$

Where, a: membership start point, b: membership left shoulder, c: the peak or center and d: membership (right shoulder).

In simulation setup, we set four parameters ( Node Speed, E2E delay, Throughput and Tansmission Power) as the input and the QoS as the output. In this approach, there is one fuzzy inference system that has been taken advantage of. The crisp value of the input parameter and the member function MF and the Linguistic Variables LV description of input parameters is explained in Table 1. The QoS level has six LV (0,1,2,3,4,5) and all MFs are represented in Triangular type as shown in Table 2.

Table 1. MF of Input Variables.

| Variable | Linguistic Variable | Crisp Value | MF Type |
|---|---|---|---|
| Node Speed (m/s) | Low | 0-0- 50-80 | Trapezoidal |
| | High | 30- 50 – 100-100 | Trapezoidal |
| E2E Delay (ms) | Low | 0-0 -0.5-1 | Trapezoidal |
| | Moderate | 0-1-2 | Triangular |
| | High | 1-1.75-2.5-2.5 | Trapezoidal |
| Throughput | Low | 0-0-0.25 – 0.5 | Trapezoidal |
| | Moderate | 0.1 –0.5- 0.9 | Triangular |
| | High | 0.5 -0.75-1-1 | Trapezoidal |
| Transmission Power (mW) | Low | 0-0-375-750 | Trapezoidal |
| | Moderate | 150-750-1350 | Triangular |
| | High | 750-1350-1500-1500 | Trapezoidal |

Table 2. MF of QoS Variables.

| Variable | Linguistic Variable | Crisp Value | MF Type |
|---|---|---|---|
| QoS Levels | 5 | 80-100-100 | Triangular |
| | 4 | 60-80-100 | Triangular |
| | 3 | 40-60-80 | Triangular |
| | 2 | 20-40-60 | Triangular |
| | 1 | 0-20-40 | Triangular |
| | 0 | 0-0-20 | Triangular |

The number of the rule base is 54 depending on the number of the LV and input variables. The rule base of FIS is presented in Table 3.

Table 3. FIS Rule Bases.

| Node Speed | Delay | Throughput | Transmission Power | QoS Levels |
|---|---|---|---|---|
| Low | Low | High | High | 5 |
| Low | Low | High | Moderate | 4 |
| Low | Low | High | Low | 3 |
| Low | Low | Moderate | High | 4 |
| Low | Low | Moderate | Moderate | 3 |
| Low | Low | Moderate | Low | 2 |
| Low | Low | Low | High | 3 |
| Low | Low | Low | Moderate | 2 |
| Low | Low | Low | Low | 1 |
| Low | Moderate | High | High | 4 |

| | | | | |
|---|---|---|---|---|
| Low | Moderate | High | Moderate | 3 |
| Low | Moderate | High | Low | 2 |
| Low | Moderate | Moderate | High | 3 |
| Low | Moderate | Moderate | Moderate | 2 |
| Low | Moderate | Moderate | Low | 1 |
| Low | Moderate | Low | High | 2 |
| Low | Moderate | Low | Moderate | 1 |
| Low | Moderate | Low | Low | 0 |
| Low | High | High | High | 3 |
| Low | High | High | Moderate | 2 |
| Low | High | High | Low | 1 |
| Low | High | Moderate | High | 2 |
| Low | High | Moderate | Moderate | 1 |
| Low | High | Moderate | Low | 0 |
| Low | High | Low | High | 1 |
| Low | High | Low | Moderate | 0 |
| Low | High | Low | Low | 0 |
| High | Low | High | High | 4 |
| High | Low | High | Moderate | 3 |
| High | Low | High | Low | 2 |
| High | Low | Moderate | High | 3 |
| High | Low | Moderate | Moderate | 2 |
| High | Low | Moderate | Low | 1 |
| High | Low | Low | High | 2 |
| High | Low | Low | Moderate | 1 |
| High | Low | Low | Low | 0 |
| High | Moderate | High | High | 3 |
| High | Moderate | High | Moderate | 2 |
| High | Moderate | High | Low | 1 |
| High | Moderate | Moderate | High | 2 |
| High | Moderate | Moderate | Moderate | 1 |
| High | Moderate | Moderate | Low | 0 |
| High | Moderate | Low | High | 1 |
| High | Moderate | Low | Moderate | 0 |
| High | Moderate | Low | Low | 0 |
| High | High | High | High | 2 |
| High | High | High | Moderate | 1 |
| High | High | High | Low | 0 |
| High | High | Moderate | High | 1 |
| High | High | Moderate | Moderate | 0 |
| High | High | Moderate | Low | 0 |
| High | High | Low | High | 0 |
| High | High | Low | Moderate | 0 |
| High | High | Low | Low | 0 |

In simulation process for the rule base of FIS, we observe the following point of model performance:

1. In Fig. 7 ( Fig.7 on the next page): The QoS levels can be changed dynamically between QoS ranking points ( 0 to 5) depending on the input parameters of the IoT-MANET. As shown in the figure, The QoS level is 65.7 (That is mean the rank of QoS is 3) when node speed equal to 28.4 (m/s), E2E delay equal to 0.616 (ms), throughput equal to 0.807 and transmission power equal to 790 mW.

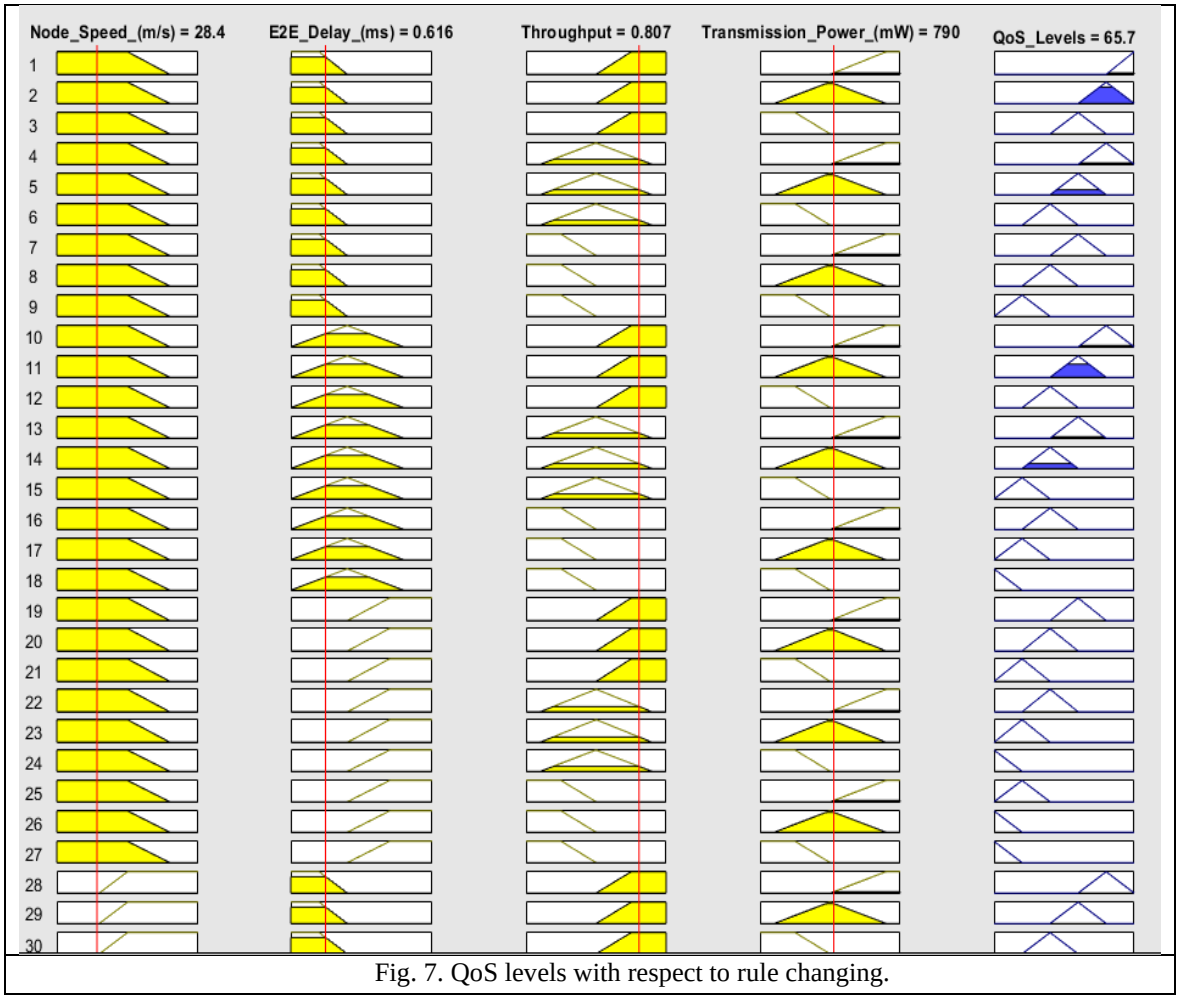



Fig. 7. QoS levels with respect to rule changing.

2. In Fig. 8: QoS levels has a positive relationship with Transmission Power and a negative relationship with E2E delay here, which means QoS scores is jointly determined by these two factors. As we can see, increasing value of transmission power will influence a higher QoS rank outcome, while increasing E2E delay will result in smaller values of QoS rank.

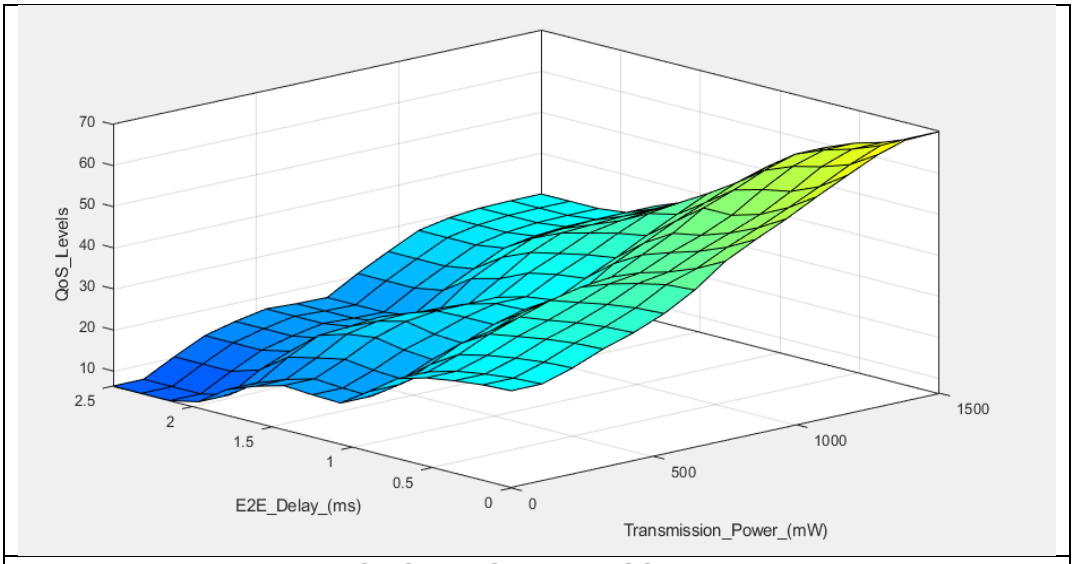



Fig. 8. QoS levels regarding to E2E delay & transmission power.

3. In Fig. 9: The increasing in throughput pulls QoS ranking up while the increases in node speed pull it down; thus, QoS scores is influenced by the joint function of node speed and throughput (vice versa).

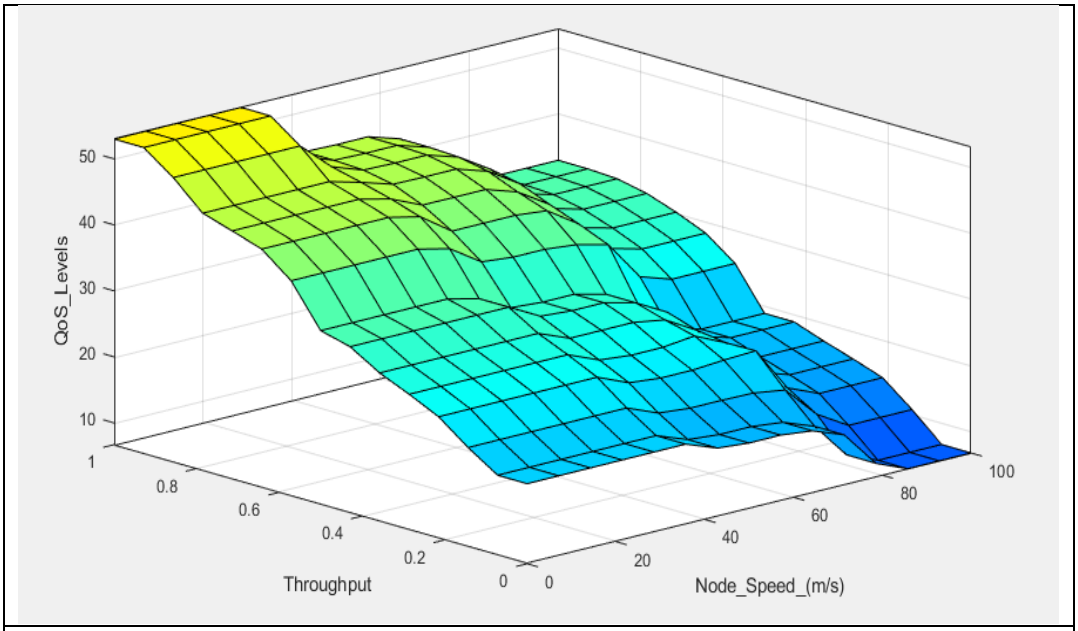



Fig. 9. QoS levels regarding to node speed & throughput.

4. The previous observation of the system performance shows the proactive agent machine to observe the network and achieve a suitable QoS levels. This agent machine will work properly to choose suitable IoT-MANET routing protocol and increase NQoS by maintain the number of retransmissions, give suitable way for Adaptive Modulation & Coding (AMC) and manage the Hop count number.

## 8. Discussion

### *8.1* IoT-MANET Routing Protocol Selection

QoS levels directly affects on the protocol selection in the network. If the level of QoS is very low (has

score 1), then the selected network protocol (SNP) will be DSDV because DSDV Works in static/low-mobility networks; proactive tables help maintain routes even under poor QoS, though overhead is high. At Low or Moderate value of QoS (2 or 3 score), the SNP will be DSR because the DSR is better than DSDV in small/moderate networks; handles moderate QoS with route caching and Balanced choice; performs reasonably with average QoS conditions. When QoS score is high or very high (4 or 5 score) the SNP will be AODV because AODV adapts well to dynamic conditions with high throughput, scales efficiently and low delay.

### *8.2* IoT-MANET NQoS Variable

The QoS levels affect directly on the QoS variables in network layers: AMC, Retransmission and hop count as across layer improvement. The explanation of this effect is presented in Table 4.

Table 4. IoT-MANET NQoS Variable Regarding to QoS Scores.

| QoS Score | AMC (Adaptive Modulation & Coding) | Retransmissions | Hop Count |
|---|---|---|---|
| 1 (Very Poor) | Robust (low modulation, strong coding, e.g., BPSK + strong FEC) | Many | Long (≥6 hops) |
| 2 (Poor) | Robust-Balanced (QPSK + strong coding) | Moderate | Medium-Long (5–6 hops) |
| 3 (Moderate) | Balanced (QPSK/16-QAM with moderate coding) | Moderate | Medium (4–5 hops) |
| 4 (Good) | Aggressive-Balanced (16-QAM + lighter coding) | Few | Short-Medium (3–4 hops) |
| 5 (Excellent) | Aggressive (high modulation, e.g., 64-QAM, minimal coding) | Few | Short (≤2 hops) |

### *8.3* IoT-MANET Energy Consumption

In physical layer, data link layer and network layer, the energy consumption is an important factor that affects the NQoS in IoT-MANET. In the proposed model, the outcome QoS level will control energy consumption in the communication process between the nodes. Input NQoS parameter to the system model (like node speed and others) affects directly on energy saving with greater returns. The speed of nodes has a critical impact on the operational states which can be transmitting, receiving or idling. Movement of nodes at speed increases their time in transmit and receive mode, as routing has to be performed more frequently; whereas slower or stationary nodes sit idle for longer before sending packets thereby saving energy.

## 9. Conclusions

This study evaluated the performance of proposed model by using simulation toolbox of fuzzy control system in MATLAB 2021b. For IoT-MANET applications, data is transmitted from the Source to its Destination using routing protocols providing efficient mechanism to meet NQoS. In the system, we proposed proactive agent machine to improve the NQoS. The NQoS parameters of IoT-MANET, namely, node speed, throughput, transmission power and E2E delay used to determine the QoS levels. The fuzzy gives a reliable control system to evaluate the model. The proposed model's performance can clearly improve and manage the cross-layer quality of service variable and select the suitable routing protocol in order to enhance the network performance dynamically. This paper proposed system model that achieves IoT-MANET QoS management and ranking to get QoE satisfaction and solves routing protocol issue, communication process and energy consumption.

The outcomes of this study will be integrated with Next Generation quality-of-service (NGNQoS) requisites in the future research. The quality of service is also being refined and updated, either by introducing new parameters or components to measure their impact on the proposed system.

**Author Contributions:** The authors contributed to all parts of the current study.

**Funding:** This study received no external funding.

**Conflicts of Interest:** The authors declare no conflict of interest.

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