EISSN: 2707-0425

East African Journal of Science, Technology and Innovation, Vol. 4 (1): December, 2022

Implementation of Quality of Service-Oriented Distributed Routing Protocol using Fuzzy Logic in Mobile Ad Hoc Networks

[1]TUYISHIME J C, [1]MUGISHA E*

[1*]Department of Information Technology, University of Lay Adventist, Kigali, Rwanda

***Corresponding Author**: tjclaudemvuyekure@gmail.com

Abstract

A mobile ad hoc network (MANET) is a type of wireless network made up of nodes that are both wireless and mobile. This type of wireless network is a non-infrastructure network (without a central manager such as router, servers, etc.) that is hard to manage; providing the Quality of Service (QoS) is also difficult. The fuzzy logic is one of the effective methods required to achieve high QoS in MANET. We propose an Ant-colony Based Cluster-head (ABC) selection a protocol based on artificial intelligence fuzzy logic techniques in this paper. With the proposed protocol, we divide the network into clusters, then, choose a cluster head which is a node having high residual energy, the most trusted; this is achieved using Ant-colony optimization (ACO) algorithm thanks to the use of a probability function which determines the likelihood of various nodes to be selected as cluster-heads. Using the Network Simulator Version-2 (NS-2), we evaluated our Proposed Protocol with ones existing in literature; Quality of Service-Ad-hoc On-Demand Distance Vector (QoS-AODV), Bandwidth aware Multi-path Routing protocol in mobile Ad Hoc networks (BMR) and Dynamic Multi-Path Source Routing Method (MSR). We conducted various experimental evaluations varying both the number of the total mobile nodes in the network and the number of receivers from a single sender; all simulation outcomes revealed that the Proposed protocol; Quality of Service-Oriented Distributed Routing Protocol using Fuzzy Logic and clustering techniques in Mobile Ad Hoc Networks (QODFL) outperformed the existing ones as compared to existing protocols, it was able to increase both the Packet Delivery Ratio by 10.5% and throughput by 6.7 % , and the End-to-End Delivery ratio by 7.7%.

Keywords: *ACO with Fuzzy Logic; Clustering; Energy; MANET; Multimedia Applications; Quality of Service; Routing*

Received: 21/07/22
Accepted: 07/09/22
Published: 16/12/22

Cite as: *Tuyishime and Mugisha, (2022)* Implementation of Quality of Service-Oriented Distributed Routing Protocol using Fuzzy Logic in Mobile Ad Hoc Networks. *East African Journal of Science, Technology and Innovation 3(4).*

Introduction

A MANET is a wireless network made up of nodes which are naturally mobile that lacks fixed infrastructure and centralized control. MANET communication is divided into two types: single-point communication and multi-point communication which can be accomplished via multi-hop paths.

In a MANET, each mobile node can act as a router; sending data packets to other mobile nodes. For intercommunication, a mobile ad hoc network does not require wired access points or base stations. They communicate via single-hop or multi-hop through intermediate nodes to transfer data. Because MANET allows services to be provided from anywhere, at any time, no infrastructure is required (Park & Corson, 2021).

MANET can used in a variety of settings, including military battlegrounds, classrooms, conference halls, emergency services, education, entertainment, and crisis management services, among others. We can also use media tools to watch videos and listen to music from anywhere and at any time via online MANETS, which are currently being developed in massive applications such as video conferencing and video on-demand applications, among others but because of the self-organizing nature of the MANET, bandwidth is sometimes limited (Tsai *et al.,* 2016).

To address this issue, a virtual backbone network is sometimes set up; this type of network performs well in terms of routing, connectivity management, and broad casting operations. As wireless networking with virtual backbone feature has grown in popularity in recent years, many researchers have devoted their efforts to supporting real-time transmission which frequently necessitates high Quality of Service (QoS) achievement by various protocols in order to achieve successful end-to-end data packet delivery (Kuipers *et al.,* 2022).

Because of the infrastructureless nature of this type of wireless network, various routing protocols failed in providing high Quality of Service, a prominent key feature of MANETs used in various networking domains especially for unexpected events which require an immediate attention such as earthquakes, flood, accident and military operations, etc. (Elizabeth *et al.,* 2015).

Quality of Service (QoS) can be used as a metric to assess the effectiveness and efficiency of ad-hoc networks. It is a complex function because it is dependent on various network factors that vary with time, such as network PDR, network throughput, delay and jitter, etc. Providing high QoS in MANET is sometimes difficulty in MANET especially in transmitting various types of data such as text, audio, image, and video for multimedia applications (Biradar and Kulkarni, 2015).

To achieve high QoS in MANET, one of the important factors that must be considered is the energy, location, and mobility of nodes; thus, there must be a specific way to determine the residual energy and mobility; a protocol or algorithm which takes into consideration clustering is required to achieve high Quality of Service. We can use the fuzzy logic technique to determinate a location of any node i.e. its degree among other nodes in the network (Lin and Liu, 2021).

In this paper, we design and develop a new Quality of Service-Oriented Distributed Routing Protocol using Fuzzy Logic and clustering techniques in Mobile Ad Hoc Networks (QODFL) aiming at selecting a network node which consumes energy at a low level and currently has a high residual power with lower mobility, with lower degree relative to the sender compared to others; this is achieved thanks to the probability function, which is used in determining the probability for various nodes to be selected. It's the duty of the F-ANT in the fuzzy logic operation to collect these three network parameters by broadcasting a hello message throughout the whole network.

As a result, a node with a high residual Energy, low Mobility, and a low Degree is chosen as the cluster-head. We finally evaluated the proposed protocol with existing protocols namely QoS-AODV, BMR, and MSR. Those protocols have same potentials characteristics in relation to the proposed protocol in term of Quality of Service and bandwidth provision, source routing, etc.

We tested the protocol's efficacy in the NS-2 simulator using both analytical and simulation models, and the results showed that the Proposed Protocol can provide high QoS performance in terms of increased both PDR and network throughput and a reduced transmission delay.

The rest of the paper is organized as follows. Section II presents Materials and methods. Section III depicts *Methodological Experimentation.* Section IV discuss the Proposed Protocol. Section V presents Results

While Section VI presents the Discussion and Section VII concludes our Work.
The paper is concluded in Section V.

Materials and methods

Methodological tools

We simulate the whole network in the Network Simulator Version 2 which has many advantages that make it a useful tool, such as support for multiple protocols and the capability of graphically detailing network traffic. Additionally, NS2 supports several algorithms in routing and queuing. Local Area Network (LAN) routing and broadcasts are part of routing algorithm.

QODFL is an efficient protocol as it responds very well on the different hardware manufactured by different vendors, we tested the results on different hardware varying from Personal Computer (PC) to laptops. For programming and analysis purpose, we used the following hardware and software; a Personal Computer (PC) with Pentium IV processor and above, a Random Access Memory (RAM) of 2 GB and above, hard disk with 20 GB free-space and Windows 8 and above or new versions of Linux such as Fedora, Ubuntu, Mint can be also used. C++ was used as the back-end tool and TCL as front-ent tool. Gnu-plot was used for plotting purposes.

As mobile in MANET are mobile, we use the mobility model to model node movements using a random way-point model as its a model for the movement of mobile users, and how their location, velocity and acceleration change over time. For scheduling data during data transmission, a sender schedules data packets after receiving at least one acknowledgment from the receiver.

For Protocol implementation, we first implemented the Proposed protocol with new codes and finally have used the original source codes of various existing prominent QoS-oriented routing protocols to compare them with our Proposed Protocol; Quality of Service-Ad-hoc On-Demand Distance Vector (QoS-AODV) (Pradeep and Soumya, 2020), Bandwidth aware Multi-path Routing protocol in mobile Ad Hoc networks(BMR) (Yang *et al.,* 2011), and Dynamic Multi-Path Source Routing Method (MSR) (Qin and Liu, 2014).

We finally used routing metrics to compare the performance of QoS-Aware cluster-based routing protocols. Three metrics WERE used: Packet Delivery Ratio (PDR), Delay, and Throughput.

Methodological Experimentation

We simulated a network with a fixed size of 1000m x 1500m which is a good coverage area which can fit with any screen size in simulation within a rectangle area on the screen with varying number of nodes namely 10, 15, 20, 25, and 30 nodes. Simulation results were then examined. The performance of routing metrics namely PDR, Throughput, an End-to-End Delay was also assessed by comparing the Proposed Protocol to the traditional routing protocol using NS-2.

Population

The population of this network is discrete group of wireless nodes that can be identified by at least one common characteristic for the purposes of data collection and analysis. This study's population consists node's Residual Energy, Degree, and Mobility of data packets; three parameters that are regularly corrected at each node by an F_ant node.

Sampling

A sample of nodes and packets from the universe was drawn using the random sampling method (the totality of network nodes and data packets). We changed the sample size by varying the number in multiple of 5 as this minimum interval which normally presents clearly significant changes in routing metrics for low, medium, and high-dense network; sample size varies from10 to 30 nodes.

Data and Population

The population of this study is made up of nodes and primary data gathered from various analyses conducted during this research, as well as secondary data gathered from books, websites, journals, and previous research works.

Data collection Tools

During the simulation period, data was collected from the aforementioned samples and printed on

a trace file before being processed with the Aho, Weinberger, and Kernighan Computing (AWK) tool. A descriptive design based on primary and secondary data was used in this study. During the simulation processes, primary data was collected.
Secondary data was drawn from previous research works, the Internet, and other sources to support the primary data results.

Data Analysis

We used Mathematical modeling to provide a detailed analysis of the study by displaying the effects of various components and forecasting their behavior. We also used Simulation modeling using the Network Simulator Version 2 to design a digital prototype of our study's physical model in order to predict its performance in the real world.

Proposed Protocol

Several ants are launched toward the destination node in order to determine the most cost-effective path from the source to that node. Our implemented protocol, as well as the clustering and Swarm Intelligence techniques used in this protocol are described in detail using both analytical modeling and pseudo-codes.

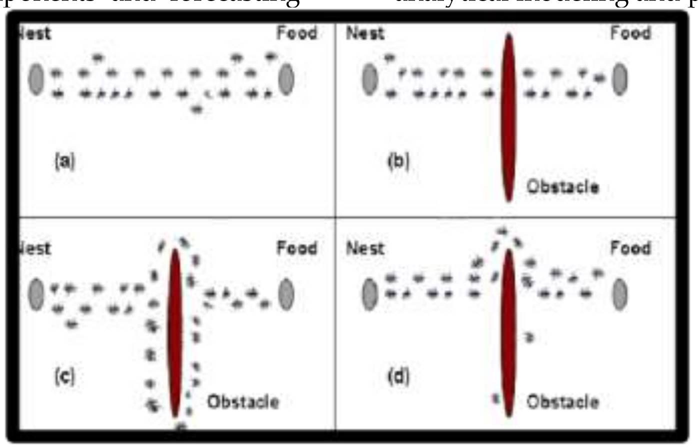


Figure 1. Ant Colony Optimization Technique

Prominent QoS-based and Optimization Techniques for the proposed protocol

Ant-Colony Optimization (ACO)

ACO, a well-known swarm intelligence approach, was inspired by the social behaviors of real-world ants. This algorithm determines the best route for routing based on the pheromone depositions made by these ants on a regular basis.

They return to their nests when they find food and leave pheromones along the paths. As a result, they are more likely to pass through these channels and strengthen (update) the existing pheromone. The pheromone begins to evaporate and loses strength over time.

Each ant in ACO chooses its next hop based on two parameters on a regular basis. The quantity of pheromone provided by ants on the path between one node and the next node on the same path, and the second is the queue length of the link.
Ants travel forward and backward along the same path depositing new pheromone from the nest to the food.

The same pheromone degrades over time due to evaporation while ants constantly seek the cheapest and best path throughout the process. Choosing the best path is a difficult task because it requires two parameters: the quantity of pheromone deposited along the path to the next-hop/node and the length of the queue along that path toward the next node.

When the forward or backward ants come across an obstacle, they deviate slightly but never lose sight of their ultimate goal: finding food (Figure 2).

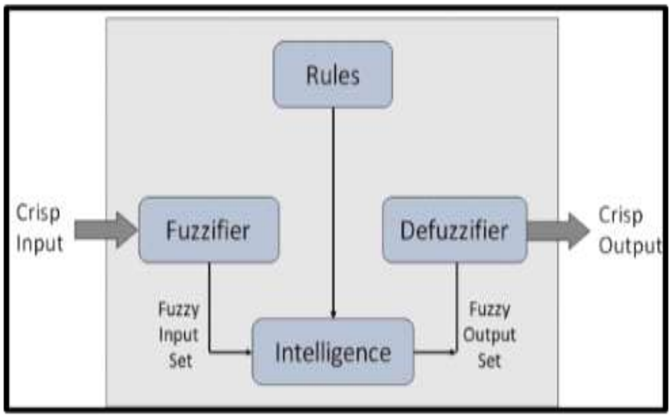


Figure 2. Fuzzy Logic System

Fuzzy Logic System (FLS)

Fuzzy logic is an artificial intelligence mechanism that mimics human reasoning by utilizing various possibilities between the digital values YES and NO or TRUE and FALSE. A computer can understand the conventional logic block, which takes precise input and produces a definite or precise corresponding output value, i.e. TRUE or FALSE which we can compare to the human response values YES or NO.

In general, the term "fuzzy" refers to things that are unclear or ambiguous. In real life, it is not always possible to decide whether a given statement is true or false. This concept at the time provided many values between true and false, but it is a way to provide flexibility in order to find the best solution to the current problem statement. This problem-solving technique is typically used to produce finite output and is implemented in software and hardware, particularly in microprocessors, microcontrollers, network, and workstation-based systems.

The Fuzzy Logic Systems have four components, each of which plays a specific role in the architecture: the Rule Base, Fuzzification, Inference Engine, and Defuzzification; their functions are depicted below, and their arrangement is depicted in Figure 2.

First component: Rule Base

The rule base is the first component in the architecture that contains various rules. The IF-THEN condition is also provided; these are extremely valuable assets for experts in controlling systems who specialize in decision-making operations. Nowadays, robust and updated fuzzy logic theories have been implemented, providing efficient methods for turning off or designing multi-purpose controllers, particularly those required to reduce the number of fuzzy rule sets.

Second Component: Fuzzification

Fuzzification is another important component that transforms and converts system inputs, i.e. crisp numbers (sensor inputs) are converted to fuzzy steps. The procedure is as follows: sharp numbers are transformed and fuzzified before being passed to various control sub-modules for further processing. During the process, the input signals or sensor inputs are classified as Large Positive (LP), Medium Positive (MP), Small (S), Medium Negative (MN), and Large Negative (LN).

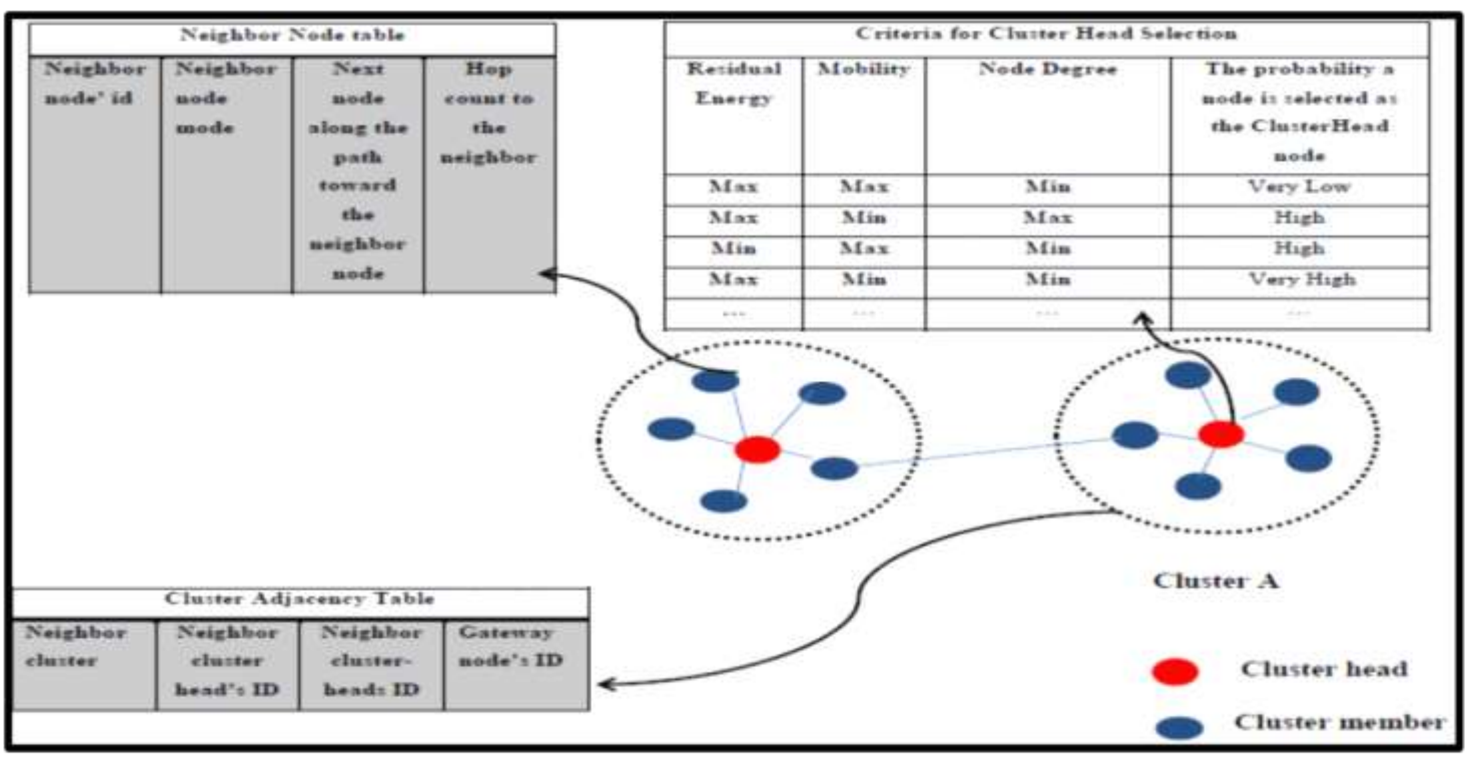
Third Component: Inference Engine

the Inference Engine is the most important component of the architecture, and it is always used to process all data. It matches the current fuzzy input and current rules, so the system knows exactly which rule to add based on the currently given input field, resulting in the execution of all rules while developing the control actions.

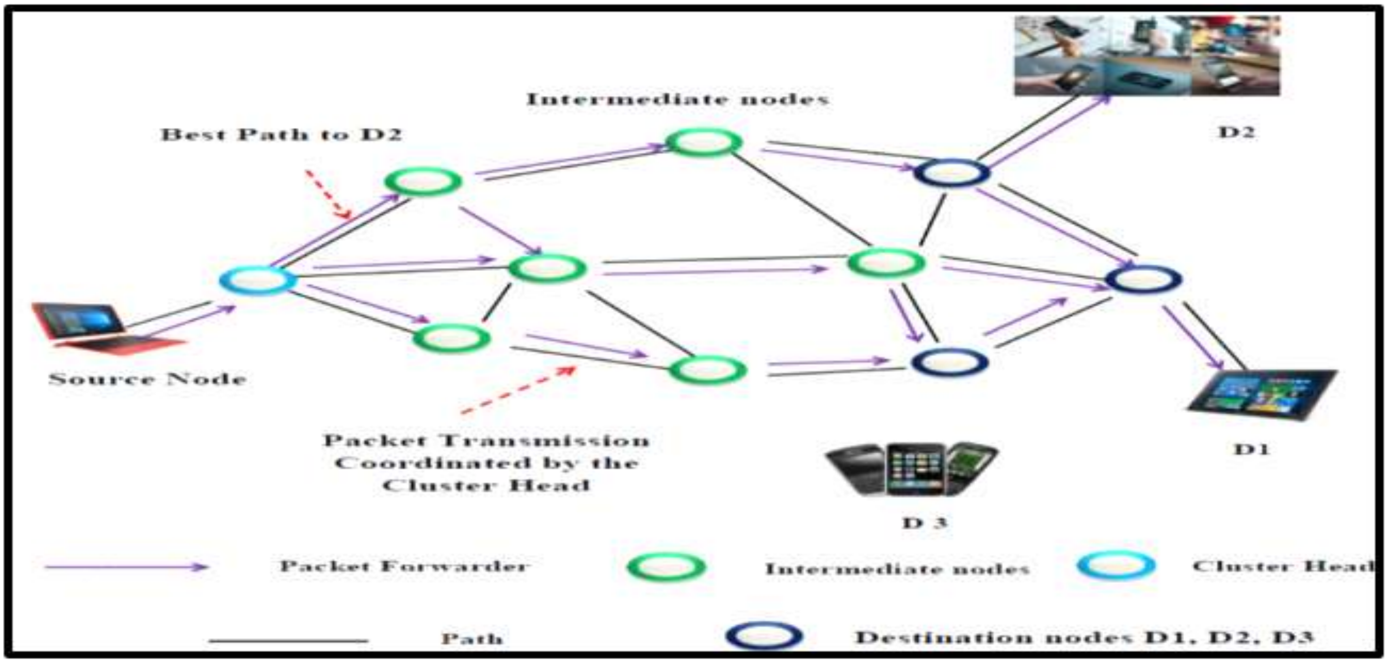
Fourth Component: Defuzzification
Defuzzification is the last module and final step in the development of a fuzzy logic system in which fuzzy sets are transformed into crisp values that the current user accepts; among many available techniques, the user must choose the most important ones to reduce defuzzification errors.

Proposed Protocol's Framework
We proposed a very efficient QoS-enhancement protocol in this research work; Quality of Service-Oriented and Ant-Colony-Based Cluster Head Selection Protocol with ACO and Fuzzy Logic Technique (QODFL) which is implemented using two popular QoS provision techniques, namely the Ant-Colony Optimization Technique with the fuzzy logic approach and the clustering technique. Its primary goal is to achieve high QoS in order to effectively transmit various types of data packets in MANET.

It accomplishes this by decreasing end-to-end latency while increasing packet delivery ratio and throughput. Based on the study's objectives, the protocol is implemented in two phases, as shown in Figure 3. The first process consists of clustering the network into small clusters and electing a cluster head, i.e. a stable and reliable node with high residual energy, less mobility, and lower node degree.
In the second phase, we use the chosen cluster head to find and maintain an optimal link along the path from a node to another, and then we transmit various types of data packets using this found path, this results in increased both PDR and throughput and highly reduced data packets' delay.



Process **1:** *Cluster head Selection*



Process 2

Packet Transmission under Cluster Head Coordination

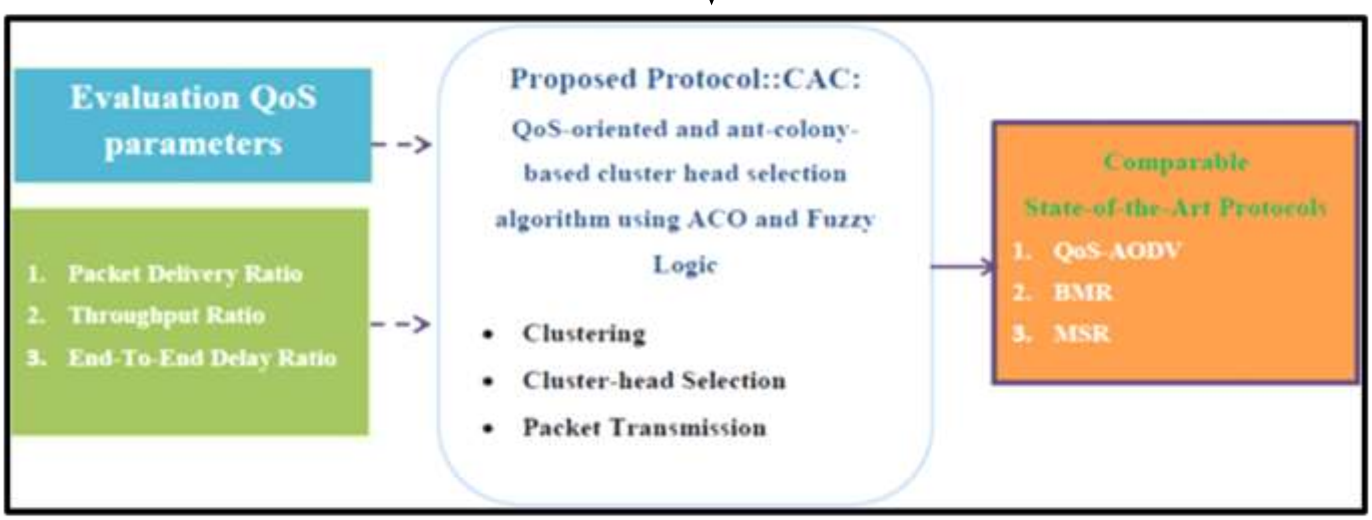


Figure 3. Framework of the Proposed Protocol

Protocol Implementation; QODFL: Analytical Modeling

The Protocol implementation consists of four prominent phases (sub-modules) namely cluster formation, cluster-head selection and cluster-head's route discover and data packet transmission; combined, these sub-modules form the Proposed Protocol's overall Design and Implementation.

A. Phase I: Cluster Formation

This model represents a MANET with mobile nodes moving in the network's communication range in various random directions. Once deployed, the network nodes are assigned unique Identifiers

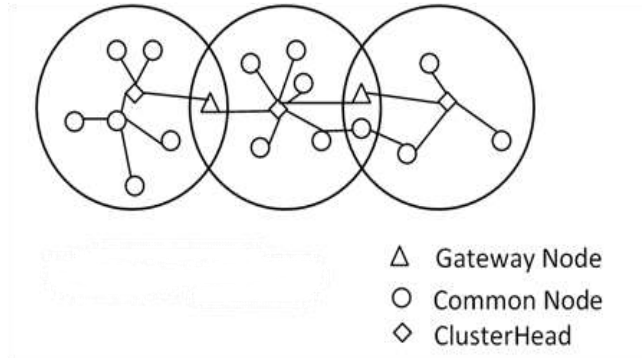


Figure 4. Cluster Formation in MANETs

(ID)s, via Carrier Sensing Multiple Access Collision Avoidance (CSMA/CA) protocol, each node regularly broadcasts its unique ID to every member node of it its neighbors' nodes.

This is the bootstrapping process and each node is required to maintain a table containing neighbor information and transmit it via wireless communication links which are available when two or more communication nodes are within the same transmission range. The broadcasted message is passed through the wireless link and is only possible when two or more nodes are within the communication range of each other.

The following terminologies are used to implement the new protocol's analytical model:
(i) Let N={n_1,n_2, ..., n_n} be set of network nodes.
(ii) = {ch_1, ch_2, . . . ,ch_m) is a set of cluster-heads which were selected such that(1>m).
(iii) T_{range} (Ch_a) is the communication and transmission range of the elected cluster-head ch_a.
(iv) W(n_i) is the node degree or weight of a network node n_i
(v) N(n_i) is the current calculated cardinality of the network node n_i.
(vi) dist(n_i,n_j) is the Euclidean distance between nodes n_i and n_j.
(vii) S(ch_a) is the current strength of the cluster head selected ch_a.

The cluster formation process divides the network into different groups of nodes, each of which forms a cluster.
The main goal of this approach is to lower the transfer rate and assign each node to a cluster so that communication between them is easier. Each node can be one of three types: a common or normal node, a cluster-head node, or a gateway node.

Energy Model

Rao & Singh (2014) developed a model to assess a network node's residual energy in order to determine how long it will remain awake during packet transmission operations.
We used the same model in this study to calculate the amount of power consumed by nodes in a given amount of time.

We use various metrics used to evaluate the node's energy such as receiving power (energy consumed by the node while receiving packets), transmission power (Energy consumed during the transmission of data), and sleep-power (small energy consumed by a node during sleeping mode), and idle-power (power consumed during idle time of the node).

Energy consumption of a node n_i at time interval t is given by
Econs(n_i,)=E residual (n_i, t_0)-Eresidual (n_i, t_1) (1)
Where E is the Energy-level (n_i,t_0) and E residual-Energy(n_i,t_1) is the Energy currently available in

network at node n_i between two respective times(t_0 to time t_1).

Models of Node Mobility and Node Degree

The combined weights of different parameters are used to elect the best node as the cluster head; this node is taken from a set of ordinary nodes. Mobility causes more CH reelection and link updating, resulting in poor cluster stability. Thus, considering the mobility of the nodes is critical for creating stable clusters.

A node's transmission range (say) n_i is in the form of an ellipse with radius r composed, for example, of k nodes. Within the ellipse, n_i's neighboring nodes can go far away or come closer to the node, as long as they are within n_i's transmission range.

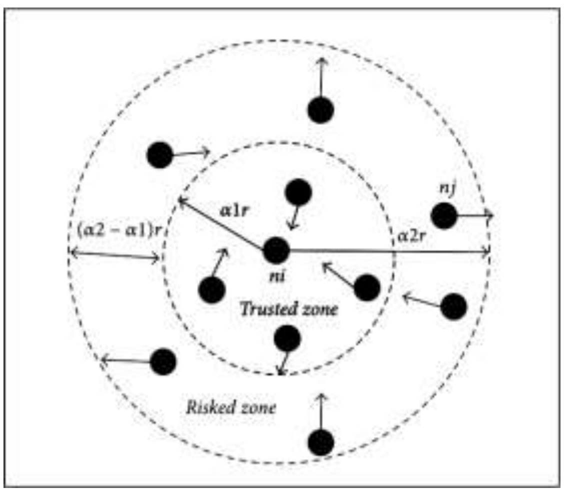


Figure 6. Transmission range zones with the direction of mobility

To calculate the network node's mobility in respect to the current distance between the transmitting node and the receiving one, we use the current strength of the signal received at the respective node and coming from two consecutive packets.

We can calculate the mobility between two network nodes such as nodes n_i and n_j by using the following formula:

The previous receiving power is calculated as: $RxPr^{old}_{n_{j \to n_i}}$

As a result, the communication range of the node can be divided into small transmission zones of n_i ones trusted and other risked zones.

In Figure 5, we can see the trusted zone depicted as an inner ellipse having a radius of 1r, the other zone is the risked zone having a width of r (a 2-a1).

Both a_1 and a_2 are the relative coefficient that is calculated based on the speed of the network node. We can determine whether it will-suited to be a candidate for cluster head node selection by considering both its current mobility, the related distance between the node and its neighbors, and lastly the total number of nodes available within its transmission range.

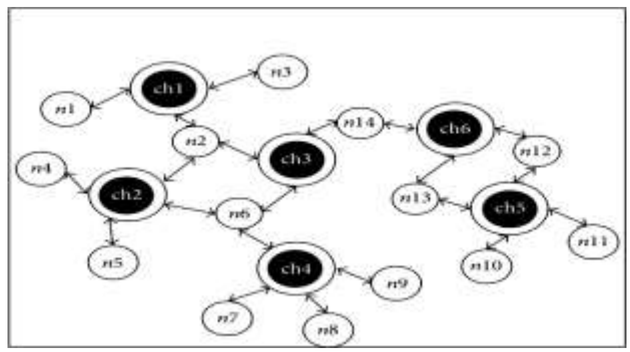


Figure 5. *Topology of the network with elected CHs*

$$\boldsymbol{M^{Rel}_{n_i}}(n_j) = 10 \log_{10} \frac{\boldsymbol{RxPr^{new}_{n_j \to n_i}}}{\boldsymbol{RxPr^{old}_{n_j \to n_i}}} \qquad \textbf{(2)}$$

in (2), the receiving power is calculated as: $RxPr^{new}_{n_{j \to n_i}}$

These two network nodes receive the "HELLO" data packet transmitted from node n_i toward node n_j.

When a given node is located in the risked zone and has been detected to have negative mobility this means that it's moving far away from the original node dedicated to estimating its weight in order to check whether this node can be selected as a cluster-head.

During this process, this neighboring node will be immediately discarded as its location has been detected outside the transmission range. On the other hand, when a node has positive relative mobility and is within the communication range and this node is moving toward the network node calculating its weight will be chosen as CH, and its located in the trusted zone but is moving further away, this results in priority being reduced proportionally to the distance between the nodes and the original one.

Phase II: Cluster-head selection sub-module

I. If [the delay timer expires and both cluster-head nodes are within transmission range of each other], the relative priority of the nodes must be calculated using prominent parameters such as energy, mobility, and a degree in each neighboring node.

II. We then compare the calculated priorities of the two network nodes; the new cluster head will take the old one's charge when its calculated priority is higher than the old one; a charge handover is performed between them, and the old cluster-head will be tuned to cluster member again.

III. In order to select both a cluster-head and a cluster member in the network, we use the lowest ID.

Algorithm for Cluster-Head Selection

BEGIN

NC: The number of clusters in a specific region.

NCHN: The network's number of Candidate Cluster-Heads.

R: Residual Energy.

M: Node's mobility

The sender node transmits RREQ and receives RREP.

Candidates should keep their local databases up-to-date.

Determine M, R, i=1.

While (i<=NCHN)

Check to see if node i in the i^{th} cluster is still within the sender's transmission range.

If a node's R and M are the lowest in the cluster

Compare it to other nodes' R and M and Choose node i as the N^{i}CH in the i^{th} network i= i +1

/

NnCH should now have one Cluster-Head.

Otherwise

Reject the end node.

End if

End While

END

Estimation of the Remaining Power with Mobility and Degree Sub-Algorithm

BEGIN

Total number of network member (nodes) (N)

Determine Mobility of Nodes(M)

Estimate Node Degree n_i (D)

Determine the Remaining Power of each Node(R).

Choose cluster-head candidate based on their current M and R values.

Determine the current Source (S) and Destination (D) among the selected nodes (Dist)

Calculate the interval(nDist) between each candidate node and the transmitting node a possible path to the

destination.

i=1

Do While (i<=N)
If (niDist)
Make the current network node n_i the candidate of cluster-head selection and include it in the ClusterHead Group;
Otherwise, keep the network node n_j and reject n_i
End If
End DO
END

Phase III: Cluster Head's Route Discovery and Packet Transmission Sub-module

A Cluster head node is critical in determining the best routing path. When the best path data request packet is generated by any node in the group, it has to first contact the cluster node which will then inspect their local database to determine whether the target node is within the same cluster, i.e. intra-cluster routing, or outside the current cluster's range, i.e. routing between clusters (inter-cluster).

In case of outside routing, the cluster has to regularly check the global routing table to make sure whether the node is in any of its either horizontally or vertically located clusters and if so, it will form the relevant path. If the target node is not located near the vertically or horizontally located clusters, the cluster-head will go further with the diagonally located CH and inquire about that node data.

- ✓ *For external cluster routing, the CH will consult its global database to see if the target node is in any of its horizontal or vertically located clusters, and if so, it will form the path.*
- ✓ *If the target node is not located near the vertical or horizontal clusters, the CH goes one step further by approaching the diagonally located CH and inquiring about the target node data.*

CHAPTER 1 *The diagonally placed CH searches the target again in its horizontal and vertically located clusters, and this process is repeated until the true destination node is discovered.*

- ✓ *Using the particle swarm optimization technique, our protocol will determine the best path to take for packets and then start the routing process.*

a. *It will use the same parameters previously used to elect an optimal cluster-head namely Node's Residual energy [R], Node's Mobility [M] and Node's Degree [D].*

These parameters are input variables to the fuzzy rule Base; so the total number of fuzzy rule generated are $3^3=27$ rules for fuzzy rule base which are shown in the following in Table 1:

To find the route, the CH will go through the following steps:

i. The source node sends a Hello message to all of its neighbors.
ii. The message is then forwarded to its mates in the network by the Forwarding node(F_ant).
iii. Forwarding ANT collects each network's remaining power, the distance between it and the target node, and the reachability too.
iv. After reaching the destination, bwrANT returns in the opposite direction.
v. The frwANT information is used as input to the Fuzzy Logic System. Based on those three input parameter metrics, the fuzzy logic system generates 27 rules.
vi. Using those rules, an optimal path is chosen based on the probabilistic values obtained by evaluating each available route using QoS parameters.
vii. The procedure is repeated until the session is completed (when the most optimal path is found to route packets through).

Using ACO, the F_ANT will collect information from all network nodes by multicasting a Hello message. Then (I) is entered into the Fuzzy Logic System (FLS). FLS generates Fuzzy Rules (FRL) from the Fuzzy Rule Base using the Fuzzy Inference Engine. The fuzzy logic will then assign linguistic value (P) to the input parameters. Finally, it compares those values to the output and selects the best path.

Table 1. Fuzzy Rules

Residual Energy (R)	Mobility (M)	Degree (D)	Node Selection (Probability)
Less	High	High	Very Less
Less	High	Medium	Very Less
Less	High	Low	Very Low
Less	Medium	High	Less
Less	Medium	Medium	Less
Less	Medium	Less	Very Less
Less	Less	High	Less
Less	Less	Medium	Less
Less	Less	Less	Very Less
Medium	High	High	Less
Medium	High	Medium	Medium
Medium	High	Less	Medium
Medium	Medium	High	High
Medium	Medium	Medium	Medium
Medium	Medium	Less	Less
Medium	Less	High	High
Medium	Less	Medium	Medium
Medium	Less	Less	Medium
High	High	High	Medium
High	High	Medium	Less
High	High	Less	Less
High	Medium	High	High
High	Medium	Medium	High
High	Medium	Less	Medium
High	Less	High	Very High
High	Less	Medium	Very High
High	Less	Less	High

Very Less, Less, Medium, High, and Very High are the linguistic values. The Fuzzy Inference Engine generates a total of 27 rules in the new protocols. Table 1 shows the 27 rules and their probabilities. For example, a node with a low Residual Energy but with both high Distance to the neighbor node and reachability, has a low probability of being chosen as an optimal path, whereas a node with a low Residual energy but with high Distance and medium value of reachability has a very low probability of being chosen.

When a node has a medium Residual energy and Distance but a low Reachability value, the probability value generated by its selection is high. The same procedure is used to generate each of the 27 rules. Only optimized paths to route packets through are chosen using those rules.

Table 2. Parameter values for simulation

Parameter	Values
Number of nodes	60
Interface type	Phy/WirelessPhy
Channel	Wireless Channel
Mac type	Mac/802_11
Queue type	Queue/DropTail/PriQueue
Queue length	150 Packets
Antenna type	Omni Antenna
Propagation type	TwoWayGround
Size of packet	512-1024
Protocol	PROPOSED PROTOCOL
Traffic	CBR
Simulation area	1500M*1500M
Node mobility speed	1…50 m/s

Results

By varying routing metrics, we compare the performance of our new mechanism PROPOSED PROTOCOL (QODFL) to those found in the literature.

PDR Performance Evaluation

The Packet Delivery Ratio parameter metric in NS-2 is used to compare the performance of PROPOSED PROTOCOL to the existing QoS protocols, namely QoS-AODV, BMR, and MSR. Table 3 and Figure 7 show the results of the performance evaluation of PDR with varying node counts.

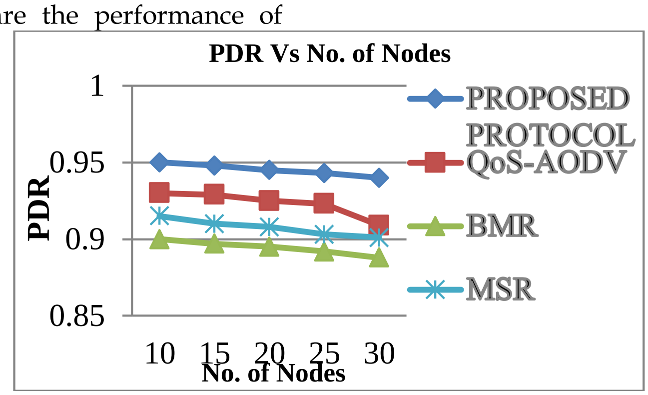


Figure 7. PDR vs. No. of Nodes

When compared to the other three protocols, the Packet Delivery Ratio of PROPOSED PROTOCOL remains high for the overall simulation time; however, Generally, for even better best protocols, naturally, the PDF decreases as the network nodes increases, this also happens to the PROPOSED PROTOCOL as it decreases slightly as the number of nodes increases but in the percentage (about 5%) lower than other protocols' due to a lack of capacity to handle highly dense networks. This proves the out-performance of the Proposed Protocol as it increases the PDR of the MANET of all studied cases.

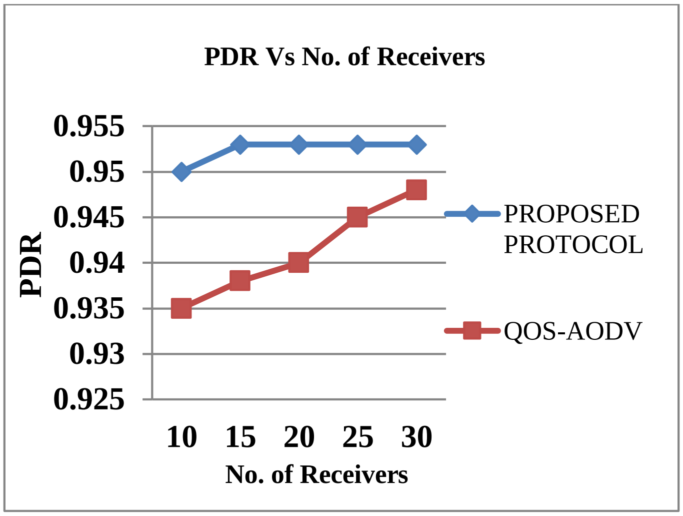


Figure 8. PDR vs. No. of Receiver Nodes

As shown in Table 4 and Figure 8, the PDR of the new protocol is compared to that of QoS-AODV. The number of receivers is taken into account when evaluating performance. The number of receivers varies between 10 and 30 nodes during the simulation process. PROPOSED PROTOCOL achieves the best results due to two distinguishing characteristics: the availability of high-quality links and the ability to select a stable path.

One interesting finding is that the PDR of both protocols increases in direct proportion to the number of receivers. However, the PROPOSED PROTOCOL, maintains a high PDR that QoS-AODV never achieves, proving the outperformance of PROPOSED PROTOCOL.

Table 3. PDR of Proposed Protocol and existing protocols varying number of nodes

Number of Nodes	Packet Delivery Ratio			
	Proposed protocol	**QoS-AODV**	**BMR**	**MSR**
10	0.95	0.93	0.9	0.915
15	0.948	0.929	0.897	0.91
20	0.945	0.925	0.895	0.908

25	0.943	0.923	0.892	0.903
30	0.94	0.909	0.888	0.901

Table 4. PDR of Proposed Protocol and QoS-AODV varying number of Receivers

Number of Receivers (Nodes)	**Packet Delivery Ratio**	
	PROPOSED PROTOCOL	**QoS-AODV**
10	0.95	0.935
15	0.953	0.938
20	0.953	0.94
25	0.953	0.945
30	0.953	0.948

Table 4. End-to-End Delay of PROPOSED PROTOCOL and existing approaches

Number of Nodes	**End to end delay [(secs)]**			
	PROPOSED PROTOCOL	**QoS-AODV**	**BMR**	**MSR**
10	0.5	1.2	1.5	1.8
15	3	2.5	4.3	3
20	7	8.8	8.8	9.5
25	9	12	12	13
30	12	15	16	16

Performance Evaluation with Delay

As shown in Table 5 and Figure 9, when considering end-to-end delay and varying the number of nodes, the PROPOSED PROTOCOL's delay is maintained at a lower level when compared to the existing ones' during the overall simulation time, making the PROPOSED PROTOCOL a better one.

The best performance behavior of the Proposed Protocol is achieved by selecting paths with lower distance and reachability values as optimal paths first.

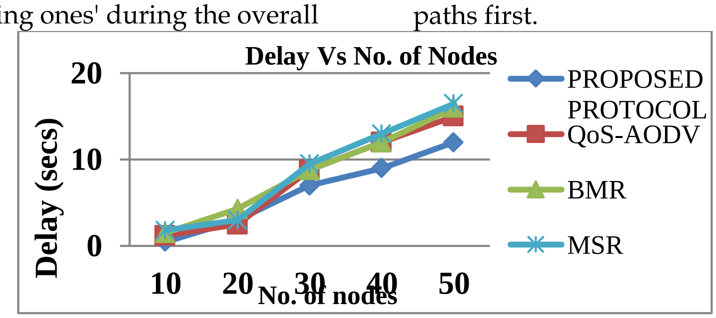


Figure 9. End-to-End Delay vs. No. of Nodes

Table 5. Delays for PROPOSED PROTOCOL and BMR with the varying number of receivers

Number of Receivers (Nodes)	End-to-End Delay [(secs)]	
	PROPOSED PROTOCOL	**BMR**
10	11	12
15	11.5	12.6
20	11.8	12.9
25	12.2	13.5
30	12.5	14

Table 6. Throughputs for Proposed Protocol and existing approaches with the varying number of nodes

Number of Nodes	Throughput [Kb/s]			
	PROPOSED PROTOCOL	**QoS-AODV**	**BMR**	**MSR**
10	0.96	0.94	0.92	0.925
20	0.958	0.939	0.918	0.922
30	0.955	0.935	0.915	0.92
40	0.951	0.938	0.913	0.928
50	0.95	0.93	0.909	0.91

Table 7. Throughputs of Proposed Protocol and MSR varying Number of receivers

Number of Receivers (Nodes)	Throughput [kb/s]	
	PROPOSED PROTOCOL	**MSR**
10	0.97	0.93
15	0.968	0.927
20	0.965	0.925
25	0.963	0.923
30	0.96	0.921

The PROPOSED PROTOCOL is compared to BMR in Table 6 and Figure 10. PROPOSED PROTOCOL outperforms BMR protocol yet again because it maintains a lower end-to-end delay (by 8% lower than other's) ratio for both low and high number of receivers.

Performance Evaluation with Throughput

The performance of the new Proposed Protocol in comparison to QoS-AODV, BMR, and MSR is depicted in Table 7 and Figure 11. The results obtained by varying the network size, i.e. the number of nodes, while using throughput as an evaluating parameter metric show that the PROPOSED PROTOCOL achieves the highest throughput ratio (about 8% higher than others') when compared to the existing ones.

The effects of the total number of packets received by the source from multiple receivers are shown in Table 8 and Figure 12. The experiment results show that the throughput values of both protocols vary from high to low as the number of receivers increases, which is due to multiple receivers sharing the same channel at the same time regardless of the decreasing throughput values.

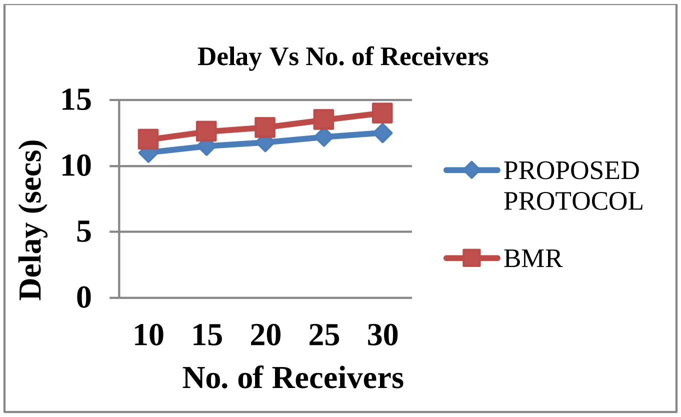


Figure 10. *End-to-End Delay vs. No. of Receiver Nodes*

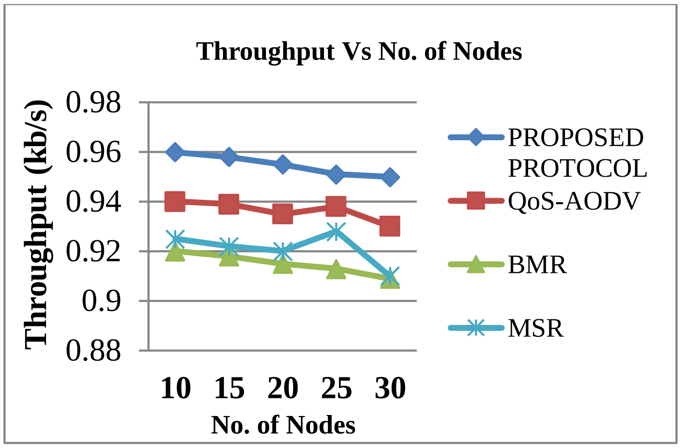


Figure 11. *Throughput vs. No. of Nodes*

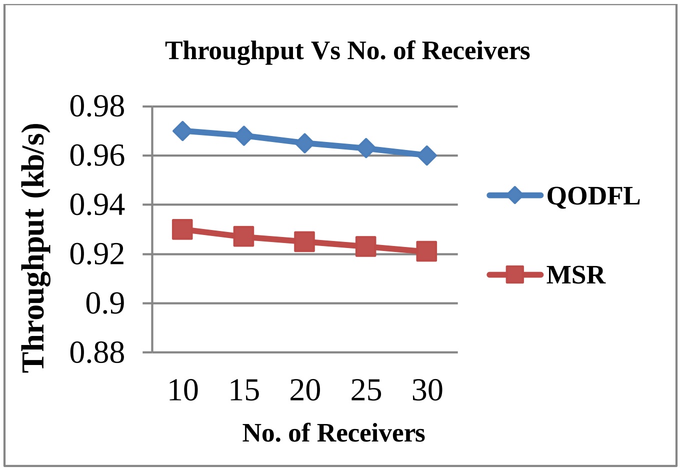


Figure 12. Throughput vs. No. of Receiver Nodes

Discussion

The proposed QODFL protocol, which is a hybrid of ACO and fuzzy logic mechanisms, was evaluated.
It also looked into two important aspects of MANET: multicast and multimedia transmission techniques.
Three parameter metrics were used to evaluate performance: distance (Dt), residual energy (Re), and reachability (Rc).

F ANT, which is used in ACO, collected the parameters by sending hello messages to each node.
The data was fed into the fuzzy logic system, which generated a set of 27 different fuzzy rules based on the fuzzy rule base input parameters of the Fuzzy Inference System (FIS).

Finally, FIS calculated the probabilistic value determining whether a specific node in the network could be chosen as an optimal path. After determining the best route to take for packet transmission, the packet transmission process begins, followed by route maintenance.

The new rout discovery mechanism selects routs for transmission that have less traffic on them. Another prominent mechanism was included in the Proposed Protocol that provides more transmission opportunities for Real Time traffic in MANET. The proposed protocol allocates more bandwidth to RT traffic and reduces transmission delay for RT data packets without affecting Best Effort traffic.

A RT data packet now travels much faster to its destination due to efficient transmission. The experiments were run on the NS-2 simulator, which compared the proposed protocol (QODFL) to the existing ones (QoS-AODV, MBR, and MSR). Various scenarios were investigated by varying the number of nodes and receivers and employing various prominent routing metrics such as PDR, End-to-End Delay, and throughput. Following implementation, the proposed protocol improves both throughput and PDF and reduces latency to a greater extent.

The proposed protocol QODFL outperformed the existing ones in all of the cases studied; this accomplishment was made possible by combining multiple prominent techniques used in the protocol's implementation. In comparison to existing protocols, the protocol proved to be more efficient in transmitting both ordinal and multimedia data packets even in highly dynamic MANETs.

As a result, compared to protocols existing in literature, the proposed improved QoS protocol is better suited for the transmission of real-time data over the MANET of moderate low, moderate, and high-density and mobility in Mobile Ad Hoc Networks.

Conclusion

We proposed a very efficient QoS-routing protocol in this research study to overcome various negative issues that arise during data packet transmission operations and inhibit QoS provision in Mobile Ad Hoc Network.
PROPOSED PROTOCOL is a hybrid of popular QoS-improvement techniques.

To demonstrate the superiority of our proposed protocol, we conducted a performance evaluation using network popular parameter metrics collected using the ACO technique at each node by a F ANT and forwarded to the fuzzy logic system, which generated a combination of 27 different fuzzy rules based on the input parameters provided from the Fuzzy Inference System's fuzzy rule base (FIS).

The probabilistic values were then calculated by FIS and used to determine whether a path could be chosen as the best route. The optimal path discovered was then used to relay data packets from source to destination; route maintenance operations were required whenever a route failed or broke, and an alternate path was used instead.

The performance of the proposed protocol was evaluated using the NS-2 simulator by varying the number of nodes and receivers and comparing it to those found in the literature. During the experimental analysis, prominent QoS parameters such as End-to-end Delay, PDR, and throughput were also used.

Following data analysis and interpretation, the researcher made the following recommendations:

First, there are few robust standard QoS-aware routing protocols for multimedia applications in the literature; further research into the transmission of any type of data should be conducted in this field.

Second, our proposed protocol can be expanded to include multi-path routing to avoid interference during transmission.

Third, future researchers should focus on predicting the future direction of mobile nodes to improve network lifetime and stability in MANETs with fast nodes.

Fourth, based on the importance of the MANET, we recommend the development of the IoT-based application which would therefore cover a little bit larger geographical area and the number of devices significantly high. Feature researchers can explore the performance of the proposed protocol similar to ours for the devices at least up to 100 to check the same performance in larger networks as well.

Finally, the experimental evaluation of our model in a real testbed, including indoor, outdoor, and mobile nodes would give more insights on the prediction capacity of our model in a larger set of experiments.

References

Park, V. & Corson, M. S. (2021). *A Highly Adaptive Distributed Routing Algorithm for Mobile Wireless Networks*, In Proc. INFOCOM, Kob.

Kuipers, F., Van Mieghem, P., Korkmaz T., & Krunz, M. (2022). *An overview of constraint-based path selection algorithms for QoS routing*", IEEE Communications Magazine.

Lin, C. R. (2022). *On-demand QoS routing in multihop mobile networks*. In Proc. of Infocom.

Tsai, J., Chen, T., & Gerla, M. (2016). *QoS Routing Performance in Multihop, Multimedia, wireless Networks*. In Proc. of IEEE ICUPC.

Elizabeth, M., Royer, P., & Samir, R. Das. (2015). *Quality of Service for Ad Hoc On-Demand Distance Vector Routing*. In Internet-Draft, draftietf-manet-aodvqos-00.txt, Work in Progress.

Hay, M., Saeed, B., Lung, C. H., Kunz, T., & Srinivasan, A. (2013). *Network Coding and Quality of Service metrics for Mobile Ad-hoc Networks.* 9th International Wireless Communications and Mobile Computing Conference (IWCMC), Sardinia, pp. 521-526.

Pradeep, B.S. & Soumya S. (2020). *A new method for load balancing and QOS in on demand protocols. In the MANET's perspective*.

Swati A., Nasib S.G., & Jaideep, A. (2017). *Fuzzy Logic Implementation of Antcolony Based Clusterhead Selection Algorithm*. International Journal of Advanced Research in Computer and Communication Engineering.

Tamer,D. (2022). *Dynamic Priority Packet Scheduler with Deadline Consideration*. International Journal of Advanced Research in Computer and Communication Engineering.

Sahaya, R., Vigita, S., & Golden, J. (2013). *Reliable Link-Based Routing Protocol for Highly Dynamic Mobile Adhoc Networks*. International Journal of Engineering Trends and Technology, Vol.4, PP.1636-1642.

Biradar S., & Kulkarni, P. (2015). *An Improved Quality of Service Using R-AODV Protocol in MANETs*. 3rdInternational Conference on Artificial Intelligence, Modelling and Simulation (AIMS), Kota Kinabalu, pp. 402-407.

International Journal of Advanced Networking and Applications, Vol. 1, No. 4, pp.275–281.

Yang, W., Yang, X., Liu, G., & Dong, C. (2018). *A bandwidth aware multipath routing protocol in mobile ad hoc networks*. Journal of Computational Information Systems, Vol. 7, No. 3, pp.685–6 96.

Qin, F., & Liu, Y. (2018). *Multipath based QoS routing in MANET*. Journal of Networks, Vol. 4, No. 8, pp.771–778.