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*Original Article*

# A Predictive Finest Path Selection Algorithm to Enhance QoS in MANETs

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***Abstract*** — *Mobile ad-hoc networks (MANET) consist of a set of highly dynamic self-organized mobile nodes. The nodes move freely within the network and may leave the network. The nodes in the mobile ad-hoc network are highly dynamic, and they lack Quality of Service (QoS) support. The MANETS are extensively deployed in military applications and emergency operations. Few applications require a minimum guarantee for end-to-end packet delivery, and few applications need time constraint delivery of packets. The QoS support for such applications is not provided by AODV, DSR, or any other protocols. The military applications, live transmission applications need to send a huge amount of data over the network; due to the high mobility of nodes, the chances of failure of links are also more. This will reduce the lifetime of the network. In this paper, a predictive finest path selection algorithm is proposed to enhance QoS in MANETs. The finest route selected may not be optimal for a longer period. The major challenge is not only to find the finest route but also to predict when to run the finest path selection algorithm in the future for efficient data transmission. The proposed algorithm will find the best finest path changes, link failures, and congest nodes to inform the sender before a QoS communication.*

**Keywords —** *AODV, Choke Probability, Predictive Routing, QoS, Routing*

## I. INTRODUCTION

Networking, in a broad sense, is one of the most motivating topics for research. Current advancements in the field of computer networks are in the direction of different types of wireless networks like wireless sensor networks, mobile ad-hoc networks, and other types of ad hoc networks. These ad-hoc networks are very interesting and challenging in various aspects. MANET's specifically is flexible, scalable, dynamic, and highly mobile. The QoS is defined as "*the collective effect of service performance which determines the degree of satisfaction of a user of the service*" by the United Nations Consultative Committee for International Telephony and Telegraphy. The implementation of Quality of Service in wired networks is easy when compared to wireless networks. The MANETs have various challenges in the areas of Routing, Quality of Service, Congestion control, Security, threat detection, etc. Due to their high dynamic nature, it has always been difficult to support QoS. The lightweight QoS mechanism has addressed only minimum bandwidth and maximum delay parameters. Machine learning-based route prediction will make a path for us to support QoS in MANET in a more efficient way. With the emergence of real-time applications and the widespread utilization of mobile devices and wireless devices, there is a growing need for improving the quality of service. QoS deals with better end-to-end delivery, guaranteed delivery, quick delivery, better prediction of faults, and flexible routing with dynamic topology. QoS parameters are end-to-end delay, packet drop rate, jitter, congestion, the relative motion of nodes, and resource utilization. Predicting the parameters and finding the finest path for QoS routing becomes challenging. But with machine learning-based models can predict the parameters in a better way, which in turn gives the opportunity to select the finest route. The motivation behind finding the finest QoS routing comes from its real-world applications of emergency deployment of MANETs in various fields like sensor networks, military operations, disaster relief operations, UAVs (unmanned aerial vehicles), wildlife monitoring, etc. QoS needs end to end service guarantee as well as an optimal route and stable route for trusted delivery. Hence, it is very much important to enhance the QoS mechanism in [1] to provide a better life of network and performance.

## II. LITERATURE REVIEW

Some of the recent papers deal with QoS by modifying the typical routing protocols. By incorporating various QoS-related parameters with the generic ad-hoc routing protocols, some degree of QoS is achieved [8,10].

As given in the paper [9], the author implements a priority-aware DSR routing mechanism to improve QoS. Giving different priorities to different communication types has achieved different QoS levels. It also utilizes bandwidth more efficiently and reduces packet dropping of high priority, high-quality QoS packets. But in a dynamic topology and a MANET with high mobility of the nodes, the end-to-end packet delivery in this mechanism is not guaranteed to be the quickest.

Other papers, such as [14], discuss finding backup routes whenever a node failure occurs. The backup routes are found using the nearest neighbor of the down node. Nearest neighbors are found using distance vectors and AODV (ad-hoc on-demand distance vector) routing protocol. The downside of this process is a time delay to find backup routes and related computational complexity, and increased traffic.

Ant colony optimization (ACO) based on multi-agent AODV routing is proposed in the paper [13]. Multi-agent AODV routing compares different possible routes based on hop count, delay, and energy of node and selects an optimum route. However, it is difficult to find an optimum route for a period of time. Because it is difficult to know what will be the position and status of the nodes after a given period of time and thus can ultimately the chosen optimum route might not remain as optimum one.

In the paper [12], the author mentioned various reinforcement learning-based routing algorithm. A reinforcement learning-based Q-routing algorithm is used in all of these papers. Like, Predictive Q routing, which predicts traffic trend and predicts q values.

In [4], the authors have proposed a modified AODV protocol [2] for the selection of the next hop. The selection is based on the experience gained through reinforcement learning and being more aware of network dynamics.

The network topology in [17] Q-routing is assumed to be static. The authors have proposed MARL-R to address the fundamental characteristic of dynamic topology issue in MANET. It is a light adaptation to Q-routing.

In [16], the authors proposed RL-QRP (RL-based QoS aware Routing Protocol) to transport packets of patient information reliably and also faster to its central medical facility. The location information is gathered with GPS-equipped sensor nodes in the form of Hello Packets. The nodes make use of the gathered location information to compute the path. The node path is computed based on QoS parameters requirements. The computed path is used for forwarding the packets. RL is used for QoS path computation and next-hop selection.

But the problem with all reinforcement learning-based algorithms is the need for vast scale history data or learning data and high energy need per node compared to a traditional routing algorithm.

In the paper [6], the author described QoS enhancement of a Wireless Sensor Network (WSN) by using different prediction models. Those models are trust computation of nodes and routes, mobility prediction model, energy prediction model, etc. By using ML-based predictions, it finds the optimal route.

In the paper [15], the author published a neighbor knowledge-based rebroadcast algorithm that also improves routing overhead and bandwidth usage and enhances QoS. Another reinforcement learning-based routing algorithm is proposed in the paper [7].

In another paper [1] tells about the machine learning approach of different coherent routing algorithms and compares them. The authors have proposed a knowledge learning algorithm that gathers the initial network performance information. The gathered network information is used for the optimum route selection process. The proposed algorithm is compared with standard routing algorithms by varying the number of nodes for the following network performance parameters. The graph shows the improved results for packet delivery ratio (PDR), throughput, node mobility, etc.

The authors in [8] have proposed a different hybrid algorithm, CAABO, based on the existing Cellular Automata (CA) and African Buffalo Optimization (ABO) algorithm. The proposed algorithm optimizes the path selection in MANET. Due to this, the network performance in terms of network lifetime and packet delivery was increased. It is similar to QoS based algorithm in terms of end-to-end delay. The proposed hybrid algorithm is integrated with Ad-hoc On-demand Distance Vector (AODV) routing protocol for further improving its QoS.

Link failure prediction and smart route selection are some of the important aspects of providing QoS. The authors in paper [11] specifically emphasize and implement a failure prediction model along with AODV routing.

Similarly, some authors gave QoS by bandwidth estimation like in the paper [5]. However, it still faces problems to cope with dynamic topology and mobility of the nodes and quickly react to it. Bandwidth estimation is also not straightforward as described.

Similar bandwidth and delay prediction-based video streaming service over a MANET is described by the authors of the paper [3].

Based on the above survey, the QoS mechanism needs to be extended to achieve better energy efficiency. The Predictive finest path selection QoS mechanism is introduced to achieve this goal. This mechanism utilizes the suitable neighbor nodes around the routing path to share the routing load and achieve energy conservation.

## III. QUALITY OF SERVICE (QoS)

The QoS algorithm is based on the popular link-state routing protocol, and it is not dynamic. The algorithm is predictive throughout simulation time. The input of the initial position of nodes, the movement of nodes based on the speed of nodes movement are initialized. The velocity vector along x and y with speed is calculated based on equation (2).

$$abs\_dist = \sqrt{(rel\_x^2 + rel\_y^2)} \quad (1)$$

$$Velocitt\_vector\_X = (speed * rel\_x)/abs\_dist \quad (2)$$

$$Velocitt\_vector\_Y = (speed * rel\_y)/abs\_dist \quad (2)$$

The cost matrix is calculated based on global link states calculated from the position and velocity information. Once the cost matrix is calculated, the real-time position of nodes and distance between them is calculated and updated the distance matrix between source and destination node.

The QoS algorithm will find the adjacency matrix and the set of relaxing nodes whose distance is more among the nodes using BFS. The list of predicted nodes is updated. Later, the route is built between source and destination. While building a route, if there is no update in the route path, it will use the initial path. Otherwise, it will use the predicted path if it is not equal to the previous route.

## IV. PREDICTIVE FINEST PATH SELECTION QOS ALGORITHM

To predict future routing instantly, it needs global knowledge like mobility information of all the nodes (velocity heading and velocity magnitude) and Initial position (coordinates). At every timestamp, the QoS algorithm is called to find a new route, link fails, and choke nodes. The QoS algorithm will predict the Optimal Route path for the next 10 seconds of the simulation time and predict failure for the next 10 seconds. Choke nodes and probabilities are found by finding whether at any point in time the shortest route contains articulation points and whether their probability of getting high traffic is calculated.

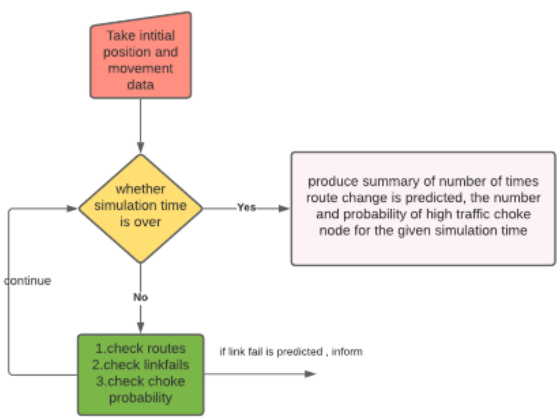


**Figure 1: Predictive Finest Path Selection QoS Algorithm**

### *A. ALGORITHM: PREDICTIVE PATH SELECTION ALGORITHM*

Begin
Initialize adjacency nodes and each node distance to 0
Find the adjacency node matrix
Use BFS method to Relax Nodes
    If distance between I and w < distance of j
    Prediction node = i
Build a route from source to destination
    If there is no update
        Use initial route
    Else if route is not equal to previous route
        Use predicted route
Convert Adjacency Matrix to Adjacency list
Find the Maximum Choke Probability
    Count the size based on node visit
    Calculate MCP = ((m+1)*(9-m)+(m)*(10-m))/P_10_2;
    If MCP > 0.5 then
        Predict as High Traffic Choke
    If MCP>0.33 and MCP < 0.5 then
        Predict as Moderate Traffic Choke
End

**PREDICTIVE FINEST PATH SELECTION QOS ALGORITHM**

Begin
    Initialize no of node = 10
    Range of wireless nodes = 250
    Permutation = 90
    Simulation time = 10sec

    Initialize nodes with position
    Movement Information with varying speed
    Find velocity vectors, and each vector is of [x,y] form where v= xi+yj
    Predict optimal route and predict failure for 10 seconds
    Find the number of times high traffic choking predicted
End

QoS algorithm based on Bellman-Ford routing is better than AODV based routing because it has global knowledge of nodes and can predict future routing accurately without a big delay. Bellman ford based predictive routing is also beneficial in terms of bandwidth and resources because it doesn't need periodic updates from neighbors.

### *B. CHOKE PROBABILITY OF A NODE*

The nodes which are articulation point (cut vertex) and carry a lot of traffic load. However, the articulation point doesn't mean it will be under traffic choking. It is possible if: There is high enough existing traffic and the cut vertex is near the center of the network.

As predicting future traffic is hard, it needs to define choke probability-based prediction only on the topology:

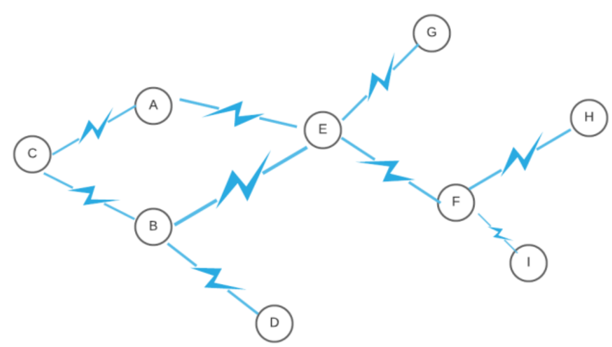


**Figure 2: Network Topology to predict choke probability**

The articulation points are: B, E, F
But across the node B: maximum connections possible is: connections are between ({A,C,E,F,G,H,I,B} and {D}) or between ({A,C,E,F,G,H,I} and {B,D}).
Total connections over B = 8*1 + 7*2 = 22
Choke prob = max connection over it / total connections possible = 22/10P2 = 25%

Across E the components are almost equal: {A,B,C,D} & {F,G,H,I}. Hence connections are
between : {A,B,C,D,E}{F,G,H,I} or {A,B,C,D}{E,F,G,H,I}.
Total connections = 5*4 + 4*5 =40
Choke prob = 40/10P2 = 48%. (which is high)
Across F the components are almost equal: {A,B,C,D, E, G} & {H, I}. Hence connections are
between : {A, B, C, D, E, G, F}{H, I} or { A, B, C, D, E, G }{F, H, I}.
Total connections = 7*2 + 6*3 =32
Choke prob = 40/10P2 = 39%.
Therefore node E has a greater chance of traffic choke.

## V. RESULTS AND DISCUSSIONS

The proposed QoS algorithm is simulated in NS2, and the performance is compared with traditional AODV for the randomly initiated nodes. The AODV algorithm is simulated against the mobility of nodes and traffic of the nodes. For the comparison of the proposed algorithm, the packet loss and route update delays are captured. The experimental analysis is performed between QoS Algorithm, and AODV is based on the following instances. The QoS algorithm performance is compared under two instances, namely: 1. frequent route changes and 2. route contains choke packets.

Instance 1: First, the performance of the QoS routing protocol was compared with low traffic flow. Assume the start node and end node are nearest. The proposed algorithm shows the route change frequency is only 0.3/s which reduces minimal packet loss, almost no link failures, and moderate choke of traffic. The results show only one packet is lost during simulation, and route change prediction is so faster than the AODV algorithm.

-------ESTIMATE SUMMARY--------
Predictive QoS Routing estimates the QoS affecting parameters for the next 10 seconds as follows:
Route change frequency: (higher route changes leads to small packet drop): 0.3 /sec
Predicted end to end link failure instances: 0
High choke frequency (number of times high traffic choking predicted): 1 /10 sec
Highest choke, found at node: 7

The delay of route update between the QoS algorithm and the AODV algorithm is tabulated. The graph in fig 3 clearly shows a 1 to 2 seconds delay between the predicted optimal route and actual route update time of AODV. The simulation results show that the proposed algorithm predicts route change before AODV prediction, so AODV is not fast to react.

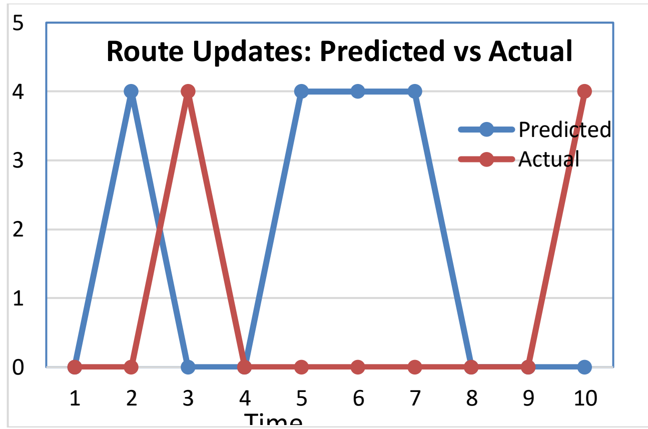


**Figure 3: Route Updates: Predicted v/s Actual**

Secondly, the performance of the QoS routing protocol was compared with high traffic flow. The proposed algorithm predicted that traffic choke would be less based on the topology of that time, and the results shows consistent with the prediction. The graph in fig 4 shows the number of QoS packets dropping compared to other packet droppings under heavy traffic is very less. The proposed algorithm has predicted moderate chocking at some nodes, and the simulation results give similar results with intermittent packet dropping.

Instance 2: The route updates are fewer, but the route contains choke nodes. First, the performance of the QoS routing protocol was compared with low traffic flow. The proposed algorithm predicts the highest choke at node 3 and moderate choke at node 6. The result data shows few packets being dropped at high choke node 3 and other nodes even in low traffic conditions, as the probability of choking is high at node 3 always. The number of packets dropped is shown in figure 5.

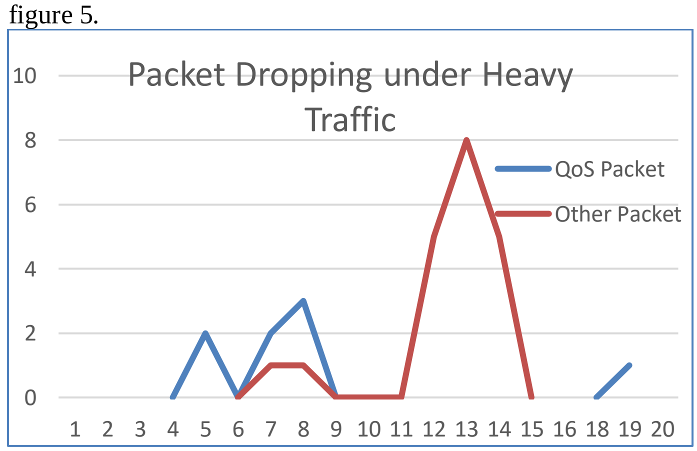


**Figure 4: Packet Dropping under Heavy Traffic**

-------ESTIMATE SUMMARY--------
Predictive QoS Routing estimates the QoS affecting parameters for the next 10 seconds as follows:
Route change frequency: (higher route changes leads to small packet drop): 0 /sec
Predicted end to end link failure instances: 0
High choke frequency (number of times high traffic choking predicted): 12 /10 sec
Highest choke, found at node: 3

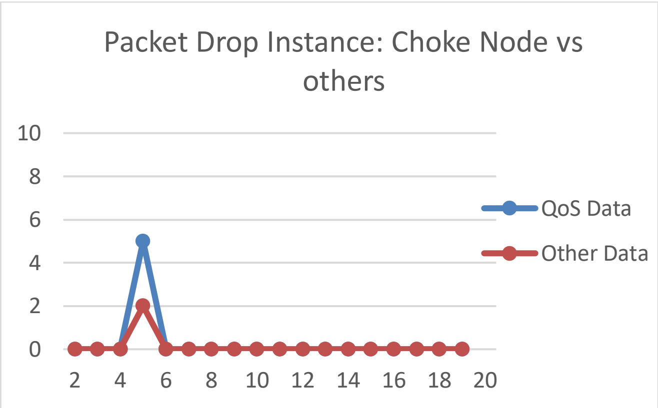


**Figure 5: Packet Drop Instance: Chock Node v/s others**

Secondly, the performance of the QoS protocol is measured with the same number of nodes with heavy traffic. The simulation results show the fewer packets are dropped when compared with other nodes. Also, the total data dropped at choke nodes is less when compared with other nodes. The graph shows a heavy drop of packets after t=10 at choke node 3 with an average rate of 8KB/s.

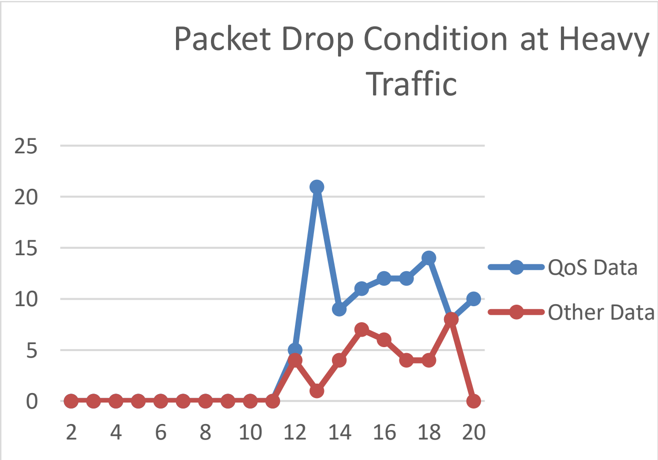


**Figure 6: Packet Drop Condition at Heavy Traffic**

## VI. CONCLUSION

QoS Support in MANET's is one of the important research areas, and providing QoS in highly dynamic topology is more difficult. The proposed algorithm works well on predicting route update frequencies and probable choke nodes. The algorithm can predict and inform before starting the transmission in MANET. The proposedQoS algorithm is based on the standard Bellman-Ford algorithm that requires link-state information of global nodes. The routing has a low cost in terms of resources, bandwidth and also it is more reactive than AODV. The performance of the proposed algorithm has less packet drop and less data loss under low traffic and high traffic conditions. The performance of data transmission in choke nodes has outperformed when compared with the traditional AODV protocol.
Further, this approach assumes MANET nodes not to be very randomly moving but on steady mobility. It can be further enhanced for highly dynamic nodes in MANET.

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