QoS Enhancement using optimal route prediction and congestion prediction in MANET

Report

Submitted in partial fulfilment of the requirements for the degree of

MASTER OF TECHNOLOGY in

Computer Science and Information Security

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May, 2021

DECLARATION

I solemnly declare that the project report *QoS Enhancement using optimal route prediction and congestion prediction in MANET* is based on my own work carried out during the course of our study . I assert the statements made and conclusions drawn are an outcome of my research work. I further certify that

1. The work contained in the report is original and has been done by me under the general supervision of my supervisor(if any).

2. The work has not been submitted to any other Institution for any other degree, diploma, certificate in this university or any other University of India or abroad.

3. I have followed the guidelines provided by the university in writing the report.

4. Whenever I have used materials (data, theoretical analysis, and text) from other sources, we have given due credit to them in the text of the report and given their details in the references.

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CONTENTS

ABSTRACT

MANETs (mobile ad hoc network) consists of highly dynamic and mobile set of nodes. With its dynamic topology and variable parameters, the MANETs lack QoS support. Various real-world applications said above requires some degree of confidence in end to end packet delivery. And some applications need time constrained delivery in interactive applications. There is no quality of service provisions in a typical ad hoc routing like AODV, DSR etc. To facilitate Quality of service in this project I propose a predictive optimal path selection algorithm to enhance QoS in the MANET. For large quantity of data transfers needed such as video streaming, live and interactive applications or live military communications within a MANET requires long time. But as the nodes are mobile and links are prone to failure, the routing parameters also varies over time. The optimum route may not remain optimum over time. So, the problem is not only to find safe and optimum routes but to also predict when the route selection algorithm may need to be run again to react and adapt while transmitting large data. The following implementation will find out prediction of route changes, link failures and choke nodes to inform the sender before a QoS communication.

INTRODUCTION

Networking, in a broad sense, is one of the most motivating topics for me. 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 network, and other types of ad hoc networks.

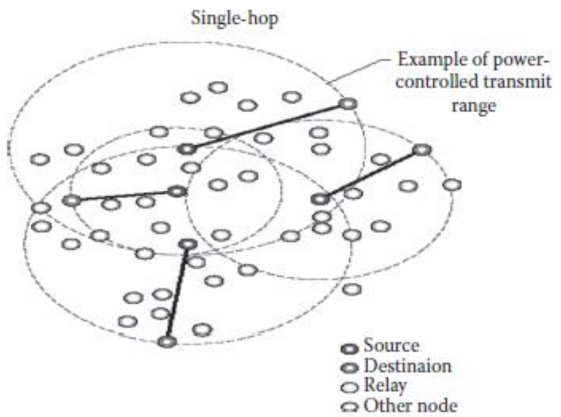


FIG 1. Single hop mobile ad hoc network [*Mobile ad hoc networks: current status and future trends*. CRC Press, 2016.]

These ad hoc networks are very interesting and challenging in various aspects. MANET specifically is flexible, scalable, dynamic, and highly mobile. Which have various challenges from the point of view of routing, Quality of Service, Congestion control, security, threat detection etc. Due to their high dynamicity nature it has been always difficult to support QoS. Machine learning based route prediction will make a path for us to support QoS in MANET in a more efficient way. The emergence of real time applications and widespread utilization of mobile devices and wireless devices there is a growing need for improving quality of service. QoS deals with better end to end delivery, guaranteed delivery, quick delivery and better prediction of faults and flexible routing with dynamic topology. QoS parameters are end to end delay, packet drop rate, jitter, congestion, relative motion of nodes and resource utilization. Predicting the parameters and finding optimal path for QoS routing becomes challenging. But with Machine learning based models we can predict the parameters in a better way, thus in turn gives opportunity to select an optimal route. The motivation behind finding optimal 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.

Literature survey:

Some of the recent papers deals 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.

Like given in the paper [Jayabarathan et al. 2016] the author implements priority aware DSR routing mechanism to improve QoS. Giving different priorities to different communication different QoS levels are achieved. And it also utilizes bandwidth more efficiently and reduces packet dropping of high priority, high quality QoS packets.

But in a dynamic topology and in a MANET with highly mobile nodes the end to end packet delivery in this mechanism is not guaranteed to be quickest.

Other papers such as [Rao et al. 2014] discusses about finding backup routes whenever a node failure occurs. The backup routes are found using nearest neighbor of the down node. Nearest neighbors are found using distance vectors and AODV (ad hoc on demand distance vector) routing protocol.

Downside of this process is time delay to find backup routes and related computational complexity and increased traffic.

Ant colony optimization (ACO) based multi agent AODV routing is proposed in the paper [Mostafa et al. 2018].

Multi agent AODV routing compares different possible routes based on hop count, delay and energy of node and selects optimum route. However, it is difficult to find 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 [Mammeri, Zoubir 2019] the author mentioned various reinforcement learning based routing algorithm. 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 [Chetret et al. 2004] proposed a modification to AODV protocol [C. Perkins et al. RFC 3561, 2003] to make the next-hop selection dependent on the experience gained through reinforcement learning and more aware of network dynamics.

MARL-R(*NATG*) *(Mobility-Aware RL-based Routing)* _ In Q-routing, network topology is assumed static. To address changes in topology of MANETs due to node mobility, [Y.H. Chang 2004] proposed MARL-R, a light adaptation to Q-routing.

RL-QRP (RL-based QoS aware Routing Protocol) _ [*X. Liang 2008*.] proposed a routing protocol to deliver packets (which contain patient body temperature, heart rate, and so on) to medical
center reliably and on-time. Sensor nodes are GPS-equipped and exchange their location information through periodic Hello packets. With location information, nodes compute available paths according to QoS requirements of data packets like data rate, maximum delay and the link quality of available paths and then forward data packets. RL is used for QoS path computation and next hop selection.
But the problem with all reinforcement learning based algorithm is the need of vast scale history data or learning data and high energy need per node compared to a traditional routing algorithm.

In the paper [Dhanalakshmi et al. 2021] 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[Robinson et al. 2019] the author published a neighbor knowledge based rebroadcast algorithm which also improves routing overhead and bandwidth usage and enhances QoS.

Another reinforcement learning based routing algorithm is proposed in the paper [Ghaffari Ali. 2017].

In another paper [Balaji G.N, 2018] it tells about machine learning approach of different coherent routing algorithms and compares them. They have introduced knowledge learning algorithm which would enable the network to gather the information about its initial performance, and on the basis of this gathered information, optimum route is established. Henceforth, comparison is made between the varying number of nodes by considering certain performance parameters: packet delivery ratio (PDR), throughput, node mobility etc.

this paper [Hassan, Mustafa Hamid, et al. 2018] is proposing a different hybrid algorithm based on the Cellular Automata (CA) and African Buffalo Optimization (ABO) algorithm. The new CAABO algorithm is used to optimize the path selection in MANET, this, in turn, increases the packet delivery ratio and the node lifespan. The algorithm is similar to the QoS-based methods with regards to the mean end-to end delay value. 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 is one of the important aspects to provide QoS. This paper [Maamar et al. 2016] specifically emphasizes and implements a failure prediction model along with AODV routing.

Similarly, some authors given QoS by bandwidth estimation like in the paper [Chen et al. 2005]. 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 in [JSAC].

Similar bandwidth and delay prediction-based video streaming service over a MANET is described by authors of the paper [Castellanos et al. 2016].

<u>What are the problems to have QoS in MANET?</u>

- QoS needs end to end service guarantee
- QoS needs optimal route and stable route for trusted delivery.

The Algorithm implemented

The algorithm implemented works on finding two predictions in a MANET.
As MANETs are mobile the given algorithm finds that throughout the timeline of QoS communication:

1. The shortest path for a QoS packet.
2. Whether there is possibility of frequent route changes in near future.
3. Whether there is possibility of end-to-end link failure
4. Whether there is a possibility that at a certain moment the route contains a traffic choke point.

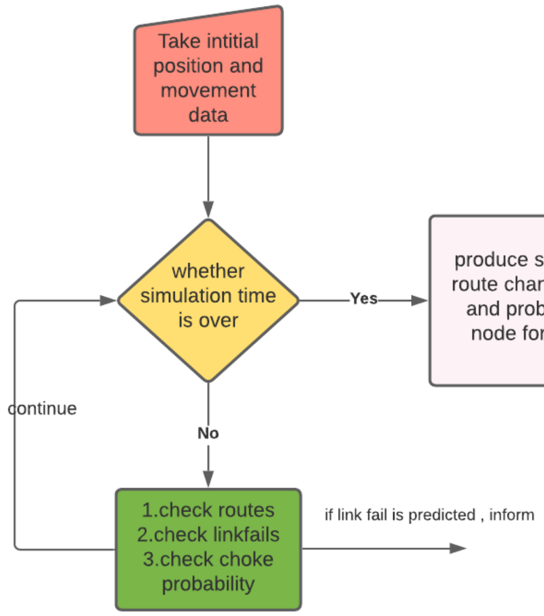
Why short-term route prediction is better instead of only Realtime-routing?

1. Near-term route prediction helps us to assess if there are very frequent changes in the routing possible. We want to avoid frequent route changes for QoS. Because in MANET, traditional Realtime routing like AODV gets periodic distance vector updates and it takes little bit of time every time to converge. Meantime any QoS packet might be lost. If AODV routing table is not reactive enough to frequent topology changes.

2. It can also predict the instances where end to end connection may be lost because of some nodes getting out of range and to prevent moderate/low packet loss.

3. It can predict whether there can be a possibility of traffic choking on a node which is on the path of QoS transmission to prevent heavy packet loss.

Algorithm: QoS_BELLMAN FORD:



Flowchart: QoS_BELLMAN_FORD algorithm outline

The QoS_BELLMAN_FORD algorithm is based on link state routing protocol but it is not realtime, it is predictive over a period of simulation time. (implemented on simulation time = 20 units of time = 10 seconds(1 simulation time unit = 500ms)). It is a purely a c++ program which takes input data from mobility files and traffic files generated by ns2.(check results section)
At every timestamp, bellman ford algorithm is called to find new route, link fails and choke nodes. Choke nodes and probabilities are found by finding whether at any point of time the shortest route contains of articulation points and whether their probability of getting high traffic is calculated below.

Why bellman-ford is used and why it is better than AODV:

To predict future routing instantly, we need global knowledge like:

- mobility information of all the nodes (velocity heading and velocity magnitude)
- Initial position(co-ordinates)

Bellman – ford based QoS is better than AODV based routing because
It has global knowledge of nodes and can predict future routing accurately without 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.

Is predicting future location possible in a MANET using current position and movement:

If we are predicting for only a smaller amount of near future.
And if the node's mobility is highly steady and predictive like in FANET aircrafts do not frequently or abruptly change velocity and direction quickly and they maintain it.
or in marine ad hoc networks of ships the mobility is very steady and predictive because ships do not change velocity and heading randomly and quickly and they can't do it.
So, in these scenarios predictive routing will work pretty well.

<u>What is referred to as "choke node" and how it is found?</u>

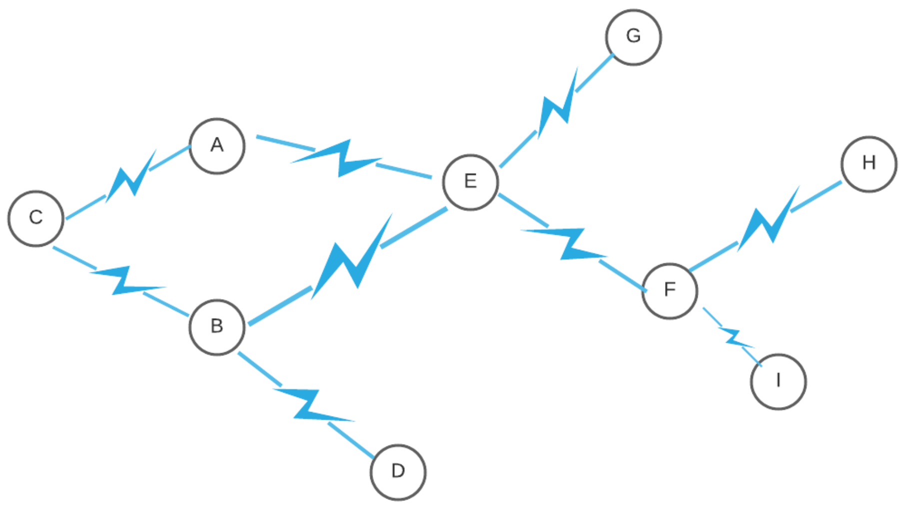
The nodes which are articulation point(cut vertex) and carries a lot of traffic load.
However, articulation point doesn't mean it will be under traffic choking it is possible if:

1. There is high enough existing traffic.
2. The cut vertex is in near the center of the network.

Current research on cut vertex identification and it's importance on traffic congestion and QoS being carried out. Please refer papers[18][19] for more details.

<u>How we defined the choke probability of a node ?</u>

As predicting future traffic is hard, we define choke probability based only on the topology:



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)
Therefore node E has greater chance of traffic choke.

Results and analysis

Results of QoS bellman ford is compared with traditional AODV performance in a randomly initialized MANET in network simulator 2. (ns2)
In ns2, "setdest" tool is used to simulate mobility of nodes and "cbrgen" tool is used to simulate traffic. Datas like packet loss and route update delays are captured and compared with our algorithm output.

Scenario 1: frequent route changes possible
Simulation 1 under scenario 1:

Traffic setup: low
Start node = 1
End node = 2

Algorithm results:

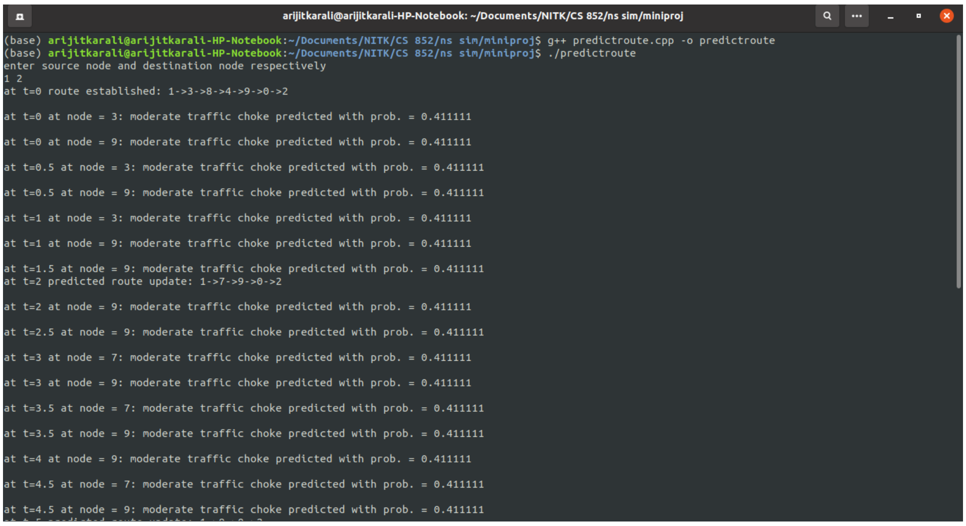
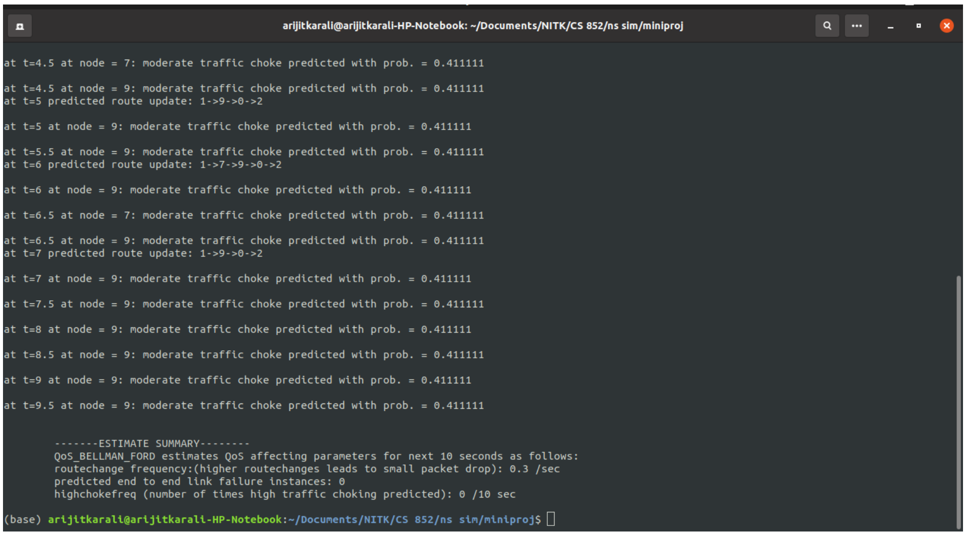
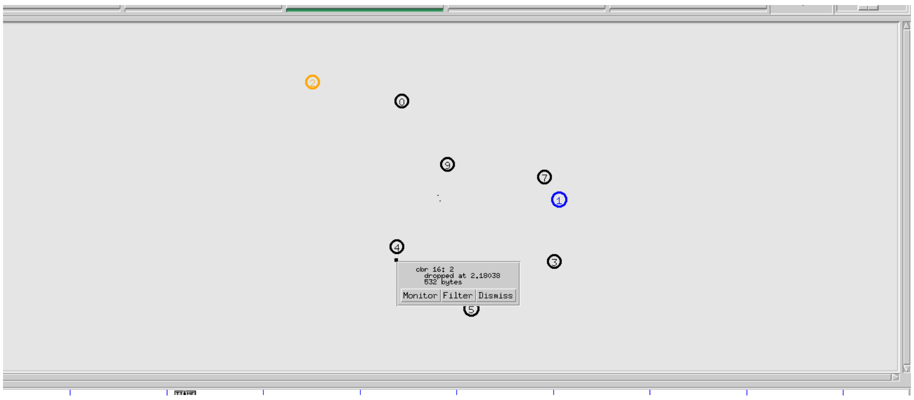


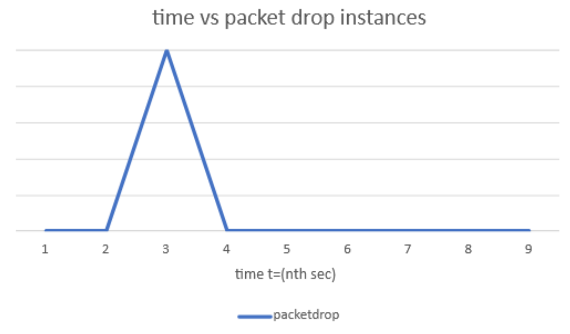
Fig 1: QOS BELLMAN FORD Algorithm predicts route updates and choke nodes for next 10 seconds



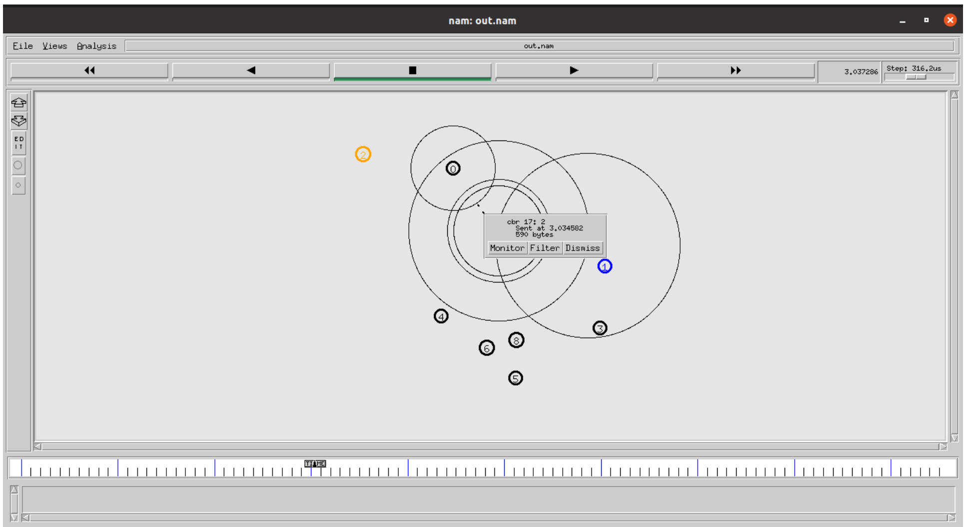
<u>Fig 2: QOS BELLMAN FORD Algorithm predicts route updates and choke nodes for next 10 seconds summarizes result</u>

As seen from fig 1 and fig 2 route change frequency is 0.3/sec which might lead to some minimal packet loss and no linkfails and moderate traffic choke.





<u>Only One packet seen dropped at t = 2.1 sec which is consistent with predicted minimal packet loss</u>



Route change is seen in ns2 at t=3 sec whereas it is predicted by our algorithm at t=2 sec, so AODV is not fast to react.

See the route update delay between AODV and QoS bellman ford:

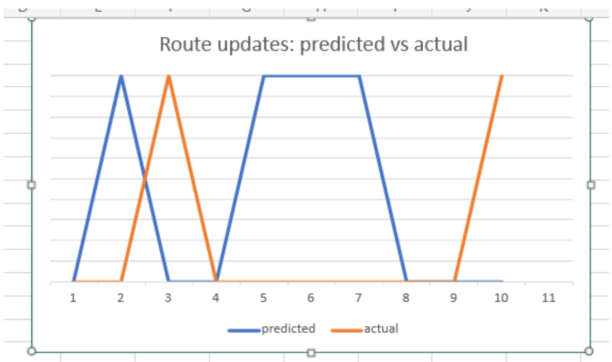


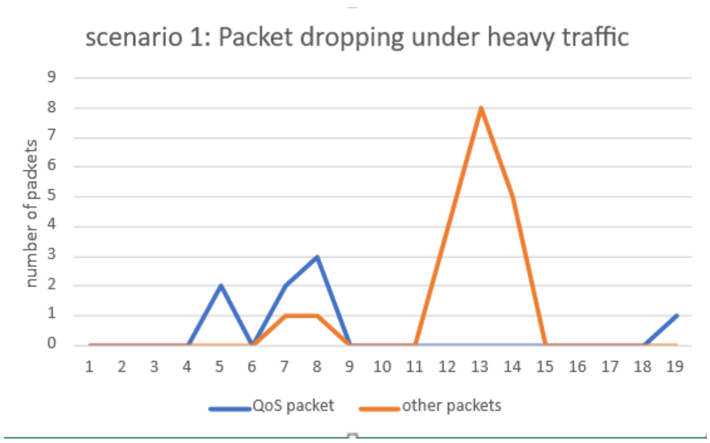
Fig 3: (x axis: time(nth second)) 1 to 2 second delay between predicted optimal route update time and actual route update time of AODV

Scenario 1: with heavy traffic (start node,end node same)

In this case, we start the QoS prediction between same nodes(1 and 2) but with high traffic in circulation. Our algorithm predicted that traffic choke will be less based on topology of that time and we see result consistent to prediction.

<u>Fig 4: The instances when a few packet seen dropped</u>

<u>Comparison of QoS packet dropping vs other packet droppings under heavy traffic scenario 1:</u>



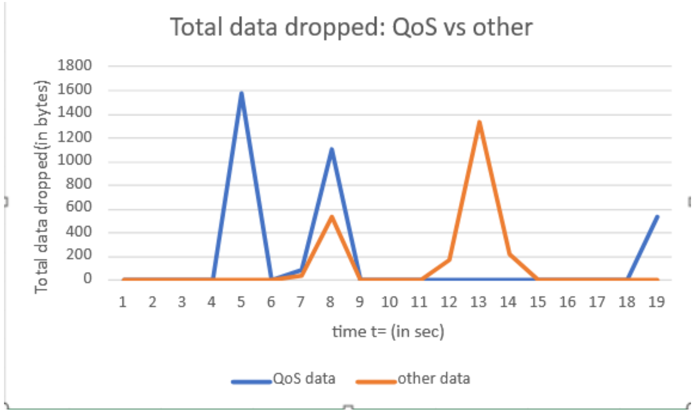


Fig 5: algorithm predicted moderate choking at some node, simulation gives similar results with intermittent packet dropping

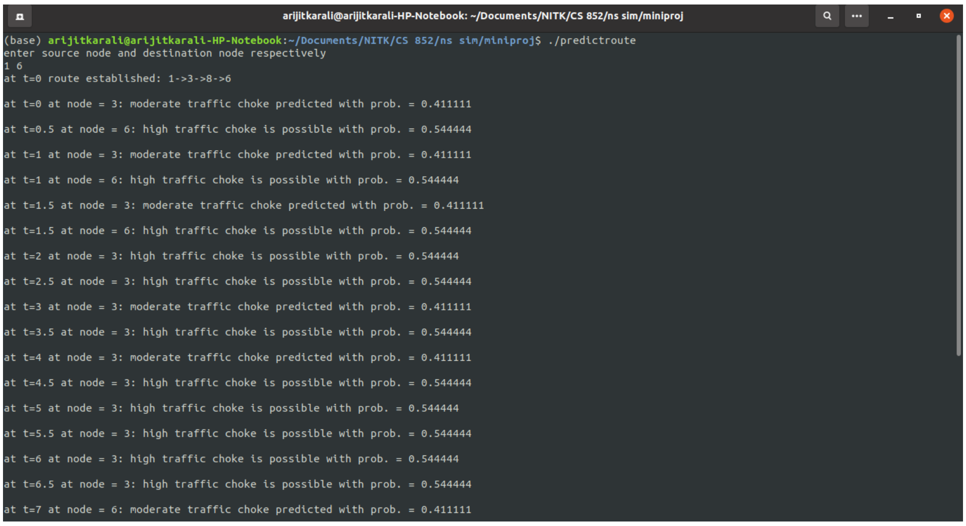
<u>Scenario 2: route updates are less but route contains choke nodes</u>

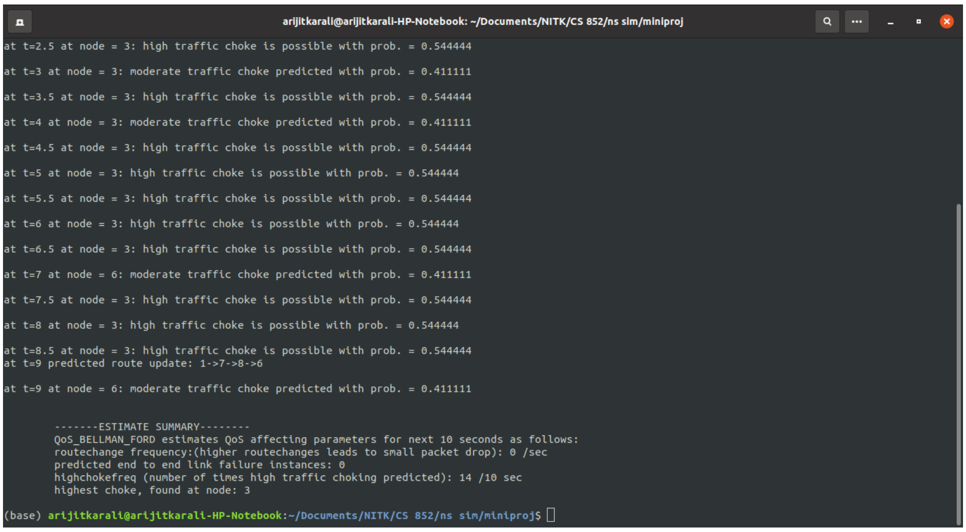
<u>Simulation 1:</u>

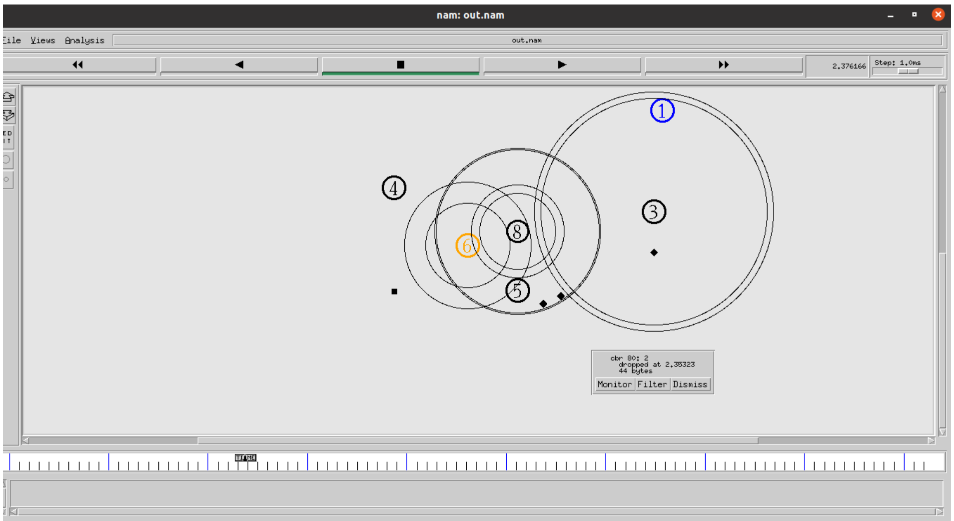
Start node = 1

End node = 6

Traffic :low

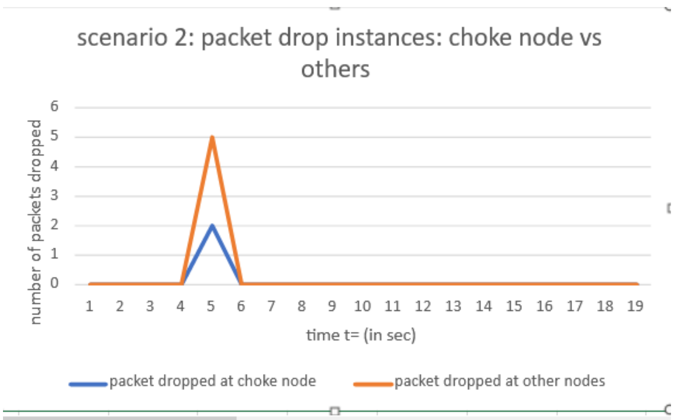


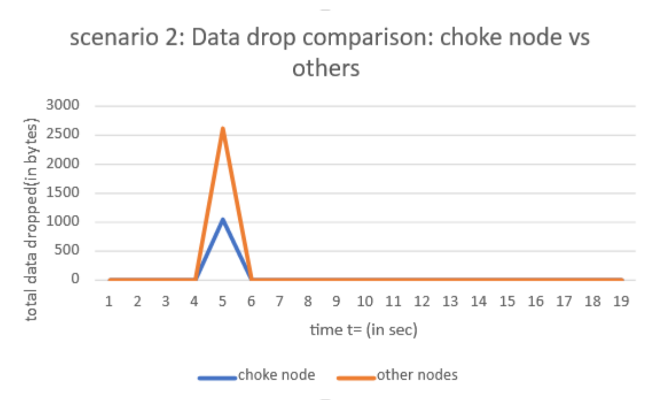




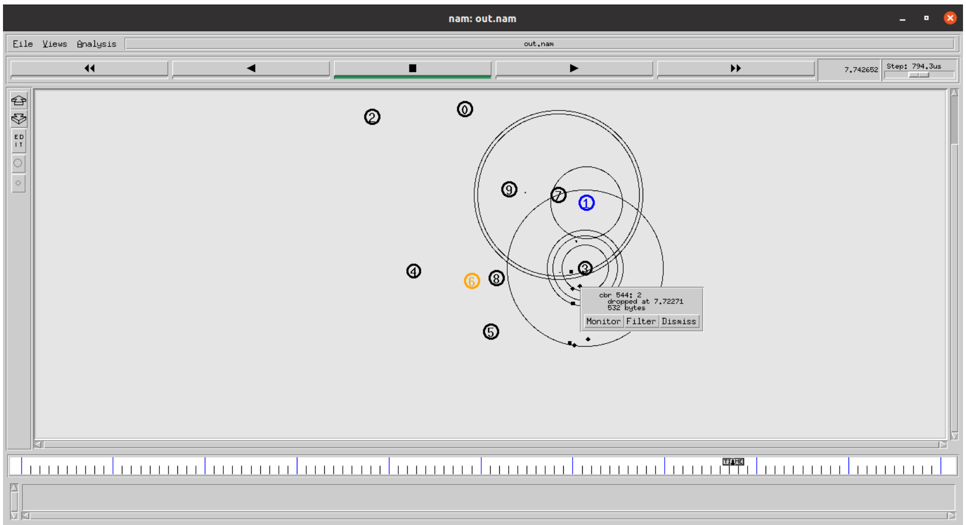
<u>packet dropping seen at several nodes</u>

Algorithm predicts 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 condition, as probability of choking is high at node 3 always.
Results for low traffic are:

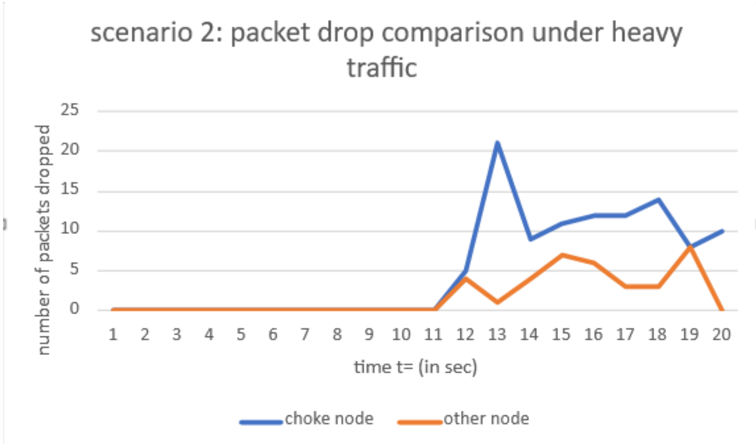


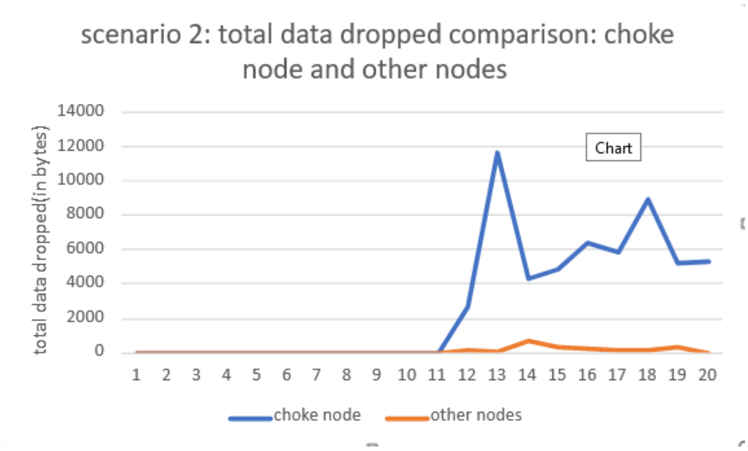


Simulation2: (same nodes, heavy traffic)



Heavy packet dropping seen at choke node 3





<u>Heavy packet dropping after t=10 seen at choke node 3 with avg rate of 8 KB/sec</u>

CONCLUSION

The algorithm works well on predicting route update frequencies and probable choke nodes and can inform or alert before starting a QoS transmission. Also QoS bellman ford needs link state of global nodes, so it needs prior information but the routing itself is less costly in terms of resources, bandwidth and more reactive than traditional AODV.
But this approach assumes Manet nodes not to be very randomly moving but on a steady course like told earlier. So probably it will be most suitable for QoS support in FANET or marine ad hoc nets.

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