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Performance Evaluation of AODV nth BR Routing Protocol under Varying Node Density and Node Mobility for MANETs

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Abstract

Background: A Mobile Ad Hoc Network (MANET) consists of many independent nodes that operate over a wireless topology with numerous Quality of Service (QoS) requirements. So, a robust routing protocol that also provides QoS parameters to its different range of applications is needed. Various network parameters like node density, node mobility, field size etc. also effects the QoS parameters of MANETs. **Methods:** The traditional reactive routing protocols do not have any backup route in case of a node failure and hence are not effective for MANETs. Ad Hoc on Demand Distance Vector Backup Routing (AODV BR) protocol performs better than traditional routing protocols but is not effective when the backup route fails. So, to counter this problem, the authors had proposed AODV nth BR that keeps on providing backup routes when multiple nodes fail and hence successfully transfers the data to the destination. The nodes for backup routing are selected based on their distance from the failed node and energy efficiency. **Results:** In this paper, the performance of AODV nth BR has been compared with AODV, DSR and AODV BR protocol under varying node density (nodes 20, 60,100) and node mobility conditions (5m/s, 20m/s, 50m/s). The values for Packet Delivery Fraction (PDF) for 60 nodes at speed 20m/s in case of AODV nth BR protocol after 6000 rounds is 0.3054. Comparatively, value of AODV BR is 0.2664, AODV is 0.1936 and DSR is 0.1056. QoS performance is measured in terms of end to end delay, packet delivery fraction and lifetime of devices and it has been shown through simulated results that AODV nth BR protocol gives better output than traditional routing protocols. **Conclusion:** From the simulated results explained in detail in the paper, it has been observed that route after link breakage is found to be best with AODV nth BR protocol and this can be clearly seen in the QoS parameters obtained.

Keywords: AODV BR, AODV nth BR, MANETs, Node Density, Node Mobility

1. Introduction

Mobile Ad Hoc Networks (MANETs) enable data transmission in difficult geographical locations and are useful in civil and military applications[1]. These devices facilitate a range of applications and hence a spurt in the popularity of these devices has been seen in recent times. MANET applications involve network of various computers in a small as well as large area, military deployment of various nodes etc.[2] All these applications require transfer of real time as well as multimedia data that requires the system to provide sufficient Quality of Service (QoS) parameters. In all these and various other applications, node failure results in poor performance or degraded QoS parameters. Hence, it is strongly desired that MANETs should be supported by an efficient and robust routing protocol that caters to its requirements. However, the main challenge is to find a suitable routing protocol that supports the challenging demands of a network like MANET and also provides sufficient QOS parameters. Also, there are other network parameters like node density, node mobility etc. that also affect the system performance[3].

The paper is organized as follows. In section 2, reactive routing protocols like AODV, DSR and its variant AODV

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BR protocol have been discussed along with AODV nthBR protocol[4]. Along with the routing protocols, effect of variation in node density and node mobility has also been discussed here. In Section 3, simulation environment along with the parameters considered for simulation are discussed. In Section 4, results obtained for AODV nthBR protocol under different node densities and node mobility are compared with AODV, DSR and AODV BR for various QoS parameters. In Section 5, work done is summarized.

2. Related Work

2.1 Various Routing Protocols

Routing protocols can be mainly classified into proactive or table driven and reactive or on demand[5]. In table driven routing protocols nodes need to maintain the routing information and this information has to be updated continuously even if the nodes are not participating in any communication. Although this kind of an approach leads to less packet transfer delay between nodes as route information of all nodes is available but at the same time it leads to a large control overhead especially in MANETs where nodes are changing their position constantly. As proactive routing protocols are not suitable for ad hoc networks, conventionally reactive or on demand routing protocols are used for MANETs. Here, routes to the destination are established on demand thus reducing the overhead considerably[6].

Two of the most prominent routing protocols that are used for route establishment in MANETs and also simulated in this paper are Ad Hoc On Demand Distance Vector (AODV), Dynamic Source Routing (DSR) Protocol. In AODV protocol, a routing table is maintained and a new route is found out only if the route to the current destination is not available[7],[8]. However, AODV does not address the problem of route/node failure and does not suggest any alternate path to transmit data in case of node failure. This leads to high packet loss, broken routes and other low QoS parameters.

Dynamic Source Routing Protocol (DSR) contains a route cache maintained by each node[9]. A record of all the nodes passed through it is maintained and based on this data, the optimal path is selected. In DSR each packet carries full routing information. Also, a record of all the nodes passed through it is maintained and based on this data, the optimal path is selected. DSR too does not provide any solution for broken path or node failure leading to poor QoS parameters.

In order to improve QoS parameters a variant of AODV called AODV BR was proposed[10]. Here a backup routing along with a primary route is created so as to have a backup path in case of link failure. A mesh like structure is created to provide an alternate route[11]. Alternate routes are established by overhearing the packets that are being transmitted and show better performance in terms of total number of processed messages. On detecting a failed node repairing procedure occurs near the failed node of the primary path. AODV BR provides a backup route when a node failure occurs but does not provide any solution when the backup route also fails. To overcome this problem, AODV with nth Backup Route (AODV nthBR) technique was proposed that provides backup routes in MANETs. On failure of the original route, the next nearest, energy efficient node is selected as backup route and when that back up route also fails then the next backup route is found out and checked for energy efficiency. The process continues until a suitable path is selected for routing. Nodes in the path of routing are selected on the basis of distance from the current node and its available energy. Nearest node to the failed node is selected using distance vector calculation and this node is checked for its energy efficiency and if the remaining energy is within the threshold value required for packet transmission then node is selected for backup route. There is no duplicity of data packets that are transmitted to the destination as data packets are not simultaneously transmitted on multiple routes.

2.2 Effects of Node Density and Node Mobility

Apart from the routing protocols node density plays an important role in affecting the QoS parameters of the network. Sparse networks (with few mobile nodes) have difficulty in sending and receiving packets as nodes are not in communication range with one another[12]. Also, MANETs are multihop in nature; hence more energy is consumed by the nodes as they need to transfer not only their own data packets but data packets of other nodes also. On the other hand, dense networks result in increased interference. Besides node density, node mobility also is a crucial factor in affecting network performance[13,14]. In very high mobility nodes it is difficult to establish routes or communication link between two nodes leading to packet loss[15]. Frequent link breakages are common in networks with high node mobility and increased number of mobile nodes needs more demand for mobility support[16].

In a previous work by the authors[17] AODV nthBR protocol had been simulated for small, medium and large MANETs and their QoS parameters analysed. This paper in an extension of the authors' previous work simulates and compares the performance of AODV nthBR protocol with other reactive routing protocols under varying node density and node mobility.

3. Simulation Setup and Implementation

3.1 Network Scenario

Figure 1 shows a rectangular field area of size 100*m* × 100*m* with destination initially placed in the centre and then made mobile at the start of data transmission. Network has been simulated for sparsely populated system (20 nodes), medium sized system (60 nodes) and densely populated system (100 nodes) with node mobility varying as 5m/s, 20m/s and 50m/s. All the nodes are randomly placed in the field area and initial energy of a node is 0.5J and total packets to be transmitted are 4000 with each packet of size 1 bit and number of transmission rounds being 6000. Although the simulation set up is such that values of node densities and node mobility can be modified according to system requirements but for simulation and analysis purpose the above mentioned node densities and node mobility values are considered.

3.2 Implementation of AODV nthBR

Distances between all the nodes are calculated using distance vector calculation[18,19].

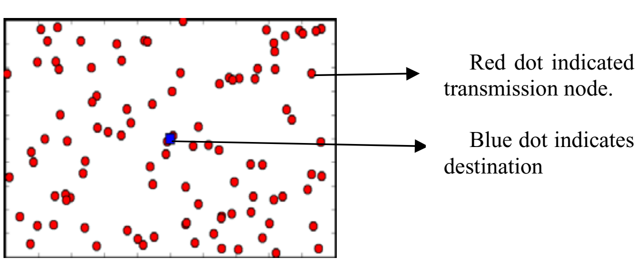

Figure 1. MANET Simulation set up with red dots denoting the transmitting nodes and blue dot denoting the destination.

Average distance between the transmitting device and destination D_{bs}

$$D_{bs} = \left(\left(one\ dimension\ of\ field\right) / \sqrt{2\pi k}\right)(\mathrm{k}=1) \qquad (1)$$

$$D_{bs} = 0.765 \times one\ \mathrm{dim}\, ension\ of\ field\ \frac{\square}{2} \qquad (2)$$

Also, the calculated average energy E_a of a node after a particular round is given by

$$E_a = E_t \times \left(\frac{1 - \left(\frac{r}{R_{\max}} \right)}{n} \right) \qquad (3)$$

R_{max}=Maximum number of Rounds

E_t = Total Energy

The total energy dissipated in the network during a round is calculated by:

$$E_t = bits\ data \times \left(2 \times n \times E_{tx} + n \times E_{da} + K_{opt} \times E_{mp} \times (D_{bs})^4 + 4 \times n \times E_{fs} \times (D_{ch})^2\right) \qquad (4)$$

E_{tx} = Electronics Amplifier energy

n = No. of nodes in field

E_{mp} = Transmit Amplifier Energy

E_{tx} = Received Amplifier Energy

E_{da} = Data Aggregation Energy

K_{opt} = Optimum number of node groups

D_{ch} = Average distance between transmitting node and the destination

E_{fs} = represent amplifier energy consumptions for a short distance transmission.

At the start of the data transmission, packets are sent to the destination through multihop transmission involving intermediatory nodes. In case of a node failure, the node that is nearest to the failed node is found out using distance vector calculation as given in equation 1 and 2. Also, the energy of the selected node is calculated (equation 3). If energy of the selected node is within the threshold value required for packet transmission then node is selected for backup route else the next nearest node is found out using distance vector and energy calculation method. If the next nearest node fulfils the criteria of distance and energy requirements, then the node is selected for packet transmission otherwise the process of finding the suitable node continues. Network parameters for simulation are given in Table 1.

Table 1. Network Specifications

Simulation Parameters	
Field Size	100m X 100m
Number of nodes	20,60,100
Number of Packets	4000
Number of Rounds	6000
Speed of the nodes	5m/sec, 20m/sec, 40m/sec
Protocols	AODV,DSR,AODV BR, AODV nthBR

4. Results

Simulations were performed in MATLAB, an open source package and QoS parameters were obtained in terms of end to end delay, lifetime of devices and packet delivery fraction. Value of all the QoS parameters have been calculated for node densities 20, 60 and 100 with value of node mobility varying as 5m/sec, 20m/sec and 40m/sec.

4.1 End to End Delay

End to end delay is the total latency experienced by a packet to traverse the network from the source to the destination. It is the summation of the node delay at each node plus the link delay at each link on the path. The total node delay includes the protocol processing time and the queuing delay at each node.

As seen from the results obtained (Figure 2- Figure 10), end to end delay is maximum in case of DSR protocol. The least end to end delay is obtained when data is transmitted through AODV nthBR protocol. A spike can be initially seen in case of AODV nthBR protocol. This is because at the start of transmission, the number of alive devices or devices capable of transmission is more in case of AODV nthBR and also due to backup

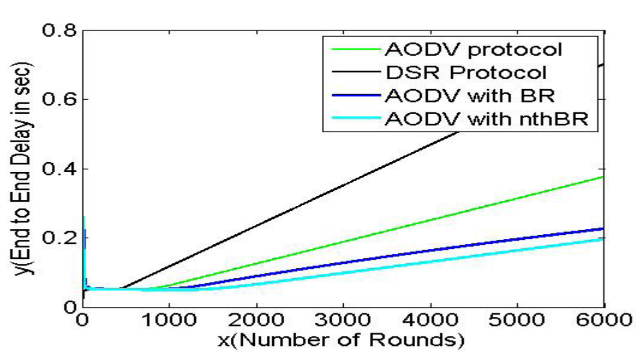

Figure 2. End to end delay (Speed 5m/s and 20nodes).

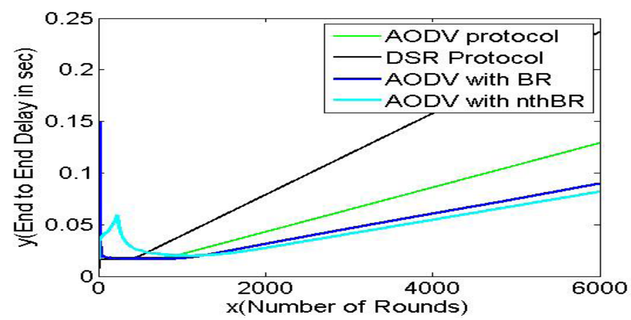

Figure 3. End to end delay (Speed 5m/s and 60 nodes).

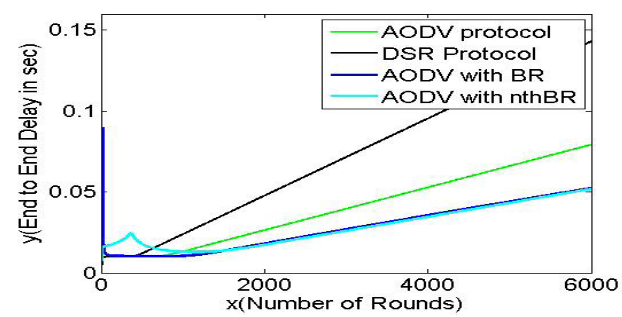

Figure 4. End to end delay (Speed 5m/s and 100 nodes).

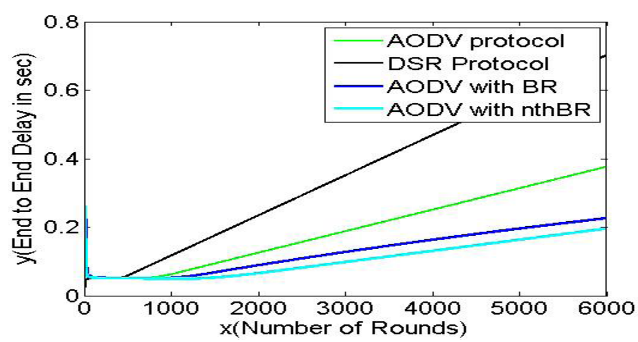

Figure 5. End to end delay (Speed 20m/s and 20 nodes).

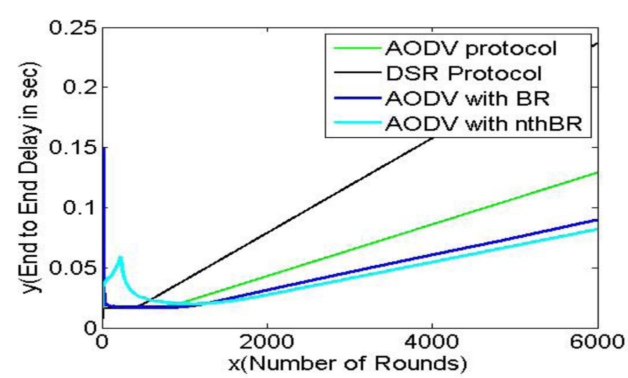

Figure 6. End to end delay (Speed 20m/s and 60 nodes).

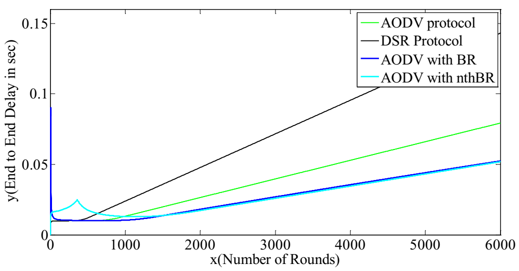

Figure 7. End to end delay (Speed 20m/s and 100 nodes).

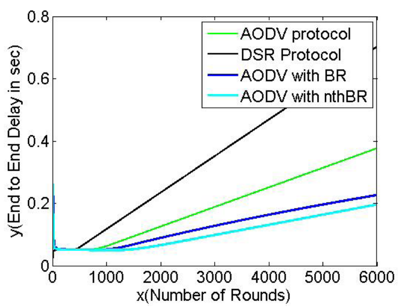

Figure 8. End to end delay (Speed 40m/s and 20 nodes).

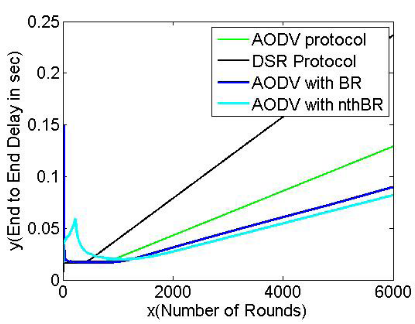

Figure 9. End to end delay (Speed 40m/s and 60 nodes).

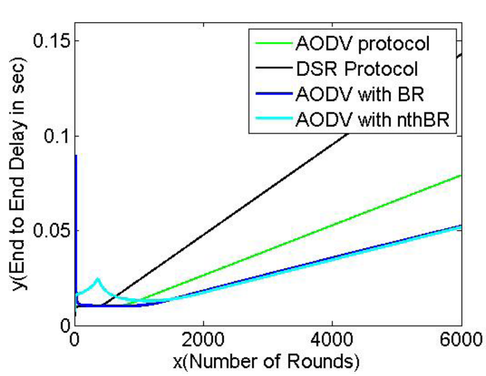

Figure 10. End to end delay (Speed 40m/s and 100 nodes).

scheduling of packets at the start of steady state phase, any inactive node is replaced with a backup node and then the communication continues through the backup node. However, this initial delay at the start up is covered during the overall communication. Also, as observed from Figure 7 and Figure 10, the end to end delay obtained for AODV nthBR is marginally lesser than AODV BR. Figure 7 shows the end to end delay when number of nodes are high and Figure 10 shows the end to end delay when speed of nodes is fast (40m/sec). The marginal difference in value of AODV nthBR is due to the initial presence of more number of nodes in case of AODV nthBR protocol and this effect is more visible when numbers of nodes are more or when speed of nodes is fast. Our main purpose is to obtain a backup route network in such a way that a chance of communication failure is minimal and this becomes possible with the help of AODV nthBR.

4.2 Lifetime of Devices

Lifetime of devices means the number of nodes that are alive or capable of data transmission per number of rounds. Figures (11-19) show that as the number of rounds increase the maximum number of alive nodes (devices that are capable of transmission) decreases. For the same number of rounds, DSR has the least number of nodes that are capable of transmission. AODV and AODV BR have more number of nodes capable of transmission than DSR for the same number of rounds. However, as seen from the Figures (11-19), as the number of transmission rounds increase, the number of energy efficient devices (capable of transmitting packets) is more in case of AODV nthBR for all the cases. Since more number of energy efficient devices are available for packet transmission, better QoS parameters can be obtained with AODV nthBR protocol.

4.3 Packet Delivery Fraction

Packet Delivery Fraction (PDF) defined as the ratio of the total number of data packets received by the destination to the total number of data packets transmitted.

$$PDF = \frac{Data\ received\ by\ destination}{Data\ sent\ by\ transmitter} \quad (5)$$

In Figures 20-28, the y-axis represents the percentage of packets received at the destination for the given number of rounds and for varying node densities and node mobility. It is observed that maximum percent packets are received at the destination when the data transmission is done with AODV nthBR. As observed from the Figures 21,22,24,25,27 and 28, where the number of nodes are more than 60, it is seen that there is a slight delay in increase in the value of PDF in case of AODV nthBR. This is due to the backup arrangement of nodes for data transmission and also because when the system is dense there will be more number of alive nodes (nodes having energy capable of data transmission) that are available resulting in a slow start up at the beginning. To show that PDF obtained with AODV nthBR protocol is maximum as compared to other protocols, the authors have prepared Table 2, Table 3 and Table 4 that give a comparison of PDF obtained for different protocols. Although the results can be obtained for any number of nodes, the authors have taken the number

Table 2. Packet Delivery Fraction When Speed 5m/s and Number of Nodes 60

Protocol	Number of Rounds		
	2000	3000	6000
AODV	0.1936	0.1936	0.1936
DSR	0.1056	0.1056	0.1056
AODV BR	0.2664	0.2664	0.2664
AODV nthBR	0.3054	0.3054	0.3054

Table 3. Packet Delivery Fraction When Speed 20m/s and Number of Nodes 60

Protocol	Number of Rounds		
	2000	3000	6000
AODV	0.1922	0.1922	0.1922
DSR	0.1058	0.0.1058	0.1058
AODV BR	0.2764	0.2764	0.2764
AODV nthBR	0.3247	0.3247	0.3247

Table 4. Packet Delivery Fraction When Speed 40m/s and Number of Nodes 60

Protocol	Number of Rounds		
	2000	3000	6000
AODV	0.1922	0.1922	0.1922
DSR	0.1058	0.1058	0.1058
AODV BR	0.2767	0.2767	0.2767
AODV nthBR	0.3242	0.3242	0.3242

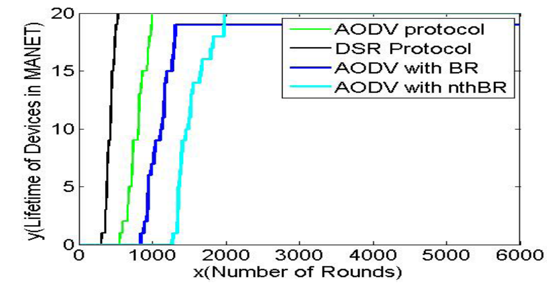

Figure 11. Lifetime of devices (Speed 5m/s and 20 nodes).

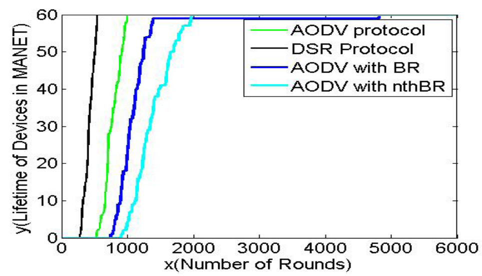

Figure 12. Lifetime of devices (Speed 5m/s and 60 nodes).

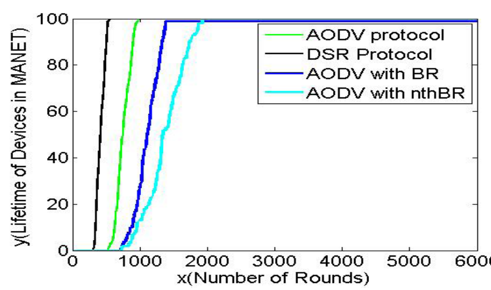

Figure 13. Lifetime of devices (Speed 5m/s and 100 nodes).

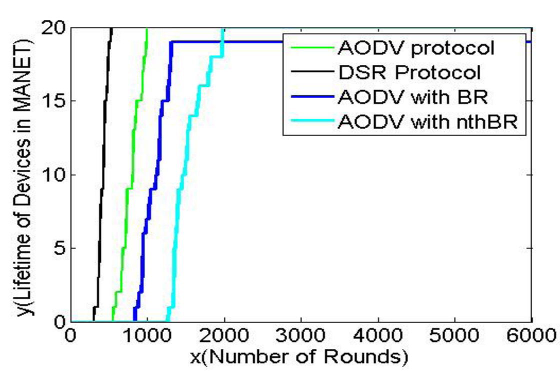

Figure 14. Lifetime of devices (Speed 20m/s and 20 nodes).

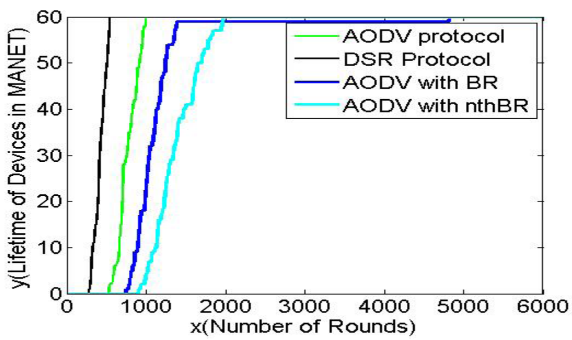

Figure 15. Lifetime of devices (Speed 20m/s and 60 nodes).

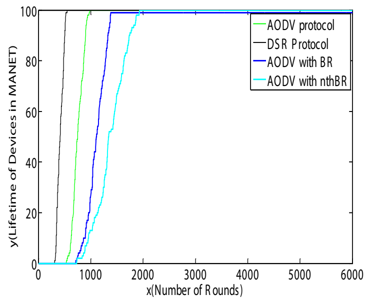

Figure 16. Lifetime of devices (Speed 20m/s and 100 nodes).

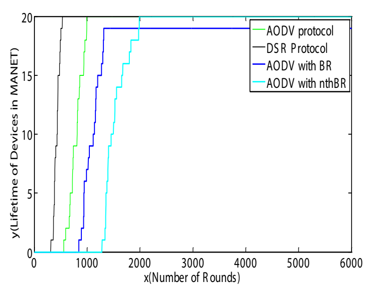

Figure 17. Lifetime of devices (Speed 40m/s and 20 nodes).

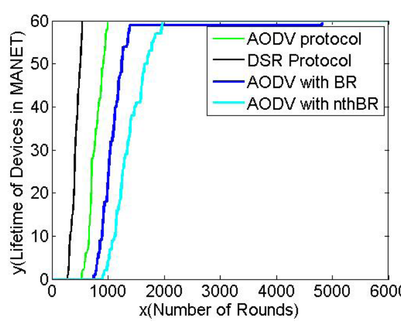

Figure 18. Lifetime of devices (Speed 40m/s and 60 nodes).

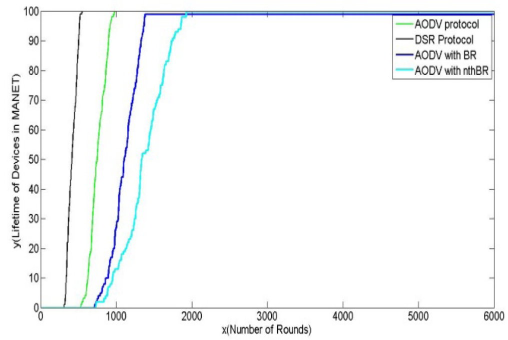

Figure 19. Lifetime of devices (Speed 40m/s and 100 nodes).

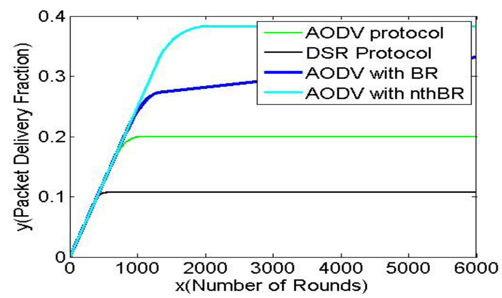

Figure 20. Packet delivery fraction (Speed 5m/s and 20 nodes).

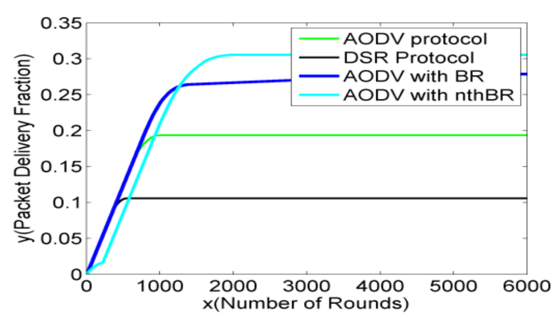

Figure 21. Packet delivery fraction (Speed 5m/s and 60 nodes).

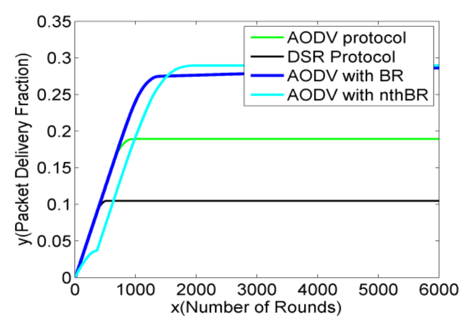

Figure 22. Packet delivery fraction (Speed 5m/s and 100 nodes).

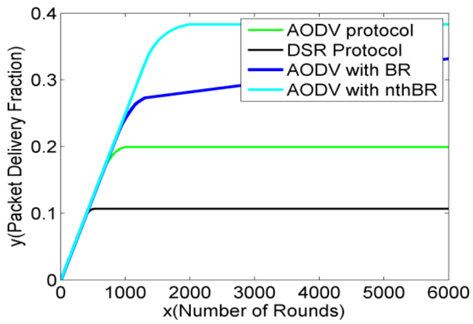

Figure 23. Packet delivery fraction (Speed 20m/s and 20 nodes).

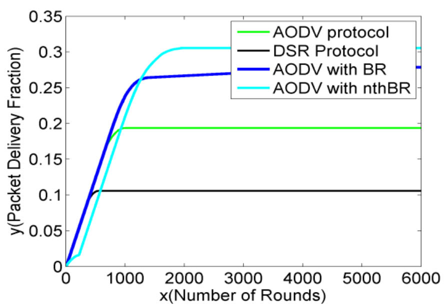

Figure 24. Packet delivery fraction (Speed 20m/s and 60 nodes).

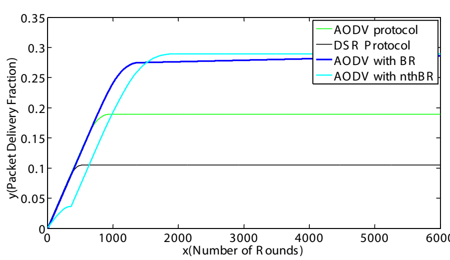

Figure 25. Packet delivery fraction (Speed 20m/s and 100 nodes).

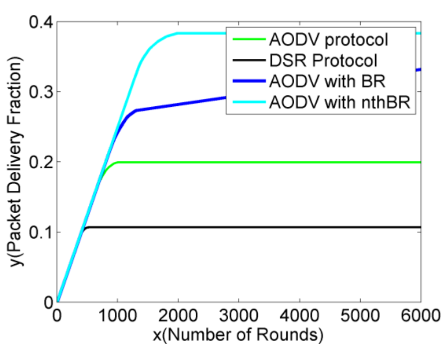

Figure 26. Packet delivery fraction (Speed 40m/s and 20 nodes).

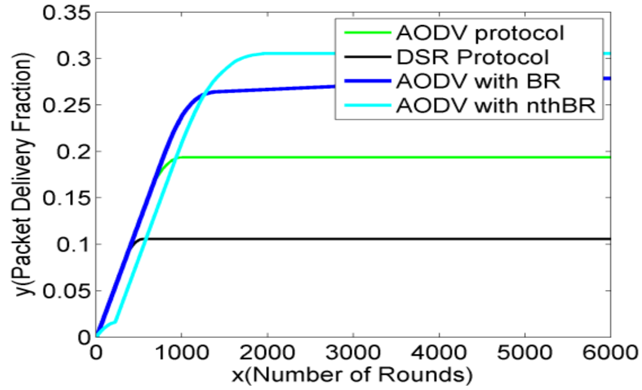

Figure 27. Packet delivery fraction (Speed 40m/s and 60 nodes).

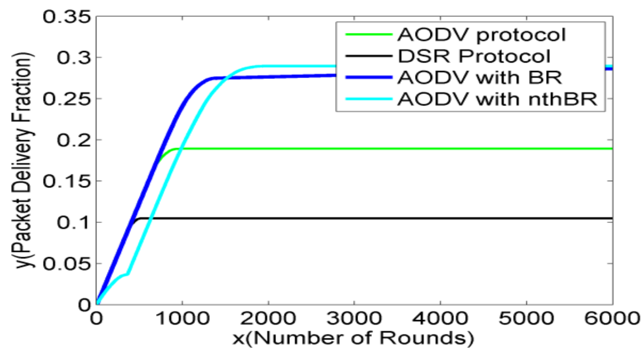

Figure 28. Packet delivery fraction (Speed 40m/s and 100 nodes).

of nodes for tabular comparison as 60. From Tables 2, 3 and 4 it can be observed that PDF obtained with AODV nthBR is maximum for varying node speeds.

5. Conclusion

In this paper AODV nthBR protocol has been simulated for various values of node densities and node mobility and the results have been compared with AODV, DSR and AODV BR protocol. The values of node densities are selected in such a way that each value represents a small, medium and large sized MANETs. Similarly, the values of node mobility are selected to represent slow, medium and fast moving MANETs. On comparing end to end delay when number of nodes is 100, the results obtained with AODV nthBR and AODV BR is almost comparable. This is because large number of nodes require more time for calculation. For all other QoS parameters, results obtained with AODV nthBR has been found to be best compared to other reactive routing protocols.

6. References

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