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MANET Routing Protocols Performance Evaluation in Mobility

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1. Introduction

Ad-hoc network is a collection of wireless mobile nodes dynamically forming a temporary network without the aid of any established infrastructure or centralized administration. Routing protocols in mobile ad-hoc network helps node to send and receive packets. In this chapter our focus is to study Reactive (AODV and A-AODV), Proactive (DSDV) based on Random Waypoint mobility model. In this chapter, a new routing protocol A-AODV is proposed. The performance of three routing protocols (AODV, DSDV, and A-AODV) based on metrics such as packet delivery ratio, end to end delay, and throughput are studied. The simulation work is done with the NS-2.34 simulator with the ordered traffic load.

Mobile ad-hoc networks, also known as short-lived networks, are autonomous systems of mobile nodes forming network in the absence of any Centralized support. This is a new form of network and might be able to provide services at places where it is not possible otherwise. Absence of fixed infrastructure poses several types of challenges for this type of networking. Among these challenges is routing, which is responsible to deliver packets efficiently to mobile nodes. So routing in mobile ad-hoc network is a challenging task due to node mobility. Moreover bandwidth, energy and physical security are limited. MANET is the Art of Networking without a Network. In the recent years communication technology and services have advanced. Mobility has become very important, as people want to communicate anytime from and to anywhere. In the areas where there is little or no infrastructure is available or the existing wireless infrastructure is expensive and inconvenient to use, Mobile Ad hoc NETworks, called MANETs, are useful. They form the integral part of next generation mobile services. A MANET is a collection of wireless nodes that can dynamically form a network to exchange information without using any pre-existing fixed network infrastructure.

Each device in a MANET is free to move independently in any direction, and will therefore change its links to other devices frequently. Each must forward traffic unrelated to its own use, and therefore be a router. The primary challenge in building a MANET is equipping each device to continuously maintain the information required to properly route traffic. Such networks may operate by themselves or may be connected to the larger Internet.

2. Challenges in MANETs

The major open Challenges (S.Corson & J.Macker, 1999; H.Yang et al., 2004) to MANETs are listed below:

a. **Autonomous**- No centralized administration entity is available to manage the operation of different mobile nodes.
b. **Dynamic topology**- Nodes are mobile and can be connected dynamically in an arbitrary manner. Links of the network vary timely and are based on the proximity of one node to another node.
c. **Device discovery**- Identifying relevant newly moved in nodes and informing about their existence need dynamic update to facilitate automatic optimal route selection.
d. **Bandwidth optimization**- Wireless links have significantly lower capacity than the wired links.
e. **Limited resources**- Mobile nodes rely on battery power, which is a scarce resource. Also storage capacity and power are severely limited.
f. **Scalability**- Scalability can be broadly defined as whether the network is able to provide an acceptable level of service even in the presence of a large number of nodes.
g. **Limited physical security**- Mobility implies higher security risks (H.Yang, et al., 2004) such as peer-to- peer network architecture or a shared wireless medium accessible to both legitimate network users and malicious attackers. Eavesdropping, spoofing and denial-of-service attacks should be considered.
h. **Infrastructure**- less and self operated- Self healing feature demands MANET should realign itself to blanket any node moving out of its range.
i. **Poor Transmission Quality**- This is an inherent problem of wireless communication caused by several error sources that result in degradation of the received signal.
j. **Adhoc addressing**- Challenges in standard addressing scheme to be implemented.
k. **Network configuration**- The whole MANET infrastructure is dynamic and is the reason for dynamic connection and disconnection of the variable links.
l. **Topology maintenance**- Updating information of dynamic links among nodes in MANETs is a major challenge.

Wireless application scenarios lead to a diverse set of service requirements for the future Internet as summarized below:

1. Naming and addressing flexibility.
2. Mobility support for dynamic migration of end-users and network devices.
3. Location services that provide information on geographic position.
4. Self-organization and discovery for distributed control of network topology.
5. Security and privacy considerations for mobile nodes and open wireless channels.
6. Decentralized management for remote monitoring and control.
7. Cross-layer support for optimization of protocol performance.
8. Sensor network features such as aggregation, content routing and in-network Processing.
9. Cognitive radio support for networks with physical layer adaptation.
10. Economic incentives to encourage efficient sharing of resources.

3. Overview of AODV, DSDV and RWMM

3.1 Ad Hoc on-demand distance vector routing (AODV)

The AODV protocol (Perkins & Royer, 1999) is a reactive routing protocol for MANETs. It discovers routes once demanded via a route discovery process. The protocol uses route request (RREQ) packets sent by the sender node and circulating throughout the network. Each node in the network rebroadcasts the message except the sink node. The receiver replies to the RREQ message with a route reply (RREP) packet that is routed back to the sender node. The route is then cached for future reference; however in case a link is broken, a route error (RERR) packet is sent to the sender and to all the nodes as well so as to initiate a new route discovery. To maintain routing information, AODV uses a routing table with one entry for each destination. Thus, the table is used to propagate RREP to the source node. AOOV (Geetha Jayakumar & G. Gopinath, 2007, 2008) also relies on time, which means that if a routing table is not used recently, it will expire. Moreover, once a RERR is sent, it is meant to warn all nodes in the network; hence, this makes it very efficient to detect broken paths.

3.2 Destination-sequenced distance vector routing (DSDV)

The DSDV protocol (C. Perkins & P.Bhagwat, 1994) is a routing algorithm that focuses on finding the shortest paths. The protocol is based on the Bellman-Ford algorithm to find the routes with improvements. The latter algorithm is very similar to the well-known Dijkstra's algorithm with the support of negative weights. DSDV (Md. Monzur Morshed et al., 2010) falls in the proactive category of routing protocols; hence, every mobile node maintains a table containing all the available destinations, the number of hops to reach each destination, and a sequence number. The sequence number is assigned by the destination node its purpose is to distinguish between old nodes and new ones. In order for the nodes to keep track of moving other nodes, a periodic message containing a routing table is sent by each node to its neighbors. The same message can also be sent if significant change occurs at the level of the routing table. Therefore, the update of the routing table is both time-driven and event-driven. Further discussion can be done for better performance, such as not sending the whole table (full dump update), but only the modified portions (incremental update). The motivation behind it is to be able to update the rest of the network through one packet. This means that if the update requires more than one packet, a full dump is probably a safer approach in this case.

3.3 Random waypoint mobility model (RWMM)

Random Waypoint (RWP) model is a commonly used synthetic model for mobility, e.g., in Ad Hoc networks. It is an elementary model which describes the movement pattern of independent nodes by simple terms.

The Random Waypoint model (F. Bai et al., 2003; Guolong Lin et al., 2004; F.Bai & A.Helmy, 2004) is the most commonly used mobility model in research community. At every instant, a node randomly chooses a destination and moves towards it with a velocity chosen randomly from a uniform distribution [0, V_{max}], where V_{max} is the maximum allowable velocity for every mobile node. After reaching the destination, the node stops for a duration defined by the 'pause time' parameter. After this duration, it again chooses a random destination and repeats the whole process until the simulation ends.

4. Altered ad-hoc on-demand distance vector (A-AODV)

Analyzing previous protocols, we can say that most of on-demand routing protocols, except multipath routing, uses single route reply along the first reverse path to establish routing path. In high mobility, pre-decided reverse path can be disconnected and route reply message from destination to source can be missed. In this case, source node needs to retransmit route request message. Purpose of this study is to increase possibility of establishing routing path with less RREQ messages than other protocols have on topology change by nodes mobility. Specifically, the proposed A-AODV protocol discovers routes on-demand using a reverse route discovery procedure. During route discovery procedure, source node and destination node plays same role from the point of sending control messages. Thus after receiving RREQ message, destination node floods reverse request (R-RREQ), to find source node. When source node receives an R-RREQ message, data packet transmission is started immediately.

4.1 Route discovery

Since A-AODV is reactive routing protocol, no permanent routes are stored in nodes. The source node initiates route discovery procedure by broadcasting. The RREQ message contains information such as: message type, source address, destination address, broadcast ID, hop count, source sequence number destination sequence number, request time (timestamp). Whenever the source node issues a new RREQ, the broadcast ID is incremented by one. Thus, the source and destination addresses, together with the broadcast ID, uniquely identify this RREQ packet. The source node broadcasts the RREQ to all nodes within its transmission range. These neighboring nodes will then pass on the RREQ to other nodes in the same manner. As the RREQ is broadcasted in the whole network, some nodes may receive several copies of the same RREQ. When an intermediate node receives a RREQ, the node checks if already received a RREQ with the same broadcast id and source address. The node cashes broadcast id and source address for first time and drops redundant RREQ messages. The procedure is the same with the RREQ of AODV. When the destination node receives first route request message, it generates so called reverse request (R-RREQ) message and broadcasts it to neighbor nodes within transmission range like the RREQ of source node does. R-RREQ message contains the information such as: reply source id, reply destination id, reply broadcast id, hop count, destination sequence number, reply time (timestamp). When broadcasted R-RREQ message arrives to intermediate node, it will check for redundancy. If it already received the same message, the message is dropped, otherwise forwards to next nodes. Furthermore, node stores or updates following information of routing table:

- Destination and Source Node Address
- Hops up to destination
- Destination Sequence Number
- Route expiration time and next hop to destination node.

And whenever the original source node receives first R-RREQ message it starts packet transmission, and late arrived R-RREQs are saved for future use. The alternative paths can be used when the primary path fails communications.

4.2 Route update and maintenance

When control packets are received, the source node chooses the best path to update, i.e. first the node compares sequence numbers, and higher sequence numbers mean recent routes. If sequence numbers are same, then compares number of hops up to destination, routing path with fewer hops is selected. Since the wireless channel quality is time varying, the best path varies over time. The feedback from the MAC layer can be used to detect the connectivity of the link. When a node notifies that its downstream node is out of its transmission range, the node generates a route error (RERR) to its upstream node. If fail occurs closer to destination node, RRER received nodes can try local-repair, otherwise the nodes forward RRER until it reaches the source node. The source node can select alternative route or trigger a new route discovery procedure. There will be at least a single path for route reply so throughput will be increased although there is high mobility.

5. Performance metrics

There are various performance metrics. As suggested (I. Awan & K. Al-Begain, 2006; V.Ramesh et al., 2010) packet delivery fraction and end to end delay is considered as two basic performance metrics. Also (S.H Manjula et al., 2008) suggested to use random way point mobility model for considering the mobility pattern of nodes in my simulation. In terms of delay and dropped packet (Rachid Ennaji & Mohammed Boulmalf, 2009) performance of AODV and DSDV were measured.

5.1.1 Packet delivery fraction

It is calculated by dividing the number of packets received by the destination through the number of packets originated by the application layer of the source. It specifies the packet loss rate, which limits the maximum throughput of the network.

5.1.2 End-to-end delay

It is the average time it takes a data packet to reach the destination. This metric is calculated by subtracting time at which first packet was transmitted by source from time at which first data packet arrived to destination. This metric is significant in understanding the delay introduced by path discovery.

5.1.3 Throughput

Throughput refers to how much data can be transferred from one location to another in a given amount of time.

5.2 Test scenarios

The simulation is conducted in three different scenarios. In the first scenario, the comparison of the three routing protocols is compared in various numbers of nodes. The number of nodes is set to 10, 20, 30, 40 and 50 while the simulation time is fixed. In the second scenario, the routing protocols are evaluated in different simulation time while the number of nodes is fixed. The number of nodes is set to 30. The simulation time are set to 175, 225, 400, 575 and 750 second. In the third scenario, the routing protocols are evaluated in different node speed. The node speed is set to 10, 20, 30, 40 and 50 m/s. The number of nodes is fixed to 30. Random Waypoint Mobility Model in common to the three scenarios considered below.

5.2.1 Test scenario 1: Varying numbers of nodes

In this scenario, all the three routing protocol are evaluated based on the three performance metric which are Packet Delivery Fraction, End-to-End Delay and Throughput. The simulation environments for this scenario are:

- Various numbers of nodes are 10, 20, 30, 40 and 50.
- Simulation Time is set to 175 seconds
- Area size is set to 500 x 500
- Node Speed is random varies between 5 to 12 m/s

5.2.1.1 Packet delivery fraction

In the figure 1, x- axis represents the varying number of nodes and y- axis represents the packet delivery fraction. Figure 1, shows that A-AODV perform better when the number of nodes increases because nodes become more stationary will lead to more stable path from source to destination. DSDV and AODV performance dropped as number of nodes increase because more packets dropped due to link breaks. DSDV is better than AODV when the number of nodes increases. A-AODV improved the PDF since it has a definite route to destination without any link break.

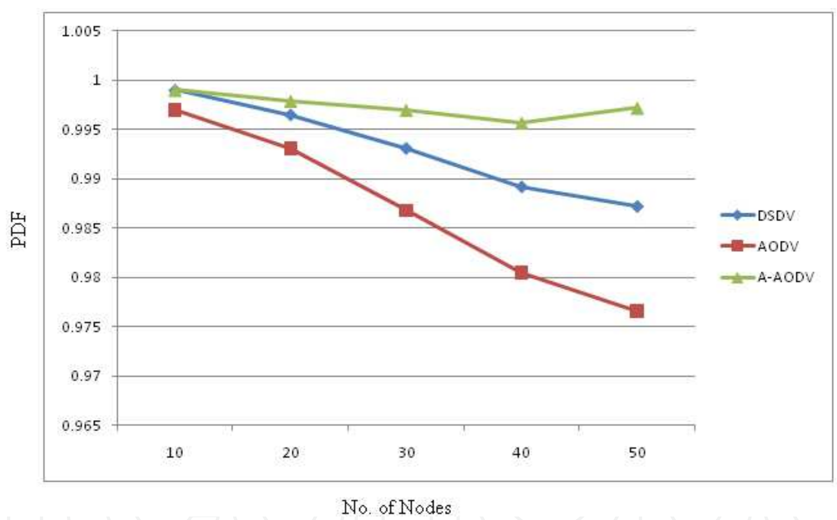

Fig. 1. Packet Delivery Fraction in Scenario 1

5.2.1.2 End-to-end delay

In the figure 2 x- axis represents the varying number of nodes and y- axis represents the end to end delay in mille seconds. A-AODV does not produce so much delay even the number of nodes increased. It is better than the other two protocols. The performance of DSDV is slightly better than AODV especially when the number of nodes cross 30. It shows that, the DSDV protocol has greater delay than AODV.

This is mainly because of the stable routing table maintenance. A-AODV produces lower delay due to the fact that it uses flooding scheme in the route reply. Thus the delay is reduced to a greater extent.

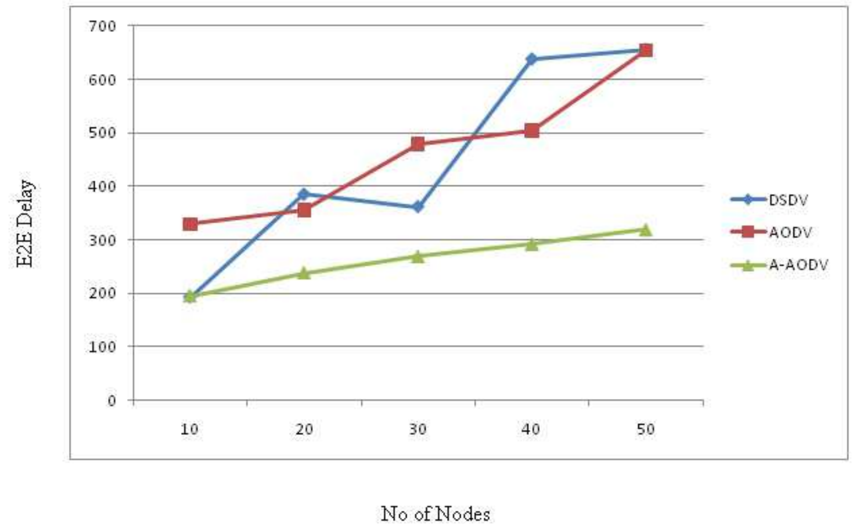

Fig. 2. End-to-End Delay in Scenario 1

5.2.1.3 Throughput

In the figure 3, x- axis represents the varying number of nodes and y- axis represents the throughput.

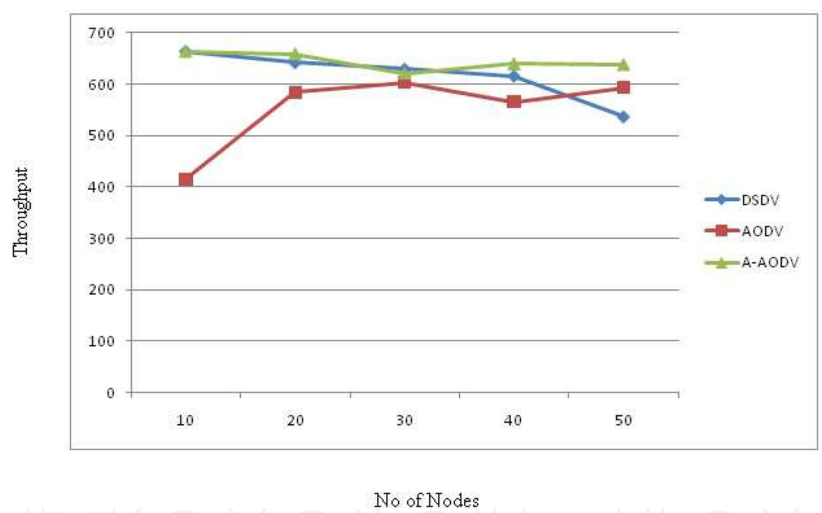

Fig. 3. Throughput in Scenario 1

From Figure 3, it is observed that DSDV is less prone to route stability compared to AODV when number of nodes increased. For A-AODV, the route stability is more so the throughput does not varied when number of nodes increases. DSDV protocol produces less throughputs when number of nodes are increased especially with a marginal difference after number of nodes is increased to 40.

5.2.2 Test scenario 2: Varying simulation time

In this scenario, all the three routing protocol are evaluated based on the three performance metric which are Packet Delivery Fraction, End-to-End Delay and Throughput. The simulation environments for this scenario are:

- Various simulation times are 175, 225, 400, 575 and 750 seconds
- Number of nodes is fixed to 30
- Area size is set to 1000 x 1000
- Node Speed is random varies between 5 to 12 m/s

5.2.2.1 Packet delivery fraction

In the figure 4, x- axis represents the varying simulation time and y- axis represents the packet delivery fraction. Based on Figure 4, contrast to AODV, A-AODV performs better. It delivers the data packet regardless to mobility rate. DSDV has the better PDF rate than AODV which has the great variation in packet drop in 225.This great variation is because of more link failures due to mobility. For AODV, it shows significant dependence on route stability, thus its PDF is lower when the nodes change its position as simulation time increased.

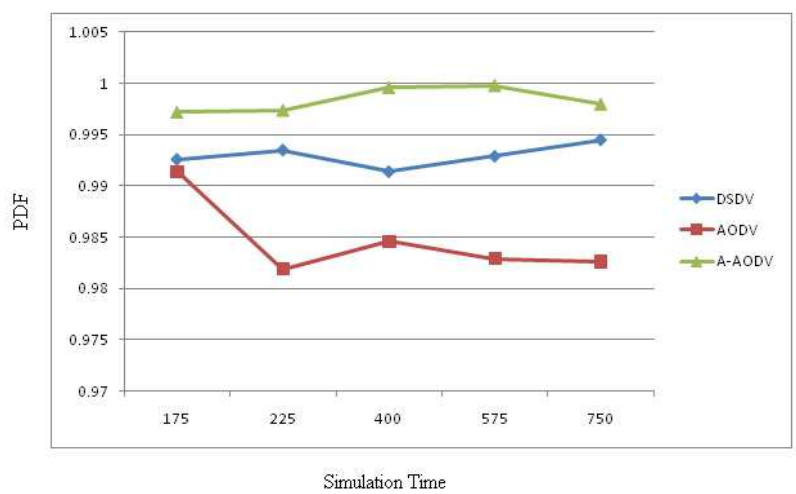

Fig. 4. Packet Delivery Fraction in Scenario 2

5.2.2.2 End-to-end delay

In the figure 5, x- axis represents the varying simulation time and y- axis represents the end to end delay in mille seconds. From the figure 5, it is inferred that A-AODV exhibits lower

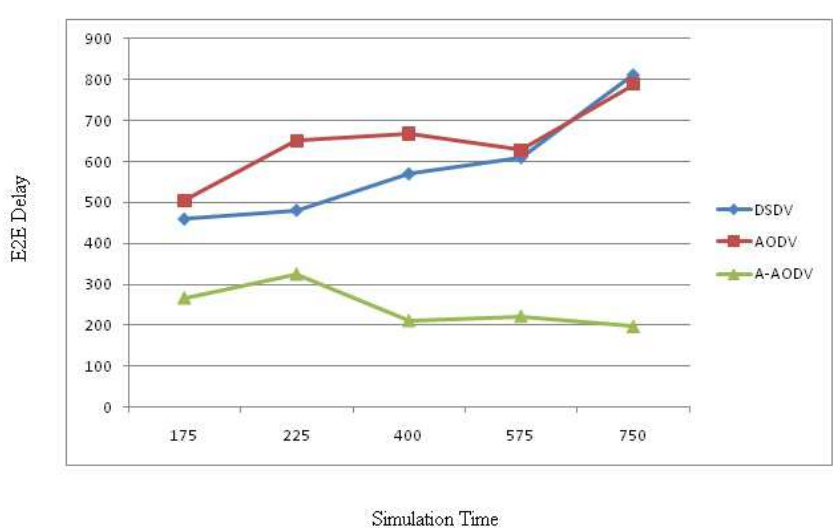

Fig. 5. End-to-End Delay in Scenario 2

average end-to-end delay all the time regardless to node mobility rate compared to the other two protocols. AODV uses a flooding scheme in route reply to create a definite route to destination to avoid link breaks. So it has lower end-to-end delay time compare to others. AODV and DSDV exhibit more or less same end-to-end delay.

5.2.2.3 Throughput

In the figure 6, x- axis represents the varying simulation time and y- axis represents the throughput. A-AODV produces better results on Throughput than the other two protocols. This is due to the route maintenance. The other two protocols fluctuate when simulation time increases because of the instability in their routing paths and link failures.

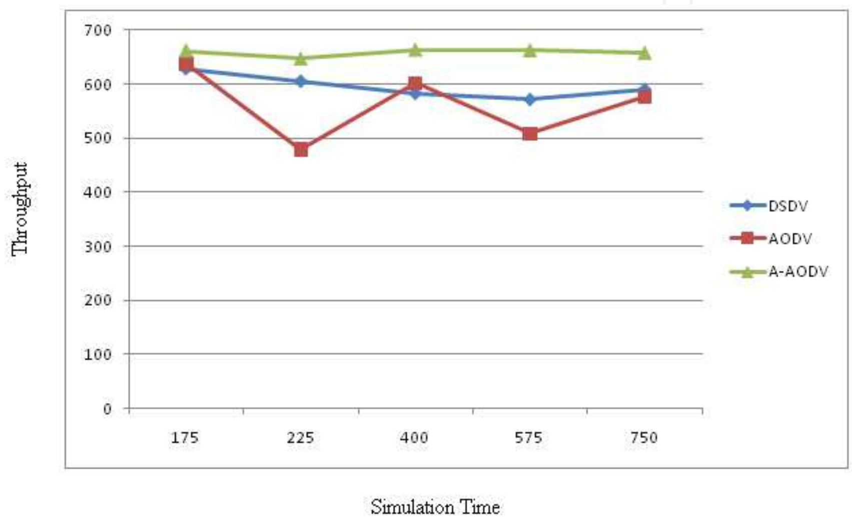

Fig. 6. Throughput in Scenario 2

5.2.3 Test scenario 3: Varying node speed

In this scenario, all the three routing protocol are evaluated based on the three performance metric which are Packet Delivery Fraction, End-to-End Delay and Throughput. The simulation environments for this scenario are:

- Various node speeds are 10, 20, 30, 40 and 50 m/s
- Simulation time is 175 seconds
- Number of nodes is fixed to 30
- Area size is set to 1000 x 1000.

5.2.3.1 Packet delivery fraction

In the figure 7, x - axis represents the varying node speed and y- axis represents the packet delivery fraction. From figure 7, it is shown that the speed of the node has less impact on DSDV protocol when node speed is up to 40. The PDF losses after node speed 40 because of the link breakage due to mobility. The node speed does not affect the PDF of the protocols AODV and A-AODV. Generally the PDF decreases in AODV protocol than other two protocols because the data transfer process need a new route discovery due to mobility. The PDF is increased in A-AODV protocol because of the multiple route-reply scheme.

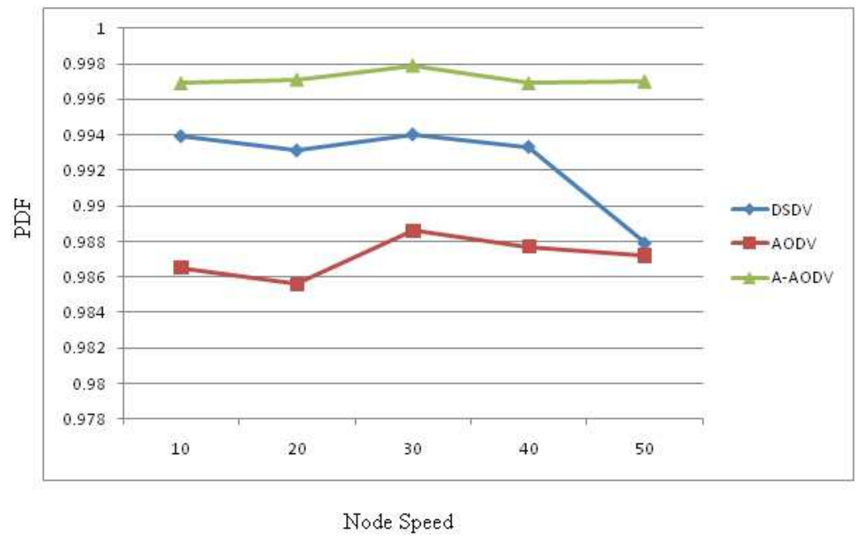

Fig. 7. Packet Delivery Fraction in Scenario 3

5.2.3.2 End-to-end delay

In the figure 8, x- axis represents the varying node speed and y- axis represents the end to end delay in mille seconds. Based on Figure 8, for varying speed, A-AODV produces less End to End Delay, but the performance of DSDV is slightly better than AODV.

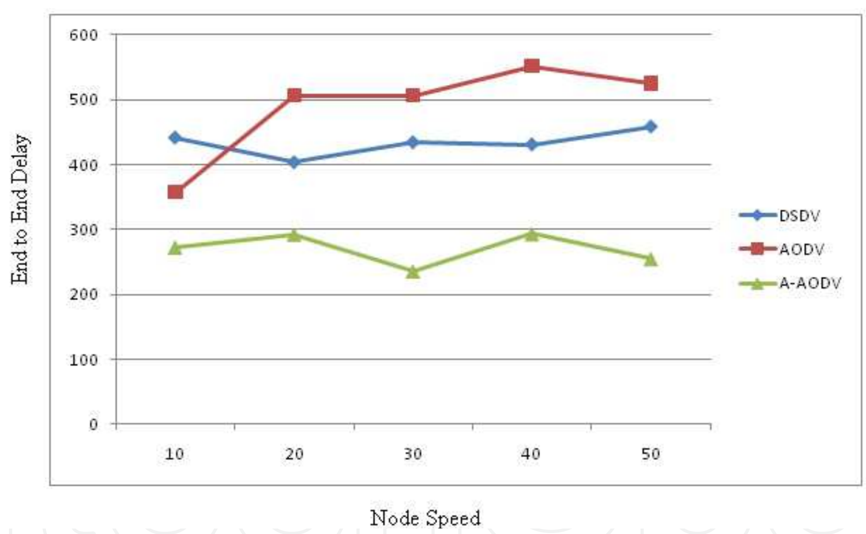

Fig. 8. End-to-End Delay in Scenario 3

The End-to End Delay is lowed in DSDV than AODV because of the proactive nature of the protocol. While considering End-to-End Delay in various scenarios A-AODV protocol works better than other two protocols because of the flooding scheme in route reply. The flooding scheme with broadcast ID in the route reply make the delay lower than the other two protocols.

5.2.3.3 Throughput

In the figure 9, x- axis represents the varying node speed and y- axis represents the throughput.

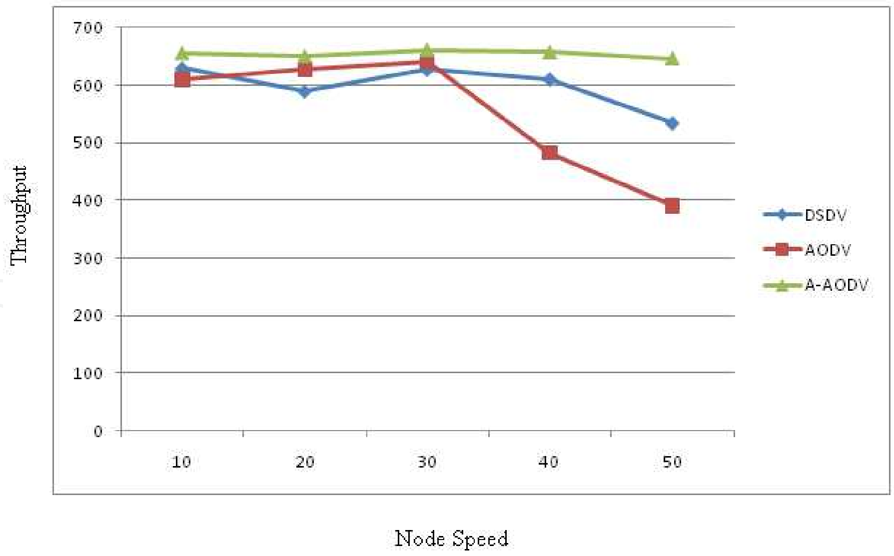

Fig. 9. Throughput in Scenario 3

The performance of A-AODV is almost same in various speeds. The throughput is maintained for various node speeds. AODV protocol has the continuous throughput decrease as node speed increases after the node speed 30 because the route table cannot be maintained to the speed of the node. In the case of DSDV protocol the proactive nature of the protocol produces the decreased throughput as node speed increases.

6. Conclusion

The performance of all the routing protocol are measured with respect to metrics namely, Packet Delivery Fraction, End to End Delay and Throughput in three different scenarios: simulation time, number of nodes and node speed. The results indicate that the performance of A-AODV is superior to regular AODV and DSDV. It is also observed that the performance is improved, especially when the number of nodes in the network is increased. When the number of nodes is increased beyond 30 and above, the performance of all the three protocols varies very much. It is due to the fact that, lot of control packets are generated in the network. It is also observed that A-AODV is even better than DSDV protocol in PDF, lower end to end delay and throughput. DSDV is better than AODV protocol in PDF. It is concluded that A-AODV improved the PDF and lowered end-to-end delay when the number of nodes are increased. Throughput is also improved. AODV has lower performance compared to DSDV in most of the scenarios.

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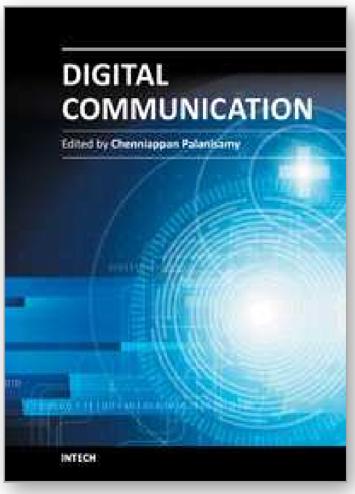

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All marketing is digital and everyone should have a digital strategy. Everything is going mobile. "The world has never been more social" is the recent talk in the community. Digital Communication is the key enabler of that. Digital information tends to be far more resistant to transmit and interpret errors than information symbolized in an analog medium. This accounts for the clarity of digitally-encoded telephone connections, compact audio disks, and much of the enthusiasm in the engineering community for digital communications technology. A contemporary and comprehensive coverage of the field of digital communication, this book explores modern digital communication techniques. The purpose of this book is to extend and update the knowledge of the reader in the dynamically changing field of digital communication.