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EVALUATIN OF QoS PARAMETERS ON TCP/IP IN WIRELESS AD HOC NETWORKS

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ABSTRACT

Wireless ad hoc network is a collection of mobile nodes interconnected by multi-hop communication paths forming a temporary network without the aid of any centralized administration or standard support services regularly available as in conventional networks. The topology of the network changes dynamically as mobile nodes join or depart the network or radio links between nodes become unusable. To accomplish this, a number of ad hoc routing protocols have been proposed and implemented, which include Destination Sequenced Distance Vector (DSDV), Dynamic Source Routing (DSR) and Ad hoc On-demand Distance Vector (AODV) routing protocols. In this paper, these protocols are evaluated by a set of parameters such as throughput, delay, packet loss, etc., and we analyze the Quality of Service (QoS) parameters from the network perspective looking into two different TCP/IP layers: transport layer and network layer. The impacts of node loads on different QoS metrics in both layers are evaluated too. As the simulation results suggest, AODV demonstrates the best performance even in the networks with moving mobile nodes. The on-demand protocols, AODV and DSR perform better than the table driven DSDV protocol. Although DSR and AODV share similar on-demand behavior, the differences in the protocol mechanisms can lead to significant performance differentials. The performance differentials are analyzed using varying network load, mobility and network size. In transport layer, because of UDP's connectionless nature, it does not need any confirmation for receiving data, which makes UDP protocol suitable in critical time applications (real time applications) in comparison with other transport layer protocols such as TCP.

Keywords: *AODV, DSR, DSDV, Delay, Throughput*

1. INTRODUCTION

A wireless ad hoc network comprises of wireless nodes communicating without the support of any fixed infrastructure or any centralized administration. A collection of autonomous nodes or terminals that communicate with each other by forming a multi-hop radio network and maintaining connectivity in a decentralized manner is called an ad hoc network. It does not operate with any static infrastructure for the network, such as a server or a base station. The idea behind such networking is to support robust and efficient operation in mobile wireless networks by incorporating routing functionality into mobile nodes. Figure 1 shows an example of an ad hoc network, where there are numerous combinations of communication patterns for different nodes. There can be different paths of connection at a given point of time from the source node to the destination node. However, each node usually has a limited area of transmission, as shown in Figure 1, by the oval circle around each node. The source can only transmit to node B, whereas node B can transmit to C and D as well. Establishment of an optimal route between the source and destination nodes is a challenging task to transmit robust communication. There are three major ad hoc

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routing protocols DSDV, DSR and AODV that are constantly being improved by IETF [1], which necessitates their comprehensive performance evaluation. In the current research work, most of the relevant metrics are taken into consideration during comparison of performance evaluation of the above routing protocols. However, the entire spectrum of metrics cannot be verified for the said comparison as these protocols possess different characterization.

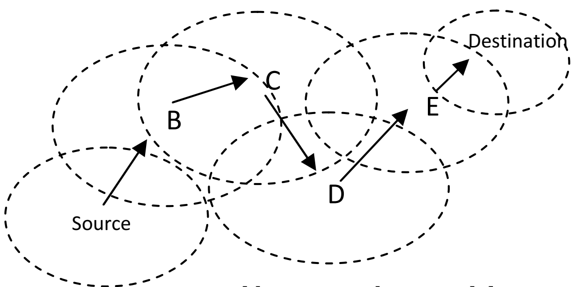

Figure 1: Ad hoc networking model.

2. WIRELESS NETWORKS

Wireless networking is an emerging technology that allows users to access information and services regardless of their geographic position. Wireless networks can be classified into the following two categories [2].

- Infrastructure based networks.
- Infrastructure-less (ad hoc) networks.

In ad hoc networks, all nodes are mobile and can be connected dynamically in an arbitrary manner. All nodes in these networks behave as routers and take part in discovery and maintenance of routes to other nodes in the network. Emergency search-and-rescue operations, file sharing applications and data acquisition in hostile environments belong to the class of applications which can be implemented in mobile ad hoc networks. The routing task in an ad hoc network is more complex than in wired networks, because this depends on many factors including topology, routing selection, initiation of the request, and specific underlying characteristics that can serve as heuristics to find quickly and efficiently the route along which the packets should be sent [3]. The ad hoc routing protocols can be divided into two groups [2, 4]:

- ***Table-driven***: This is also called as proactive routing protocol. In proactive routing, each node permanently caches routes to all possible destinations in the network, and hence, does not implement route discovery in the beginning of a session. DSDV [5] routing protocol is an example of this category.

- ***On-demand***: This is also called as reactive routing protocol. In these protocols, a route is established whenever it is required to send data to a specific destination. However it incurs significant control overhead during route discovery process. The DSR protocol [6] is an example of this group of protocols.

Each ad hoc routing protocol has advantages and disadvantages, in agreement with certain situations. However, the Mobile Ad Hoc Network Working Group specified several properties that a protocol should possess [7].

In table driven routing protocols, consistent and up-to-date routing information to all nodes are maintained at each node. In On-Demand routing protocols, the routes are created as and when required. When a source wants to send to a destination, it invokes the route discovery mechanisms to find the path to the destination. In recent years, a variety of new routing protocols targeted specifically at this environment have been developed. The following multi-hop wireless ad hoc network routing protocols cover a range of design choices:

- Destination-Sequenced Distance Vector
- Dynamic Source Routing
- Ad hoc On-Demand Distance Vector

where DSDV is a table-driven routing protocol, DSR and AODV fall under the category of On-demand routing protocols [4].

3. AD HOC ROUTING PROTOCOLS

Authors in [8] demonstrate a taxonomy of routing protocols pertaining to ad hoc networks. In this paper, we focus on three major ad hoc routing protocols as detailed below.

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4. DESTINATION SEQUENCED DISTANCE VECTOR ROUTNG

DSDV [9] is a table-driven routing scheme for mobile ad hoc networks based on the Bellman-Ford algorithm. It was developed by C. Perkins and P. Bhagwat in 1994 [5]. The main contribution of this algorithm was to find the free routes. Every node maintains a routing table that lists up-to-date routes to all available destinations, the number of hops to reach the destination and the sequence number assigned by the destination node. The number is generated by the destination, and the emitter needs to send out the next update with this number [5, 10]. The nodes periodically transmit their routing table to their immediate neighbors. A node needs to transmit the routing table to its neighbors with each update. Such update is both time-driven and event driven.

DSDV is one of the earliest proposed routing protocols, which is mostly suitable for mobile ad hoc networks with small number of nodes [5]. It has no commercial implementation since no formal specification of this algorithm is available yet. Many improved forms of this algorithm have been suggested.

DSDV requires a regular update of its routing tables, which uses efficiently battery power and a considerable amount of bandwidth even when the network is idle. Whenever the topology of the network changes, a new sequence number is necessary before the network reconverges; thus, DSDV is not suitable for highly dynamic networks.

5. DYNAMIC SOURCE ROUTING

DSR [11] is a reactive protocol i.e. it does not use periodic updates to routing tables. It computes the routes on an on demand basis and then maintains them. Source routing is a routing technique in which the sender of a packet determines the complete sequence of nodes through which the packet has to pass; the sender explicitly lists this route in the packet's header, identifying each forwarding "hop" by the address of the next node to which to transmit the packet on its way to the destination host. There are two significant phases in functioning of DSR: *Route Discovery* and *Route Maintenance*. A host initiating a route discovery broadcasts a route request packet which may be received by the immediate neighbors within wireless transmission range of it. The route request packet identifies the host, referred to as the target of the route discovery, for which the route is requested. If the route discovery is successful, the initiating host receives a route reply packet listing a sequence of network hops through which it may reach the target. In addition to the address of the original initiator of the request and the target of the request, each route request packet contains a route record, in which a record incorporates the sequence of hops taken by the route request packet as it is propagated through the network during this route discovery. DSR uses no periodic routing advertisement messages, thereby reducing network bandwidth overhead, particularly during periods when little or no significant host movement is taking place. DSR has a unique advantage by virtue of source routing. As the route is part of the packet itself, routing loops, either short-lived or long-lived, cannot be formed as they can be immediately detected and eliminated.

6. AD HOC ON-DEMAND DISTANCE VECTOR

AODV routing protocol is designed purposefully for mobile ad hoc networks [12], which is the on-demand enhancement of DSDV protocol. AODV is capable of both unicast and multicast routing. It is an on demand algorithm, meaning that it builds routes between nodes only as desired by source nodes. It maintains these routes as long as they are needed by the sources. Additionally, AODV forms trees which connect multicast group members. The trees are composed of the group members and the nodes needed to connect the members. AODV uses sequence numbers to ensure the freshness of routes. It is loop-free, self-starting, and scales to large numbers of mobile nodes [13]. AODV builds routes using a route request/route reply query cycle. When a source node desires a route to a destination for which it does not already have a route, it broadcasts a RREQ packet across the network. Nodes receiving this packet update their information for the source node and set up backwards pointers to the source node in the routing tables. In addition to the source node's IP address, current sequence number and broadcast ID, the RREQ also contains the most recent sequence number for the destination of which the source node is aware. A node receiving the RREQ may send a RREP if it is either the destination or if it has a route to the destination with corresponding sequence number greater than or equal to that contained in the RREQ. In such a case, it unicasts a RREP back to the source. Otherwise, it

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rebroadcasts the RREQ further. Nodes keep track of the RREQ's source IP address and broadcast ID [13]. If they receive a RREQ which they have already processed, they discard the RREQ and do not forward it. As the RREP propagates back to the source, nodes set up forward pointers to the destination. Once the source node receives the RREP, the route is established and it may begin to forward data packets to the destination. If the source later receives a RREP containing a greater sequence number or contains the same sequence number with a smaller hop count, it may update its routing information for that destination and begin using the better route.

As long as the route remains active, it will continue to be maintained. A route is considered active as long as there are data packets periodically traveling from the source to the destination along that path. Once the source stops sending data packets, the links will time out and eventually be deleted from the routing table of intermediate nodes. If a link fails while the route is active, the node upstream of the failure propagates a Route Error (RERR) message to the source node to inform it of the currently unreachable destination(s). On receiving the RERR, if the source node still desires the route, it can initiate route discovery for a new route.

7. QUALITY OF SERVICE IN AD HOC NETWORKS

The notion of QoS is a guarantee to be provided by the network to satisfy a set of predetermined service performance constraints for the user. The problem of QoS can be considered in two major perspectives: network perspective and application/user perspective [14]. From the network perspective, QoS refers to the service quality that the network offers to applications or users in terms of network QoS parameters, which include latency or delay of packets traveling across the network, reliability of packet transmission and throughput. From the application/user perspective QoS generally refers to the application quality as perceived by the user, i.e., the presentation quality of the video, the responsiveness of interactive voice and the sound quality of streaming audio etc. The layered QoS approaches separate QoS aspects on each layer, but in this study the QoS metrics in transport layer and network layer, shown in Table 1, are taken into consideration. QoS is also defined as the performance level of a service offered by the network to the user. In the originally used network model, traffic is transmitted only with best effort, which does not guarantee the QoS for each transmission. But, in real-time applications, QoS becomes a stringent requirement. In addition, real time traffic need to be given higher priority to ensure that the real time traffic arrive the destination on time because of the limitation of network resources especially in wireless networks.***QoS parameters***: QoS parameters differ from application to application. For an instance, multimedia applications impose bandwidth and delay as the QoS parameters, whereas, strategic applications like military services rely on the security and reliability aspects. In general, the major QoS metrics for real time applications are delay, delay variance (jitter), packet loss ratio and data rate [14, 15]. In order to evaluate the performance of ad hoc routing protocols the following metrics are used.

***Average end to end delay*: **The average time in ms it takes to transmit a packet from the source to the destination.

***Packet delivery ratio* (*percent*): **It represents the ratio of number of packets received by the destination to the number of packets sent by the source.

***Normalized routing overhead*: **The number of routing packets transmitted per data packet delivered at the destination. Each hop-wise transmission of a routing packet is counted as one transmission. The other metrics are the most important for best-effort traffic. The routing overhead evaluates the efficiency of the routing protocol. These metrics are not completely independent. For example, lower packet delivery fraction means that the delay metric is evaluated with fewer samples. In the conventional wisdom, the longer the path assumes the higher the probability of packet loss. Thus, with a lower delivery fraction, samples are usually biased in favor of smaller path lengths and thus have less delay.

Table 1: Protocols of network and transport layer.

Transport layer	Transport layer protocols (TCP & UDP)
Network layer	Routing protocols (DSDV, DSR, AODV)

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8. SIMULATION ENVIRONMENT

The evaluations of the protocols are carried out with the network simulator NS-2 [16]. The random way point network model is used in the simulation with 100 randomly distributed nodes in an area of 1000 × 1000 sq. m. The channel bandwidth of the wireless LAN is also set to 2 Mbps. The simulation parameters have been reported in Table 2. In order to enable direct, fair comparisons among the protocols, it was critical to challenge the protocols with identical loads and environmental conditions

Table 2: Simulation parameters.

Nodes	100
Area	1000 × 1000 sq.m
Packet Size	512 bits
Pause time	30 sec
Simulation Time	500 sec

Simulations incorporate Constant Bit Rate (CBR) traffic mobility model. The source-destination pairs are spread randomly over the network. Only 512 byte data packets are used. The number of source-destination pairs and the packet sending rate in each pair is varied to change the offered load in the network. Here, each packet starts its journey from a source node to a destination with a variation speed of 0-15 m/s. Node pause time is set 30 ms. Simulations are run for 500 simulated seconds. Identical mobility and traffic scenarios are used across protocols to gather fair results.

9. PERFORMANCE COMPARISON OF THE PROTOCOLS

The scenario of this study contains a wireless network with 100 mobile nodes that is fixed. The positions of nodes are initialized. During simulation, the influence of number of connections has been studied by keeping mobile nodes' speed maximum up to15 m/s. Then, the behavior of different protocols is examined by increasing the network load. At the beginning, the number of connections is set to 10 and then subsequently increased to 20, 30, 40, 50 and 60 m/s. Then the scenarios are analyzed on the basis of QoS parameters, namely, throughput, average end-to-end delay and packet delivery ratio. The values of the varying QoS parameters in each case have been shown in Table 3 in case of TCP and in Table 4 in case of UDP.

Table 3: Evaluation of connection variation for TCP.

Parameters		E2E delay in ms	Throughput in Kbps	Packet delivery ratio in %
Connections				
10	DSDV	240	31	98
	DSR	524	21	99
	AODV	257	44	97
20	DSDV	286	42	98
	DSR	720	19	98
	AODV	278	55	97
30	DSDV	284	50	98
	DSR	860	17	97
	AODV	250	60	97
40	DSDV	314	50	97
	DSR	927	19	97
	AODV	257	62	96
50	DSDV	309	62	98
	DSR	838	22	97
	AODV	262	65	96
60	DSDV	342	59	97
	DSR	872	21	97
	AODV	281	65	96

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Table 4: Evaluation of Connection Variation for UDP.

Parameters		E2E delay in ms	Throughput in Kbps	Packet delivery ratio in %
Connections				
10	DSDV	1153	11	62
	DSR	5544	6	34
	AODV	208	16	91
20	DSDV	3234	13	39
	DSR	7382	5	16
	AODV	1989	13	37
30	DSDV	4505	14	28
	DSR	10308	5	10
	AODV	2225	13	26
40	DSDV	5265	15	22
	DSR	10300	5	8
	AODV	2478	14	20
50	DSDV	5636	16	19
	DSR	10516	6	7
	AODV	2557	15	17
60	DSDV	6367	16	16
	DSR	10455	5	5
	AODV	2563	15	15

Figure 2 shows the throughput of received packets with respect to connection variation for DSDV, DSR, AODV protocols with a maximum node speed of 15 m/s with different connections in TCP, whereas Figure 3 shows the throughput of received packets with respect to connection variation for same three protocols with same speed with different connections in UDP.

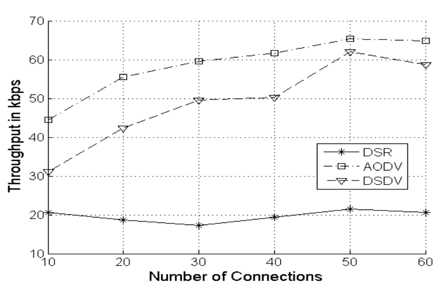

Figure 2: Connection variation throughput of DSDV, DSR, AODV protocols in TCP.

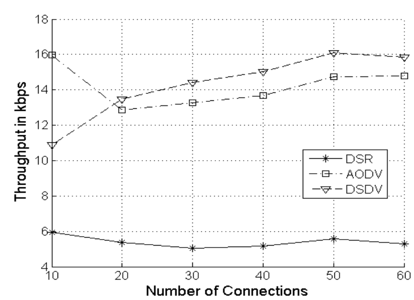

Figure 3: Connection variation throughput of DSDV, DSR, AODV protocols in UDP.

Throughput comparison: As it can be noticed, the best throughput is for AODV for TCP in the scenario with fixed nodes and with different connections. DSDV demonstrates the best throughput using UDP.

In this study an attempt was made to compare the three routing protocols under the same simulation environment. For all the simulations, the same mobility models were used with the maximum speed of the nodes was set to 15 m/s and the pause time was fixed 30 ms. Figure

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4 and Figure 5 highlight the delay in packet delivery of the DSR, AODV, DSDV routing protocols using TCP and UDP respectively.

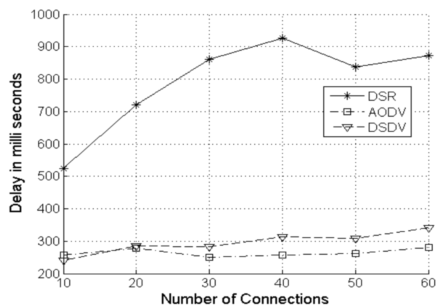

Figure 4: Connection variation delay of DSDV, DSR, AODV protocols in TCP.

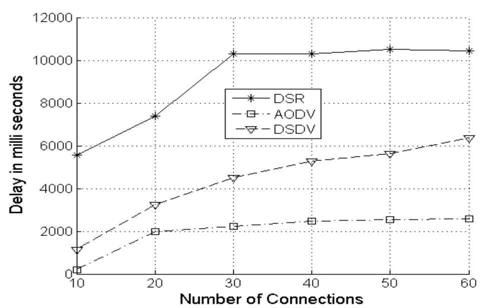

Figure 5: Connection variation delay of DSDV, DSR, AODV protocols in UDP.

Average end to end delay comparison: The average end-to-end delay of packets is higher in DSR as compared to both DSDV and AODV using both TCP and UDP. As a whole, AODV performs well as compare to DSDV and DSR.

Figure 6 and Figure 7 show the packet delivery ratio of the DSR, AODV, DSDV routing protocols in TCP and UDP respectively. As depicted in Figure 6, using TCP with less number of connections, DSR demonstrates significantly higher packet delivery ratio as compared to DSDV and AODV. With the increasing number of connections, packet delivery ratio of DSDV comes closer to that in DSR. However, AODV performs badly in any case. A similar tread holds using UDP too as shown in Figure 7.

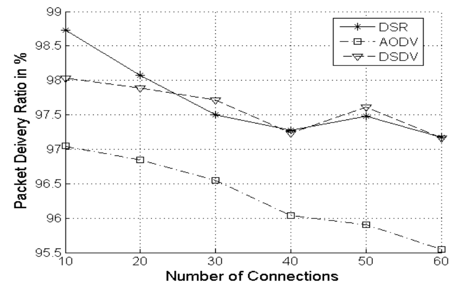

Figure 6: Connection variation packet delivery ratio of DSDV, DSR, AODV protocols in TCP.

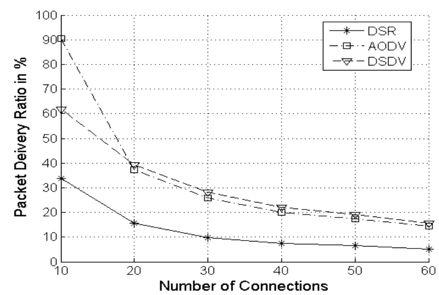

Figure 7: Connection variation packet delivery ratio of DSDV, DSR, AODV protocols in UDP.

Packet delivery comparison: The packet delivery ratio was lower in AODV as compared to both DSDV and DSR in case of TCP, where as the packet delivery ratio was lower in DSR as compared to both DSDV and AODV in case of UDP.

The scenario of studying mobility variation contains a wireless network with 100 mobile nodes, i.e. number of mobile nodes is fixed. The positions of mobile nodes are initialized. During simulation, the influence of mobility of nodes in different speed has been studied by keeping number of node connections fixed i.e. 30 in this simulation. Then, the behavior of different protocols is examined by making the speed variation of the nodes. First of all the maximum speed of the nodes is set to 5 m/s and then subsequently the maximum speed has increased to 10, 15, 20, 25, 30, and 35 m/s. Then the scenarios are analyzed on the basis of parameters throughput, average end-to-end delay and packet delivery ratio. The corresponding results and the varying QoS parameters in each case have been shown in Table 5 in case of TCP and in Table 6 in case of UDP.

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Table 5: Evaluation of mobility variation for TCP.

Parameters		E2E delay in ms	Throughput in Kbps	Packet delivery ratio in %
Speed in m/s				
5	DSDV	450	37	97
	DSR	1880	20	98
	AODV	392	46	95
10	DSDV	347	46	98
	DSR	1187	19	98
	AODV	321	54	97
15	DSDV	341	44	97
	DSR	732	22	98
	AODV	299	57	96
20	DSDV	296	41	97
	DSR	1114	12	97
	AODV	265	51	96
25	DSDV	314	41	97
	DSR	768	15	97
	AODV	260	54	96
30	DSDV	302	37	97
	DSR	1011	8	96
	AODV	249	52	96
35	DSDV	252	48	98
	DSR	629	14	97
	AODV	242	58	96

Table 6: Evaluation of mobility variation for UDP.

Parameters		E2E delay in ms	Throughput in Kbps	Packet delivery ratio in %
Speed in m/s				
5	DSDV	5913	16	31
	DSR	10214	7	14
	AODV	2798	12	24
10	DSDV	4598	16	33
	DSR	9354	7	14
	AODV	2317	14	29
15	DSDV	4642	16	31
	DSR	7685	7	13
	AODV	2214	13	27
20	DSDV	4873	14	27
	DSR	10866	5	10
	AODV	2255	13	25
25	DSDV	4962	13	26
	DSR	10404	5	10
	AODV	2245	13	25
30	DSDV	4759	13	27
	DSR	11948	3	6
	AODV	2333	12	23
35	DSDV	4508	13	27
	DSR	9127	4	9
	AODV	2238	13	25

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Throughput of DSDV, AODV, and DSR under mobility variation is demonstrated in Figure 8 and Figure 9 using TCP and UDP respectively.

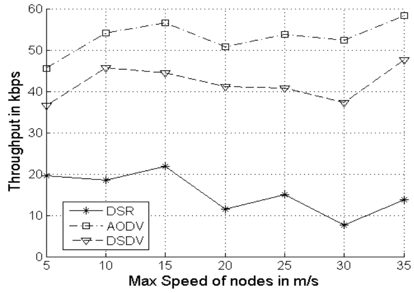

Figure 8: Mobility variation throughput of DSDV, DSR, AODV protocols in TCP.

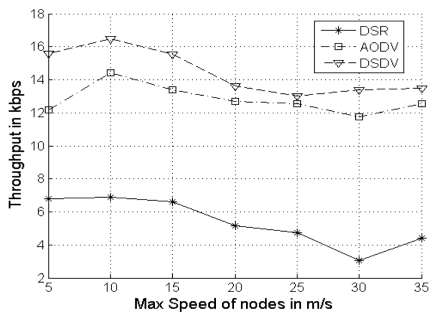

Figure 9: Mobility variation throughput of DSDV, DSR, AODV protocols in UDP.

Throughput comparison: Here, DSR provides significantly less throughput as compared to DSDV and AODV in both the scenarios due to its reactive behavior to frequent topology changes resulting from the mobility of nodes in the network. However, using TCP, AODV performs better than DSDV in terms of throughput as it does not require any route discovery, and moreover, does not need to maintain the route the route in the routing tables leading to less routing overhead as compared to DSDV. But, using UDP, DSDV outperforms AODV as AODV needs to initiate route discovering each time a path break resulting in significant communication overhead.

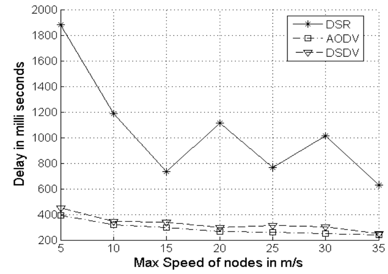

Figure 10: Mobility variation delay of DSDV, DSR, AODV protocols in TCP.

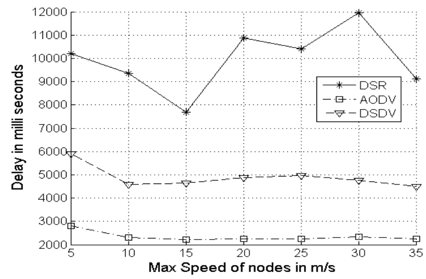

Figure 11: Mobility variation delay of DSDV, DSR, AODV protocols in UDP.

Average end to end delay comparison: As depicted in Figure 10 and Figure 11, AODV incurs minimum delay under different motilities using TCP and UDP respectively as AODV is less susceptible to topology changes resulting from node mobility as compared to DSR, and need not maintain the routing information at the nodes unlike DSDV. In addition, DSR imposes much higher latency in terms of communication overhead as well as routing overhead due to its complex route discovery and route maintenance procedures.

Figure 12 and Figure 13 demonstrate the packet delivery ratio of DSR, AODV, and DSDV under mobility variation using TCP and UDP respectively.

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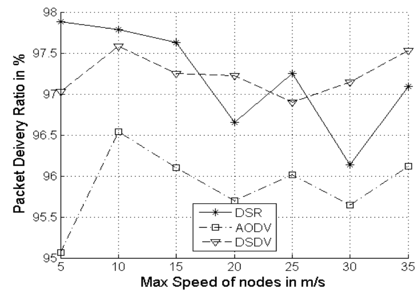

Figure 12: Mobility variation packet delivery ratio of DSDV, DSR, AODV protocols in TCP.

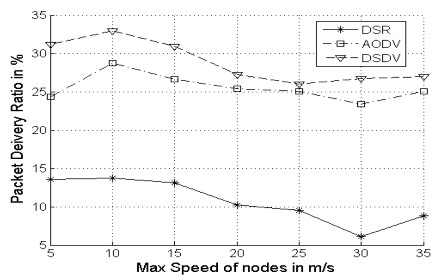

Figure 13: Mobility variation packet delivery ratio of DSDV, DSR, AODV protocols in UDP.

Packet delivery comparison: As depicted in Figure 12, DSR possesses higher packet delivery ratio at lower speeds of nodes, but however, AODV outperforms DSR under higher speeds of mobile nodes. In the entire scenario, packet delivery ratio of DSDV is significantly less as compared to DSR and AODV. Behavior of DSR and AODV is explained with the fact that nodes do not implement any routing table updates and forwarding of packets is made faster than that in case of DSDV. A regular trend is observed in case of AODV is facilitated by its ignorance to topology changes, whereas at higher speeds of mobile nodes, DSR significantly reacts to frequent topology changes.

As it can be observed from Figure 13, since DSDV caches routes to all possible destinations, it obviously does not require any route discovery, and hence, demonstrates higher packet delivery ratio as compared to AODV and DSR, which need to intimate the route discovery each time a path breaks as a request of mobility of nodes. DSR performs worse than DSDV in this scenario, as it reacts comparatively less effectively in frequent topology changes.

10. CONCLUSION AND FUTURE WORK

Different people and communities perceive and interpret QoS in different ways. The QoS problem taken into consideration in this work has two major perspectives. Networks receive their QoS parameters from the applications implicitly or explicitly and need to respond to these requests by providing QoS services. Layered QoS approaches are proposed in the current work that separate QoS aspects on each layer. This paper presents an evaluation of QoS parameters on different TCP/IP layers for wireless scenarios in an original fashion. However, the problem of QoS management remains as a major concern for applications in ad hoc networks. We intend to address in future the issues related to power and security management with a wide range of ad hoc routing protocols

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