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Transmission Range, Density & Speed based Performance Analysis of Ad Hoc Networks

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ABSTRACT

Mobile Ad Hoc Network (MANET) is a self-configured, infrastructure less network of mobile nodes which are free to move independently. It is deployed in areas where infrastructural setup like base stations, routers is not available e.g. emergency scenarios like war, earthquake etc. To send packets, routing protocols are required. To minimize the battery usage, many factors are considered like transmission power, routing protocol, node speed etc. These parameters have some effect on the use of battery power. In this paper, we have studied the effect of varying transmission range, node density and speed on three routing protocols namely OLSR, DSR and ZRP representing the three groups in which MANETs have been classified namely proactive, reactive and hybrid routing protocols respectively. The performance metrics considered were end to end delay and packet delivery ratio. There was an obvious impact on these metrics on variation of transmission range.

Keywords:- MANET, Random Waypoint Mobility Model, OLSR, DSR, ZRP, end to end delay, packet delivery ratio, transmission range, transmission power, node density, node speed.

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1. INTRODUCTION

Transmission power is an important parameter for Mobile Ad Hoc Network (MANET) [1] because each node has limited battery power and it is not easy to replace/recharge the battery. Hence, it is important to efficiently utilize the battery power to ensure longer network lifetime. If the transmission power is kept high, then although all the packets will be delivered but battery power consumption will be high. If it is kept less, then although power consumption will be low but the packets may not be able to reach destination. In order to maximize battery life, an optimum value of transmission power is to be chosen.

This study focuses on variation in transmission range. Along with that, node density and node speed is also varied, so as to have an estimate of performance in denser and dynamic networks. The studies done on transmission power are discussed below. Rahman Et.al [2] presented a study for the performance of OLSR and DYMO routing protocols under varying data rate, node velocity and transmission range with variation of 512, 768, 1024, 1280, 1536 Bytes/sec for data rate, 1, 5, 10, 15 meters/sec for node velocity and 150, 200, 250, 300, 350 meters for transmission range. The metrics considered were Packet Delivery Fraction, Average end-to-end delay of data packets and Normalized Routing Load. The protocols were simulated and compared with NS-2 under Gauss Markov mobility model.

The authors concluded that along with other parameters, transmission range has significant effect on the metrics. The effect of transmission range on ODMRP- On-Demand Multicast Routing Protocol for multicast communication was studied by Venkatalakshmi Et.al [3]. GloMoSim was used for the simulation purpose. Metrics considered were packet delivery ratio, collision and throughput. Variation was done for transmission range and mobility range. It was observed that, though increase in the transmission range enhances connectivity but it also increases the probability of collisions. Hence the effective bandwidth of individual nodes is reduced. A study for the performance of probability-based routing protocols under different transmission ranges for AODV protocol was done by Yassein Et.al [4]. NS2 was used for simulating the scenario. Packet delivery ratio, end to end delay and routing overhead were the considered metrics. Along with different probabilities (Fixed, adjusted and smart), transmission range was varied as 100, 150, 200, 250, 300m. The authors concluded that, when the transmission range and probability was increased, the performance of algorithm was improved.

Nagpal Et.al [5] designed a simulator in Matlab to study the impact of variable transmission range on power saving. In this work, minimum hop routing (MHR) and minimum total power routing (MTPR) was evaluated using Dijkstra's shortest path algorithm. The performance metrics considered were: percentage power saving and average power consumption. Variation in transmission range was done by using Received Signal Strength Indicator (RSSI) and variation in node density was done for 30, 35, 40, 45, 50 nodes. The authors concluded that power saving of MTPR is always higher than MHR.

A novel study on the effect of variation in transmission power on AODV protocol was made by Das Et.al [6]. The metrics evaluated were packet delivery fraction, routing load, average energy consumption per node and hop count. Along with variation in transmission power: 10, 15, 20 dBm, variation in number of sources: 10, 15, 25 was also considered. The author marks variations in performance and concluded that performance of the network is best for a specific transmission power (i.e. 15dBm) along with specific number of sources (15 sources).

The behavior and performance of DSDV, AODV and DSR protocols with respect to variation in transmission power of individual nodes was studied by Lalitha Et.al [7]. The performance metrics considered were: Packet Delivery Fraction/Ratio (PDF/PDR), Routing Load, End-to-End Delay, Dropped Packets, Throughput, Energy Consumption, MAC Load and Overhead. NS2 was deployed for simulation. Transmission range was chosen as 100, 150, 200, 250, 300, 350, 400, 450, 500 and 550 meters. This range was derived from the transmission power. The authors observed that the multi hop routing protocols performs good only at particular levels of transmission ranges/powers.

Grover Et.al [8] studied the impact of variation in transmission range and scalability on ZRP protocol. The scenario was simulated on NS2. The performance metrics chosen were: Packet delivery ratio, Throughput, End to End Delay and Routing Overhead. The variation in transmission range was done as 200, 300, 400, 500 and 600 meters and the variation in scale (size) was chosen as 25 and 50 nodes. Along with these, variation was also done for node speed as 100, 200 and 300 m/s. The conclusion from the study was: transmission range has inverse effect with scalability and mobility rate has inverse effect on throughput and packet delivery ratio.

The performance of AODV, DSR, Lar and OLSR for variation in transmission range was studied by Prabhakaran Et.al [9]. Reference point group mobility model (RPGM) was used to provide mobility to nodes. Packet delivery ratio, end to end delay, normalized routing load and throughput were the considered metrics. Simulations were carried out using NS2. The transmission range was chosen as: 100, 200, 300, 400 and 500 meters. The authors concluded that the performance of a routing protocol varies widely across different transmission ranges.

In the past the researchers have performed analysis of routing protocols as a function of transmission range. In this paper, we have considered node density and node speed as a function along with the transmission range. Hence we are able to provide a broader analysis for these variations, taken together into account. Organization of the rest of paper is as below. Factors affecting the performance are given in section II. In section III, routing protocols considered, are briefly reviewed followed by a brief discussion of the mobility model in section IV. Simulation setup is given in section V. Finally results are discussed in section VI.

2. FACTORS AFFECTING PERFORMANCE

The performance of routing protocols depends on various factors including:

1. Node Density: When it is low, it leads to low reachability and when it is high it does not add extra advantage, so an optimum value should be chosen.
2. Node Movement: The performance degrades when speed is high due to increase in number of link failures. When kept low, it may not be useful in applications like VANET, Underwater network etc.
3. Mobility Model: There is a variation in performance according to the mobility model chosen.
4. Transmission Range: When it is high, the nodes have high reachability but consume more battery power. When it is low, nodes have lower number of reachable paths and that is not desired.

There are other factors also but the above discussed four factors are prevalent.

3. ROUTING PROTOCOLS

A routing protocol defines the way, mobile nodes communicate with each other disseminating information that enables them to select routes between any two nodes. They have been classified into three groups:

1. Proactive protocol: The route information is obtained a priori and stored in a table for future lookup. E.g. OLSR [10].
2. Reactive protocol: The route information is calculated when and wherever required hence favoring an on demand route formation. E.g. DSR [11].
3. Hybrid protocol: It combines the advantages of proactive and reactive routing. The route is initially established with some proactive protocol and then to serve the demands from additionally activated nodes are responded with reactive flooding. E.g. ZRP [12].

In this study, optimized link state routing (OLSR), dynamic source routing (DSR) and zone routing protocol (ZRP) has been simulated. We briefly describe the functioning of these protocols.

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3.1 OLSR (Optimized Link State Routing) [10]

It is a table driven proactive routing protocol, described in RFC3626. It utilizes the link state in an optimized manner to extract information regarding topology. The change in topology causes flooding of information to all nodes. In order to reduce this overhead, Multi point relays (MPR) are used. Being a table-driven protocol, information is updated and maintained in a variety of tables. The data in these tables is based on received control traffic, and control traffic is generated based on information retrieved from these tables. The route calculation itself is also driven by the tables.

OLSR defines four types of control messages:

a. HELLO: It is transmitted periodically to all neighbors. This is done to find updates about the link status and host's neighbor.

b. TC: Topology Control message is sent periodically by a node to a subset of its neighbors. It is used to broadcast information about one's own neighbors.

c. MID: *Multiple Interface Declaration* message is transmitted to inform other nodes that the host can have multiple OLSR interface. It lists all IP addresses used by a node.

d. HNA: Host and Network Association message is transmitted to give information regarding external routing. It contains important information regarding the network and the net mask address.

3.2 DSR (Dynamic Source Routing) [11]

It is a simple and efficient reactive routing protocol designed specifically for use in multi-hop wireless ad hoc networks of mobile nodes. Here, the network is completely self-organizing and self-configuring, requiring no existing network infrastructure or administration. It follows two mechanisms namely Route maintenance and Route discovery.
Route Discovery: It is the mechanism by which a source node S which wants to send a data packet to destination D, requests for and obtains a route to D. It happens only when route to D is unknown to S.
Route Maintenance: It is the mechanism by which source node S is able to detect if there is a topology change, which results in route breakage to destination. When unavailability of a route is shown, the source S can either attempt to use any other route to D which is known by S or can revoke route discovery again to find a new route.

3.3 ZRP (Zone Routing Protocol) [12]

It is a hierarchical and hybrid protocol, hence it takes advantage of both reactive and proactive routing. It works on the principle that, nodes and its local neighborhood are separate from the global topology of entire network. Transmission power of the nodes is adjusted to control the number of nodes in the routing zone i.e. by lowering the power; number of nodes within direct reach is reduced. The routes found by ZRP are loop free routes.

ZRP utilizes two components:

1. At local level, IntrA-zone Routing Protocol (IARP) for Proactive routing component.
2. At global level, IntEr-zone Routing Protocol (IERP) for reactive routing component.

4. MOBILITY MODEL

For the simulations, Random Waypoint Mobility Model [13] is used. It was proposed by Johnson and Maltz. It is a popular model for simulations, because of its wider availability and simplicity. According to this model, a node stays at one location or point for a certain period (pause time). The value of pause time lies between P_{min} and P_{max}. This pause time is induced whenever the node changes either speed or direction. After the pause time is over, the node starts travelling randomly with the speed of the node lying between V_{min} and V_{max}, which can be changed according to the use. The process repeats, until the destination is reached.

5. SIMULATION SETUP

To study the effect of variation in Node transmission range, density and speed, Qualnet simulator was used. The routing protocols under consideration were OLSR (proactive), DSR (reactive) and ZRP (hybrid). For placement of the nodes random waypoint mobility model was utilized and the nodes were confined to an area of 1000 x 1000 sq. m area. Constant bit rate (CBR) links were used between the randomly chosen source destination pair. For the above discussed variations three scenarios are considered viz. transmission range scenario, node density scenario and node speed scenario.

a. Node Density Scenario: It is the number of nodes in the network. It was modeled by varying the number of nodes in the fixed area. It was varied from 25 to 100 in steps of 25 i.e. 25, 50, 75 and 100.
b. Transmission Range Scenario: It is the average maximum distance up to which a node can send data packets. It was modeled by varying the range of transmission. The transmission range was varied between 50 m to 500 m in steps of 100 i.e. 50, 150, 250, 350 and 450 m.
c. Node Speed Scenario: It is the speed of a node in the network. It was modeled by varying the speed of the nodes in the fixed area. It was varied from 0 m/s to 20 m/s in steps of 4 i.e. 0, 4, 8, 12, 16 and 20 m/s.

The simulations parameters are given in table 1.

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Table 1: Simulation parameters

Parameter	Value
Terrain/ Simulation Area	1000m x 1000m
Data transfer rate	2 MBPS
Node Density	25, 50, 75, 100
Transmission Range (m)	50, 150, 250, 350, 450,
Node Speed (m/s)	0, 4, 8, 12, 16, 20
Mobility Model	Random Waypoint
Channel Frequency	2.4 GHz
Packet size	512 Bytes
Data Transmission Speed	4 Packets/Second
Routing Protocol	OLSR, DSR and ZRP

The performance metrics considered are end to end delay and packet delivery ratio.

a. End to end delay: It is the average amount of time that is taken by a packet to reach final destination from source. It is the sum of delays at links. The delay at a link is the sum of the following components (if, retransmission is not considered).

- Processing delay: It is the time from the arrival of a packet until it is assigned to a queue of an output link for transmission.
- Queueing delay: It is the time the packet is in a queue before transmission starts.
- Transmission delay: It is the time between the transmission of the first bit and last bit of the packet.
- Propagation delay: It is the time for signals to traverse the link.

Average delay = Σ (tr - ts)/Pr, where ts is the packet send time and tr is the packet receive time.

b. Packet delivery ratio (PDR): It is the ratio of number of packets delivered to destination, to the number of packets sent at source. The source follows CBR (Constant bit rate) traffic. It depicts the rate of loss of packets in the network.

PDR = Data packets delivered / Data packets sent

6. RESULTS & DISCUSSIONS

6.1 End to End Delay

Figure 1 to Figure 4 shows the end to end delay for OLSR, DSR and ZRP with figure 1 showing delay for 25 nodes, figure 2 for 50 nodes, figure 3 for 75 nodes and figure 4 for 100 nodes. The speed of 0, 4, 8, 12, 16 and 20 m/s is shown as a, b, c, d, e and f respectively. It was observed that delay is decreasing with increase in speed and transmission range. We get the minimum values for DSR and maximum values for ZRP in all the cases. OLSR being a proactive protocol, stores route information in routing table. The amount of stored information increases with increase in transmission range as more nodes tend to be reachable. This results increased delay as compared to reactive protocol. DSR being a reactive protocol performs better than OLSR and ZRP. When we increase the node density then delay is decreased because more number of nodes brings more of them together, when confined to an area.

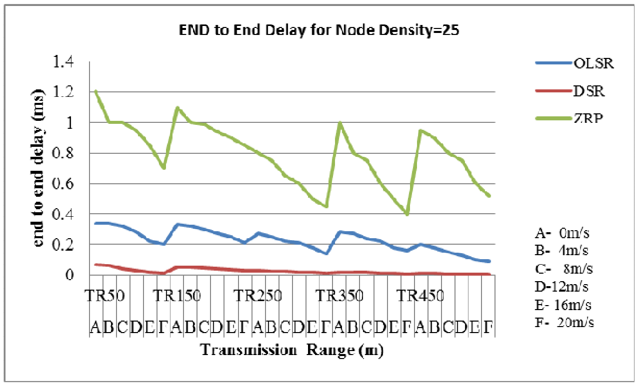

Figure 1: End to end delay for node density 25.

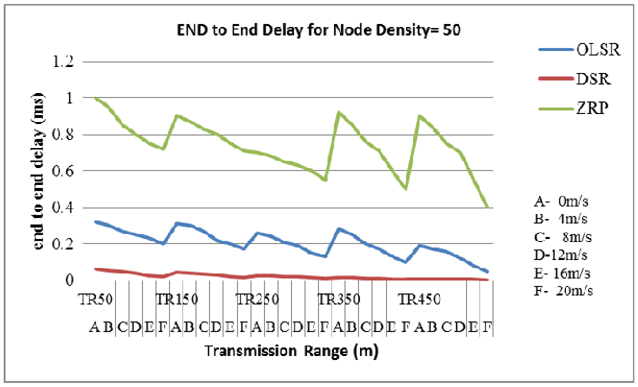

Figure 2: End to end delay for node density 50.

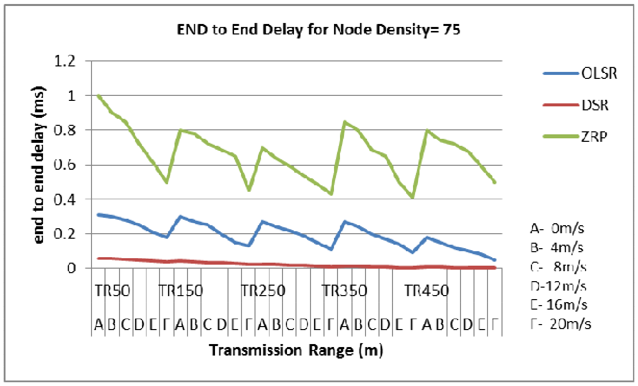

Figure 3: End to end delay for node density 75.

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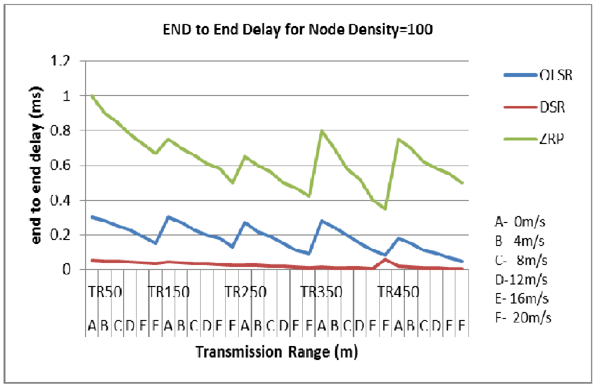

Figure 4: End to end delay for node density 100.

6.2 Packet Delivery Ratio

Figure 5 to Figure 8 shows the packet delivery ratio for OLSR, DSR and ZRP with figure 5 showing delay for 25 nodes, figure 6 for 50 nodes, figure 7 for 75 nodes and figure 8 for 100 nodes. The speed of 0, 4, 8, 12, 16 and 20 m/s is shown as a, b, c, d, e and f respectively. In all the cases DSR outperforms OLSR and ZRP. The reason is the reactive nature of DSR. With increase in transmission range the packet delivery ratio increases. When the speed of node is less than or equal to 8 m/s the packet delivery ratio decreases and when the speed is greater than 8 m/s, it increases. This phenomenon is valid, only if transmission range is less than 150 m. When the range is greater than 150m, the behavior reverts i.e. if the speed of node is less than or equal to 8 m/s the packet delivery ratio increases and when the speed is greater than 8 m/s, it decreases.

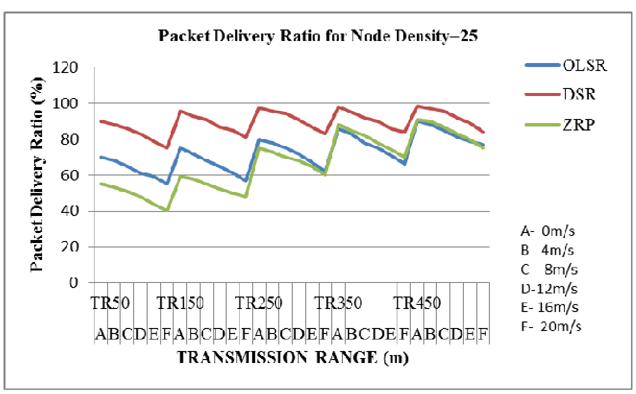

Figure 5: Packet Delivery Ratio for node density 25.

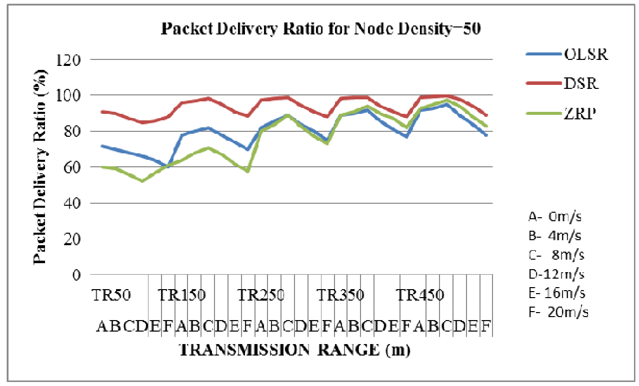

Figure 6: Packet Delivery Ratio for node density 50.

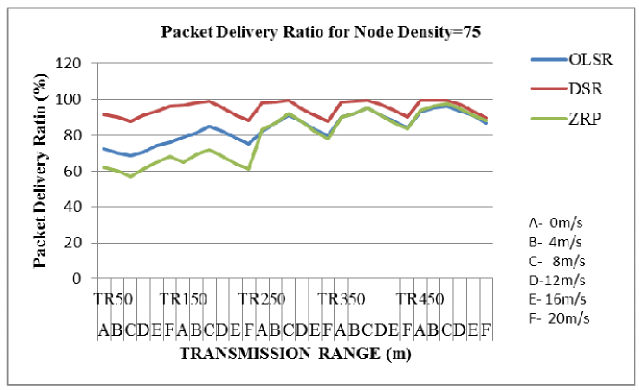

Figure 7: Packet Delivery Ratio for node density 75.

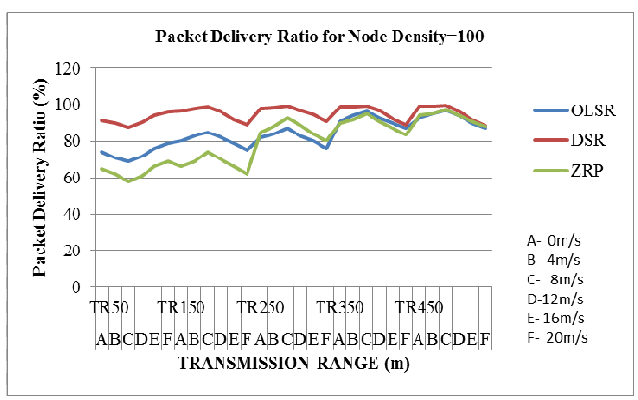

Figure 8: Packet Delivery Ratio for node density 100.

7. CONCLUSION

In this paper, we have studied the effect of variation in transmission range along with a variation in node speed and node density. End to end delay and packet delivery ratio was obtained to assess the performance of routing protocols viz. OLSR, DSR and ZRP. We observed that DSR was the better performing protocol, followed by OLSR and ZRP. In the future work more protocols and parameters will be considered.

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