Evaluating the Impact of Weather Condition on MANET Routing Protocols

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Abstract: Mobile ad-hoc network (MANET) is a dynamically reconfigurable wireless network without any centralized administration or infrastructure. Here each node acts as a router for each other nodes. Data transmission over a wireless ad hoc network links in adverse weather condition affects the network performance. Therefore, deployment of MANET during rainstorm or unfavorable environment conditions should pay special attention to the probability of data loss and delay. Previous works carried to analyze the performance of routing protocol for MANET did not include the study of impact of weather condition. For real time implementation of MANETs, this type of study is more helpful. In this paper, the impact of weather condition on the performance of routing protocols AODV, DSR and ZRP is analyzed using QualNet 5.0 simulator. The results of simulation shows that, with the increase in intensity of precipitation, performance of the protocol is degraded in the metrics like packet delivery ratio, throughput, jitter and end-to-end delay.

Keywords: Mobile Ad Hoc Network, Weather condition, AODV, DSR, ZRP, QualNet.

1. Introduction

Mobile ad hoc network (MANET) represents a group of wireless mobile nodes that can freely and dynamically self-organize into arbitrary and temporary network topologies in areas without any preexisting communication infrastructure. To provide communication through the whole network, a source-to-destination path could pass through several intermediate neighbor nodes. Therefore, every node in a mobile ad-hoc network has to act as a router and forwards the data packets to the other nodes [1]. Routing protocols for ad hoc wireless networks must address a diverse range of issues like mobility, resource constraint, bandwidth constraint and scalability. The routing protocols should be able to provide a certain level of QoS parameters like bandwidth, delay, packet delivery ratio and throughput [2]. Due to their inherent broadcast capability, MANET is well suited for both unicast and multicast applications [3].

Mobile ad hoc networks are very flexible and suitable for several types of applications, as they allow the establishment of temporary communication without any preinstalled infrastructure. The majority of applications for the MANET technology are in areas where rapid deployment and dynamic reconfiguration are necessary and the wired network is not available. These include military battlefields, emergency search and rescue sites, and replacement of fixed infrastructure in case of environmental disasters. Adverse weather conditions can pose high risks to mobile and wireless communications and it affects the network performance [4-6]. Therefore, deployment of MANET for disaster management and rescue operation during rainstorm or unfavorable environmental conditions should pay special attention to the probability of data loss and delay.

Routing protocols for Mobile ad hoc networks can be broadly classified into two main categories: Proactive or table-driven routing protocols and Reactive or on-demand routing protocols. In table-driven routing protocols, each node continuously maintains up-to-date routes to every other node in the network. For highly dynamic network topology, the proactive schemes require a significant amount of resources to keep routing information up-to-date and reliable. In on demand protocols, a node initiates a route discovery throughout the network, only when it wants to send packets to its destination. For this purpose, a node initiates a *route discovery* process through the network. Hybrid protocols are the combinations of reactive and proactive protocols and takes advantages of these two protocols. In these type of protocols the

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routes are found quickly in the routing zone. Ad hoc on demand distance vector (AODV) protocol [7] and dynamic source routing (DSR) protocol [8] are on demand protocols based on which many protocols were developed. Zone routing protocol (ZRP) [9] is a representative of hybrid protocol.

Some of the previous works done on the performance evaluation of routing protocols are reported in references [10-20]. Packet delivery ratio, throughput, jitter and end-to-end delay are taken as the performance metric in most of them. In those papers, the routing protocols are compared and their performance is analyzed under the scenarios of variation in node mobility, number of nodes, traffic load, packet size, and propagation model. AODV, DSR and TORA are compared by changing the pause time in [21]. Impact of thermal noise on the performance of the routing protocol AODV, DSDV and DSR is analyzed in [22].

Although, lots of previous works are carried out and found in literature, they will not did not dealt with the impact of weather condition on the performance of the routing protocol. For real time implementation of MANETs, this type of study over the protocol is important and more helpful. In this paper the impact of weather condition on the performance of the routing protocols AODV, DSR and ZRP is analyzed using QualNet 5.0 simulator.

This paper is organized as follows. In section 2, brief descriptions about the protocols AODV, DSR and ZRP were given. Section 3 gives details about the weather and its effect on the wireless communication. Simulation and outcomes of the simulation are discussed in section 4. Conclusion about the performance analysis was given in Section 5.

2. Brief Description of Protocols

A. Ad Hoc on Demand Distance Vector Protocol (AODV)

Ad hoc on demand distance vector (AODV) routing protocol is capable of operating on both wired and wireless network, although it has been designed specifically for wireless network. In AODV routing protocol a route is established only when it is required by a source node to transmit data packets. It provides a quick adaptation to dynamic link condition and link fault. Therefore, AODV protocol is most suitable for mobile ad hoc networks. In AODV, the source node and the intermediate nodes store the next-hop information corresponding to each flow for data packet transmission.

In this protocol, the source node floods the Route Request packet in the network when a route is not available for the desired destination. On receiving this request, the intermediate node either forwards it or sends a Route Reply to the source. The destination node and intermediate nodes having valid routes to the destination are allowed to send Route Reply packets to the source. When a node receives a Route Reply packet, information about the previous node from which the packet was received is also stored. The major difference between AODV and other on-demand routing protocols is that it uses a destination sequence number (DestSeqNum) to determine an up-to-date path to the destination. DestSeqNum indicates the freshness of the route that is accepted by the source. This feature helps to prevent routing loops.

B. Dynamic Source Routing Protocol (DSR)

Dynamic Source Routing (DSR) is an on-demand routing protocol that is specifically designed for use in multi-hop wireless mobile ad hoc networks. DSR builds routes by flooding route request (RREQ) packets if the source does not have a routing path to the destination. Any node that has a path to the destination can reply to the RREQ packet by sending a route reply (RREP) packet. DSR uses source routing in which a data packet carries the complete path to be traversed and the packet is sent through the intermediate nodes specified in the path. To limit the need for route discovery, DSR allows nodes to snoop all packets sent by their neighbors. Since complete paths are indicated in data packets, snooping can be helpful in updating the route cache. To further reduce the cost of route discovery, the RREQs are initially broadcasted to neighbors only, and then to the entire network if no reply are received.

Route Discovery and Route Maintenance are the two main process used in DSR. Route discovery is the process in which a source node finds a route to the destination if it is already not known. Route discovery is used only when the source node attempts to send a packet to a destination. If the network topology has changed due to mobility of nodes then, existing route to the destination is no longer available. Route maintenance is the process in which, a source node is able to detect a route to the destination whenever there is a change in network topology. Route maintenance is used only when the source node is actually sending packets to the destination. Automatic route shortening and prevention of route reply storms are the optimization techniques implemented in DSR to route packets more efficiently, and reduce the control overhead.

C. Zone Routing Protocol (ZRP)

Zone Routing Protocol (ZRP) is a hybrid protocol in which the network is divided into overlapping inter and intra zones. ZRP defines a zone around each node consisting of all nodes within k hops of the node. For intra zone routing (inside routing zone), ZRP uses a proactive routing protocol, Intra-zone Routing Protocol (IARP). For inter zone routing (between routing zones), ZRP uses a reactive routing protocol, Inter-zone Routing Protocol (IERP). Most of the existing proactive routing algorithms can be used as the IARP for ZRP.

A route to a destination within the local zone can be established easily with the help of routing table maintained by IARP. For routes beyond the local zone, route discovery has to be carried out. The source node sends a route requests to its border nodes. The border nodes check their local zone for the destination. If the requested node is not a member of this local zone, the route request packet is forwarded to their border nodes. If the destination is a member of the local zone of the node, it sends a route reply on the reverse path back to the source. The source node uses the path saved in the route reply packet to send data packets to the destination.

3. Weather and Its Consequence

Weather is the state of the atmosphere, to the degree that it is hot or cold, calm or stormy, clear or cloudy. Weather generally refers to day-to-day temperature and precipitation activity. Precipitation is defined as liquid or solid condensation of water vapor falling from clouds or deposited from air onto the ground. Precipitation occurs when a local portion of the atmosphere becomes saturated with water vapour, so that the water condenses and precipitates. The main forms of precipitation include fog, snow, drizzle and rain. Precipitation is measured as the amount of water that reaches horizontal ground or the horizontal ground projection plane of the earth's surface. Precipitation is measured in quantity for a certain time interval, e.g. millimeters per hour. 1 millimeter corresponds to 1 liter of water per square meter.

All wireless signals that travel from one antenna system to another experiences some form of loss. Properly designed systems use the correct antennas, frequencies, and transmit power to overcome the loss that will takes place in the propagation path. Wireless interference is an important consideration when planning a wireless network. Environmental factors like weather condition, lightning and fog can create interference to the electromagnetic signals. Weather conditions can have a huge impact on wireless signal integrity. Moisture such as fog, rain, and snow adds attenuation to the signal's path [23, 24]. For heavier raindrops the amount of attenuation is more. Also, the amount of attenuation rain can cause depends on the frequency being used.

Electromagnetic waves propagate from their source to their destination through a medium. During the propagation, an electromagnetic wave loses its intensity depending on the condition of the medium through which it travels. Anything encountered between a wireless transmitter and receiver can reduce signal strength through attenuation. This not only includes solid objects like walls and doors, but "liquid objects" like rain and mist. According to the CWNA Study Guide, 2.4 GHz signals may be attenuated by up to 0.05 dB/ km by torrential rain or

0.02 dB/ km by thick fog. Rain can also reduce signal strength through water accumulation on other objects (trees, leaves, absorbent walls) which serves to increase their attenuation.

4. Result and Discussions

The aim of this paper is to evaluate and analyze the performance of three existing routing protocols AODV, DSR and ZRP for MANETs under different weather intensity environment. The simulations are carried out using QualNet version 5.0.

A. Performance Metric

The performance metrics considered for evaluation are packet delivery ratio (PDR), throughput, end-to-end delay (EED) and jitter. They are defined as follows:

- Jitter: Jitter is the variation in packet arrival time. It is an undesired factor and need to be low for better performance in ad-hoc networks.
- End-to-End Delay: It is the average time taken by the packets to move from source to destination. Delays due to route discovery, queuing, propagation and transfer time are included in the delay metric.
- Throughput: It is defined as the rate at which bits are transferred from source to destination. Throughput refers to how much data can be transferred from one location to another in a given amount of time.
- Packet Delivery Ratio (PDR): It is defined as the ratio of number of data packets received by the receivers to the number data packets sent by the source. This ratio represents the routing effectiveness of the protocol.

B. Simulation Environments

This simulation models a network of 60 mobile nodes randomly placed within a terrain area of 1000 m x 1000 m. Nodes in this simulation move according to random way point mobility model, with pause time of 1 second and maximum speed of 10 meters per second. Two ray ground propagation model is used with the MAC layer as IEEE 802.11. Each simulation is executed for 200 seconds. Omni directional antenna is used with the channel capacity of 2Mbits/sec. The data streams are constant bit rate (CBR) streams with the size of the data packet as 512 bytes. Node 10 is used as source and node 40 is used as receiver. All the 60 nodes, including source and destination are placed randomly.

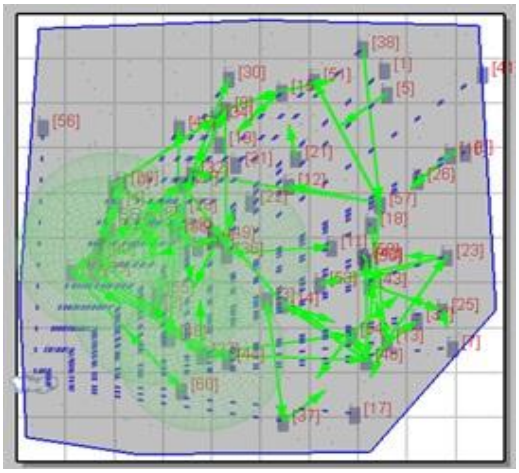

Figure 1. Simulation scenario

This simulation has a weather pattern consisting of a polygon of eight points, at an altitude of 1000 meters. Initially, without any weather pattern the performance metric is found. Next,

the intensity of precipitation is varied insteps of 10 mm/h from 10 mm/h to 60 mm/h. One of the simulation scenarios of this paper is shown in figure 1.

C. Impact of Weather Intensity

In all these simulation weather intensity of zero (0) indicates a free space condition or without any weather pattern condition.

The impact of weather intensity on packet delivery ratio (PDR) is shown in figure 2. With the increase in weather intensity, invariably the packet delivery ratio reduces for all the three protocols. However a large reduction in PDR is noticed in ZRP compared to AODV and DSR protocols. At the weather intensity of 60 mm/h, PDR value is reduced by 53.54 % in AODV and 72.28 % in ZRP from their non-weather condition.

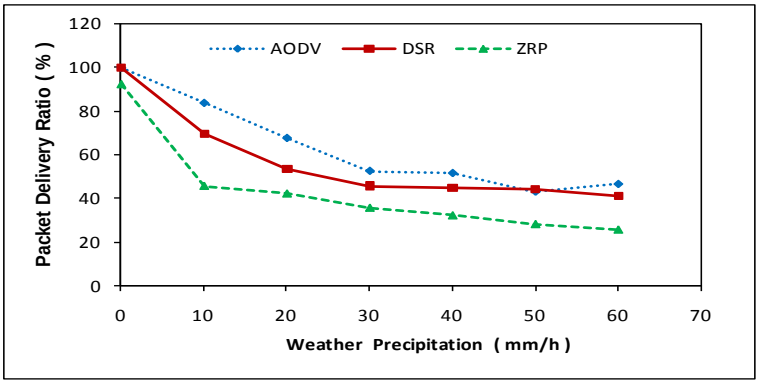

Figure 2. Impact of weather intensity on packet delivery ratio

Figure 3 illustrates the impact of weather intensity on throughput value. Similar to PDR it is found that the throughput is reduced to a large extent as the weather intensity increases. A drastic reduction in throughput is noticed in ZRP. At the weather intensity of 50 mm/h, the throughput is reduced to 1357 bits/sec from its value of 3788 bits/sec at the free space condition. That is, a reduction of 64.176 % bits/s is noticed.

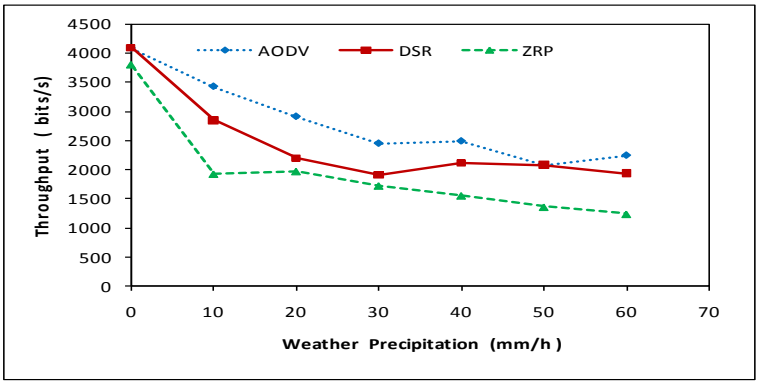

Figure 3. Impact of weather intensity on throughput

It is surprising to note from Figure 4, which shows the impact of weather intensity on end-to-end delay (EED) that, the EED delay value is raised to a large extent in DSR protocol in comparison with the other two protocols. The EED value is maintained at a near constant value in ZRP.

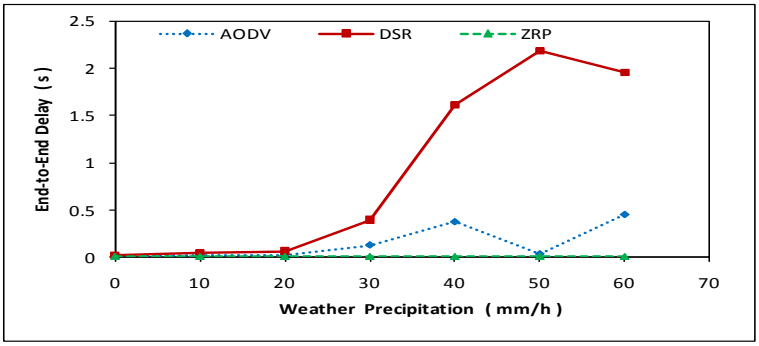

Figure 4. Impact of weather intensity on end-to-end delay

The impact of weather intensity on average jitter is shown in Figure 5. With the increase in weather intensity, jitter value is increased to a large extent in DSR protocol in comparison with the other two protocols. For video streaming application this may not be a desirable one. The percentage increase in jitter at the weather intensity of 40 mm/h, compared to weather intensity of 10 mm/h is 767 % for AODV and 1011 % for DSR.

Even though, end-to-end delay and jitter are maintained at a near constant value in ZRP, its PDR value is reduced to a large value in comparison with other two protocols with the increase in weather intensity. Therefore, under adverse weather conditions, using ZRP for MANET is not advisable. Comparatively, AODV performs well than DSR and ZRP.

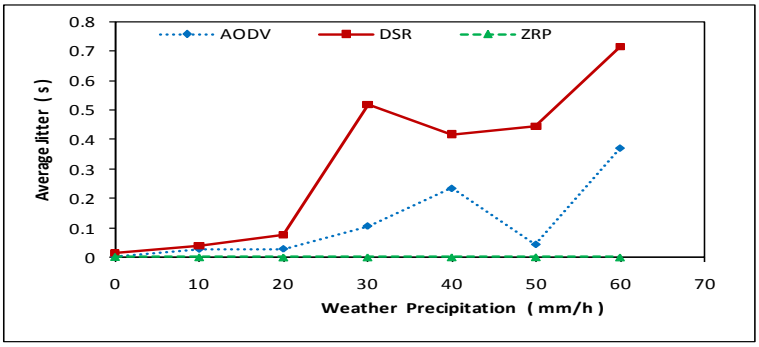

Figure 5. Impact of weather intensity on jitter

D. Impact of packet size variation under weather condition

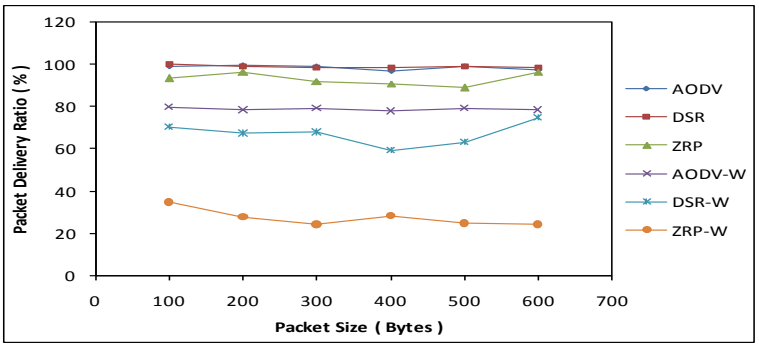

Figure 6. Packet Delivery Ratio as a function of Packet size

For this simulation, two environments are considered: One without any weather pattern and the other with the weather intensity of 10. The multicast data streams are CBR streams with the size of the data packets varying from 100 to 600 in steps of 100 packets.

Figures 6 to 9 show the performance results under varying data packet size with and without weather condition. Increase in the data packet size indicates an increase in the amount of data transmission and delivery. Figure 6 illustrates the effect of varying the packet size on the packet delivery ratio. It clearly shows that, for all the three protocols, reduction in PDR value under the weather condition is noticed. In addition to that, reduction is PDR value is found to be more in ZRP. Even with the large amount of data transmission, the PDR value is maintained without much degradant in AODV protocol.

Throughput as a function of packet size is shown in Figure 7. It is natural that, with the increase in packet size proportionately throughput also increased. Under weather condition, lower amount of reduction in throughput is noticed in AODV protocol in comparison with DSR and ZRP. As the packet size increases from 100 bytes to 600 bytes, the percentage of reduction in throughput under weather condition from its normal value increases from 55.82 % to 70.21 %, in the case of ZRP. It is not desired one, while the system requires large sized data to be transmitted.

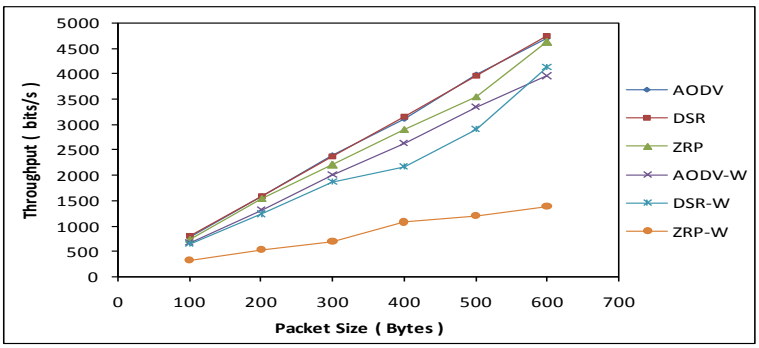

Figure 7. Throughput as a function of Packet size

Figure 8 shows the variation in average jitter value with the variation in packet size. Under free space condition, the amount of jitter is large in DSR, compared to ADDV and ZRP. Under the weather condition, the jitter value remains almost the same as free space condition in ZRP. But the amount of jitter is increased to a large value in DSR.

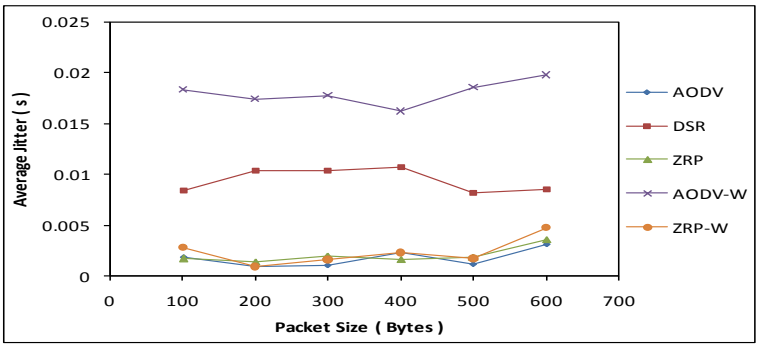

Figure 8. Average jitter as a function of Packet size

From the Figure 9, which shows the imact of packet variation on the end-to-end delay value, it is found that, ZRP maintains the EED value while, AODV shows a large increase in

EED value under the weather condition from the non-weather condition. Similar to jitter, DSR shows a large increase in EED value also.

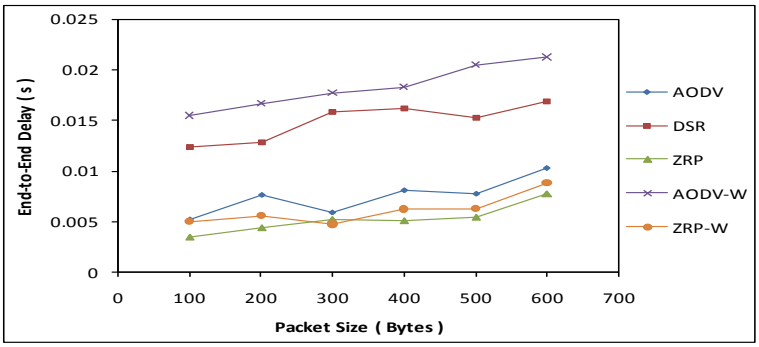

Figure 9. End-to End delay as a function of Packet size

5. Conclusioin

Data transmission over a wireless ad hoc network links in adverse weather condition affects the network performance. Previous works carried to analyze the performance of the routing protocol did not include the study of impact of weather condition. This work analyzed the performance of AODV, DSR and ZRP by varying weather precipitation intensity and by varying packet size under weather condition. Performance degradation in terms of all the performance metric is noticed for all the three protocols. It is found that, AODV performs better compared to DSR and ZRP with the increase in weather intensity, even though a reduction in packet delivery ratio is noticed. Due to large increase in end-to-end delay and jitter value, DSR protocol is not suitable to use in video streaming application under the adverse weather condition. In future, this analysis can be extended to multicast routing protocols of MANET to find their suitability under realistic weather conditions.

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