CHAPTER 6

COMPARATIVE PERFORMANCE ANALYSIS OF VARIOUS ROUTING PROTOCOLS UNDER VARYING PAUSE TIME ENVIRONMENT

6.1 Introduction

The ad-hoc network is a different kind of mobile wireless network where a set of mobile nodes form an impermanent network without using any backbone such as base station or infrastructure. However, numbers of routing protocols are there for the ad-hoc network environment, but it is not an easy task to decide which one routing protocol is efficiently best for the particular situations. Therefore, this chapter attempts to identify the best routing protocols based on some Quality of Service (QoS) metrics. Here, the chapter is subjected to the three different on-demand routing protocols; AODV, DSR, & DYMO and two different zone routing protocols (ZRP); IARP & IERP, with IEEE 802.11 MAC layer protocol in random waypoint mobility model and 50 numbers of fixed nodes (i.e. NLD=50). These five different routing protocols have been analysed, and their performances are compared in this chapter. The comparative performance evaluation has been done with the help of performance measuring metrics such as throughput, end-to-end delay, jitter, and packet delivery ratio (PDR) by using MAC and physical layer model. The simulation has been conducted for the number of times with different values of pause time like 0, 20, 40, 60, 80, and 100 (in seconds) for all routing protocols taken. Moreover, this chapter uses the QualNet simulation tool (version-7.1) to carry out the experimental results. Further, the excel sheet has been used for preparing the graphs from the collected data for different metrics. One publication based on this part of thesis work is as follows:

- Sachin Kumar Gupta, Manoj Yadav and R. K. Saket, "An Analytical Study of Various Ad-hoc Network Routing Protocols Under Certain Parameters using Qualnet-7.1," *IEEE African Journal of Computing & ICTs (Computer Chapter of the Nigeria Section, IEEE Inc, New York, USA)*, 2015, 8(3), 51-58.

6.2 Objective of Study

As in the ad-hoc network environment, there are various routing protocols available that are responsible for establishing the connection between entities, but which one of them will perform better in the particular situations is the matter of further examine. Although from the SOTA section (1.4.6), one can easily observe that several researchers have already conducted the number of studies in order to analyze and to compare the characteristics of different routing protocols through various QoS metrics for various situations and applications. However, they have considered the different set of routing protocols for their studies as chosen in this chapter. Moreover, they used different network simulators for this purpose.

The key objective of the present chapter is based on the performance comparison of five routing protocols, out of which four are reactive (AODV, DSR, DYMO, & IERP) or on-demand in nature and the remaining one is IARP that is proactive in nature. Actually, this chapter is showing its interest to see the performance differences between these five routing protocols in the variable pause time environment, where it is varied from 0 to 100 seconds in a regular interval of 20 seconds. As, in this simulation scenario, it has been considered that the mobile node is moving under the influence of the random waypoint mobility model, where node takes rest for a period of time in second, called 'pause time' before changing the direction or speed in the simulation area (it has been discussed deeply in the section '1.4.2.1'). If the pause time value is kept large that means network becomes relatively stable or if its value is small then it is expected to be highly dynamic network topology. Hence, it is absolutely important to conduct the simulation study in a variable pause time environment in order to observe that how the behavior of routing protocols is getting changed whenever the network topology turns into a relatively stable environment from a highly dynamic one.

6.3 Overview of Routing Protocols for Current Analysis and Evaluation

This chapter chooses five different routing protocols for the comparative analysis. Out of these five routing protocols, one is a proactive type routing protocol (i.e. IARP), which is somehow related to the ZRP hybrid routing protocol and the remaining four is reactive or on-demand kind of routing protocol that are AODV, DSR, DYMO, & IERP. The brief overview of these routing protocols is given as below:

6.3.1 Ad-hoc On-demand Distance Vector (AODV)

The details of the AODV routing protocol has been presented in the chapter-2.

6.3.2 Dynamic Source Routing (DSR)

The DSR protocol has been discussed in depth in the section ‘1.4.1.1’.

6.3.3 Dynamic MANET On-demand (DYMO)

The DYMO routing protocol has been discussed deeply in the section ‘1.4.1.1’.

6.3.4 Intrazone Routing Protocol (IARP)

The Intrazone Routing Protocol (IARP) is some degree of the proactive routing protocol, and it is used to enhance the performance of readily available globally reactive routing protocols [Z.J. Haas, *et al.*, 2002]. Here, the global route discoveries to the local destinations can be avoided by observing the node monitoring changes in their surrounding R-hop neighborhood (i.e. in routing zone). Whenever the route search is needed globally in the network, IARP can be utilized efficiently to guide route queries among the nodes in an outermost zone rather than blindly relaying queries from neighbor to neighbor. Moreover, the attribute of ascertained routes is being improved all the time with the help of proactive maintenance of routing zones by making them more and more robust to the changes in the network topology. Once the routes are revealed, it then provides the enhanced, real-time, and route maintenance quality in the network. One of the best features of this zone routing protocol is that the link failure issues could be minimized or bypassed by multiple-hop paths within the routing area. In the same way, other sub-optimal routes can be recognized, and the traffic could be re-routed along with shorter paths. [Z.J. Haas, *et al.*, 2002].

6.3.5 Inter Zone Routing Protocol (IERP)

Inter Zone Routing Protocol (IERP) is the type of the Zone Routing Protocol (ZRP), but it is a reactive routing component rather than proactive [Z.J. Haas, *et al.*, 2001]. It acquires a fundamental concept of the existing reactive routing protocol to get the benefit of the well-known topology of each node which is surrounded by R-hop neighborhood (i.e. routing zone), provided by the IARP. The availability of routing zone routes permits the IERP to suppress route queries for local destinations. Here, whenever a route discovery is required globally, the routing zone based border cast service can be utilized efficiently to direct route queries outward, more willingly than blindly relaying queries from neighbor to neighbor. Once a route is searched in the network, then this zone routing protocol can use routing zones to automatically re-direct data packets around the unsuccessful links. Again, in this case, other sub-optimal route segments may be point-outed, and traffic could be re-routed through the shortest paths. Actually, IERP is the universal reactive routing component of the ZRP.

6.4 Scenario Overview

This comparative study uses QualNet simulation tool to create the simulation scenario in order to observe the performance difference of considered routing protocols.

For creating the scenario, here, 50 mobile nodes are spread randomly over a constant terrain size of 1500m X 1500m and these mobile nodes are moving according to the random waypoint mobility model with a maximum speed of 10mps. Moreover, 10 SD pairs are chosen randomly, and the CBR traffic generator has been provided between mobile nodes to generate the traffic with the rate of 2KBps. In this case, the message size is 512 bytes and number of items sent is 100. Here, applied addressing is IPv4. Furthermore, the proper node configuration and settings have been done according to the parameter setup, which is given in the table (6.1). From the above-created scenario, to get the best results, the scenario simulation is run for the number of times for 500 seconds, and their average value is taken to analyze the results.

6.5 Simulation Parameters for Scenario Creation

In this chapter, the QualNet 7.1 simulation tool has been used to create the scenario. Moreover, the performance differences between the considered routing protocols are analyzed in the variable pause time environment.

For creating the scenario in QualNet tool, various parameters are required that are tabulated in the table (6.1) with their chosen values.

Table 6.1: Parameter Setup for Simulation Study

Parameter	Value
Simulation Tool	QualNet (Version 7.1)
Physical Layer Model	IEEE 802.11b
MAC Layer Protocol	IEEE 802.11
Antenna Model	Omni directional
Mobility Model	Random Waypoint
Channel Bandwidth	2 Mbps

Area	1500 m X 1500 m
Transmission Range	200 m
Transmission Power	15 dbm
NLD	50
CBR SD Pair	10
Nodes Placement Strategy	Randomly
Nodes Maximum Speed	10 mps
Data Traffic Type	CBR
Packet Size	512 bytes
Data Rate	2 KBps
Simulation Time	500 seconds
Pause Time	0, 20, 40, 60, 80, & 100 (in seconds)

6.6 Graphical Representation of QoS Metrics, and Discussion of Results

In this section, various obtained results from the simulation scenario are presented and discussed in the form of graphical manner; throughput, end-to-end delay, jitter and packet delivery ratio (PDR). Moreover, at the end of this section, the performance comparison of various considered routing protocol has been tabulated and are explained for the comparative analysis.

6.6.1 Graphical Representation of Throughput

Throughput is related to the channel capacity of the network, and it is the maximum number of data packets that can be delivered successfully over a communication channel under ideal circumstances in a particular time interval (it has discussed in depth in the section ‘1.4.4.1’).

Figure (6.1) reflects the throughput as a function of the pause time. From the figure, it may observe that in terms of throughput, DYMO achieves better than the other remaining routing protocols for the middle range of pause time values. However, at the same time, it could also be seen that AODV gives better throughput than the other remaining routing protocols for lower and higher values of pause time. Other than AODV and DYMO routing protocol, the DSR and IARP have nearly comparable throughput values. However, overall DSR gives somewhat more throughput than the IARP. IERP is one, which offers least throughput value all over the range of pause time.

From the above discussion, it is concluded that an overall AODV gives the best performance in terms of throughput. In other words, AODV routing based network outperforms than the other remaining routing based network in all types of environment i.e. stable or dynamic environment. The reason behind that may be the idea of the route maintenance in this routing, which helps it to deal with all types of network conditions either stable or dynamic situations.

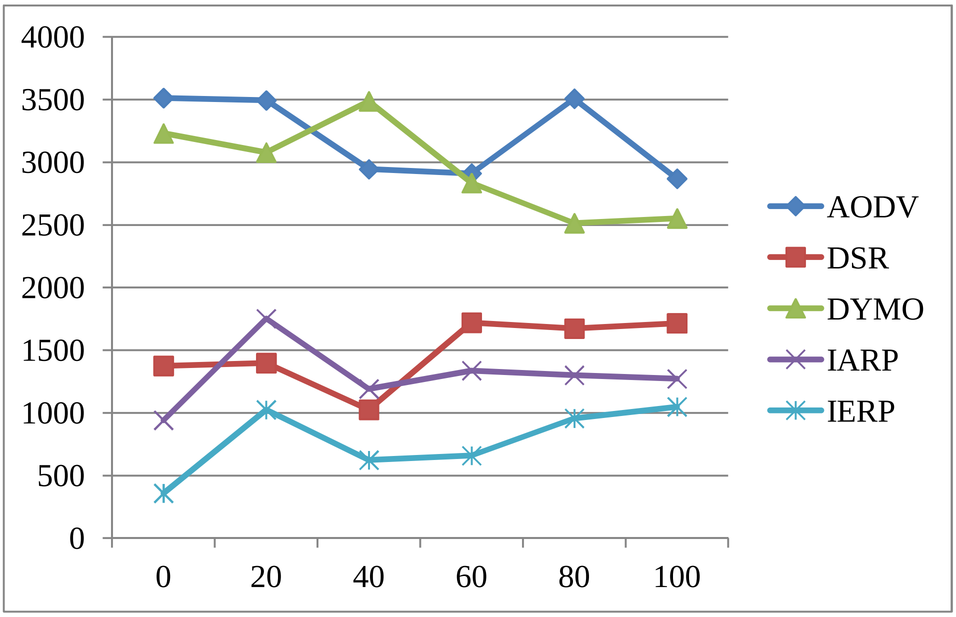

Figure 6.1: Throughput (bits/second) as a function of the pause time

6.6.2 Graphical Representation of End-to-End Delay

It is an overall average time taken by the packets to reach the destination point from the source point. It comprises all the possible delays, which are happening due to buffering during the route discovery process, re-transmission at the MAC layer, queuing at the interface point, propagation, and transfer times etc. It has been clearly explained in the section '1.4.4.1'.

Figure (6.2) depicts that the IERP has a higher end-to-end delay almost all over the range of variation of pause time, followed by a second higher end-to-end delay value, which corresponds to DSR. AODV and DYMO both have very low values of an end-to-end delay over the range of pause time variation. However, AODV has slightly lower end-to-end delay value than DYMO. At last, an IARP is one which has lowest end-to-end delay variation throughout the range of pause time.

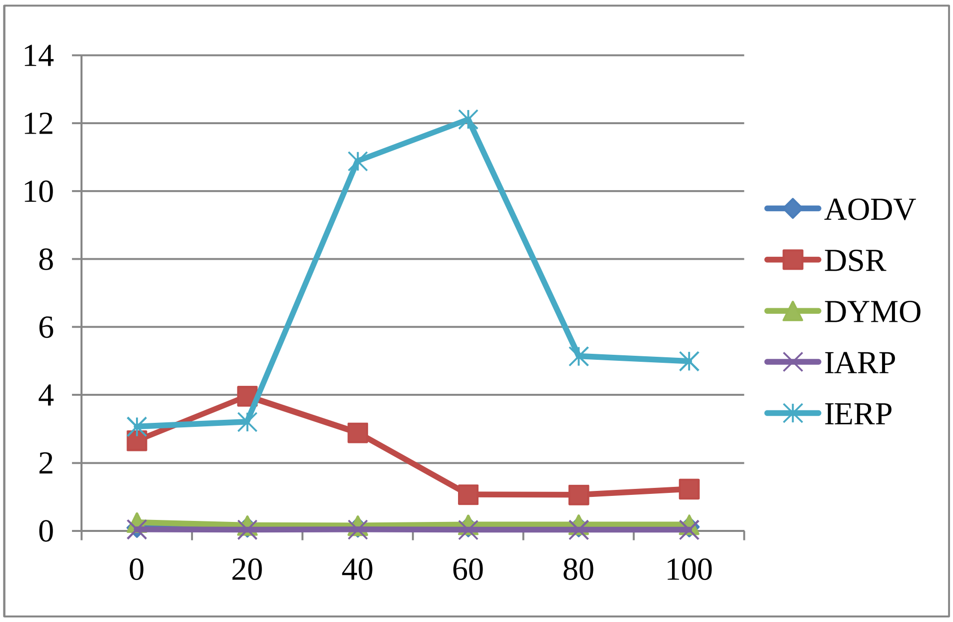

Figure 6.2: End-To-End Delay (seconds) as a function of the pause time

6.6.3 Graphical Representation of Jitter

Jitter is the variation of time of packets at the receiving point. In other words, network with constant latency has no variation or jitter; it has discussed in depth in the section '1.4.4.1'. Actually, the presence of jitter in any IP network is caused by network congestion, timing drift, or route changes.

Figure (6.3) indicates the results of jitter for all five protocols. From the figure, it could be clearly observed that the DSR acquires the highest jitter for lower values of pause time such as 0, 20 and 40 seconds and for higher values of pause time it gives good performance whereas, IERP performance is worst at higher values of pause time. AODV and DYMO have satisfactory jitter, and it is almost constant throughout the range of pause time. Among all routing protocols, IARP gives the lowest jitter value throughout the pause time variation.

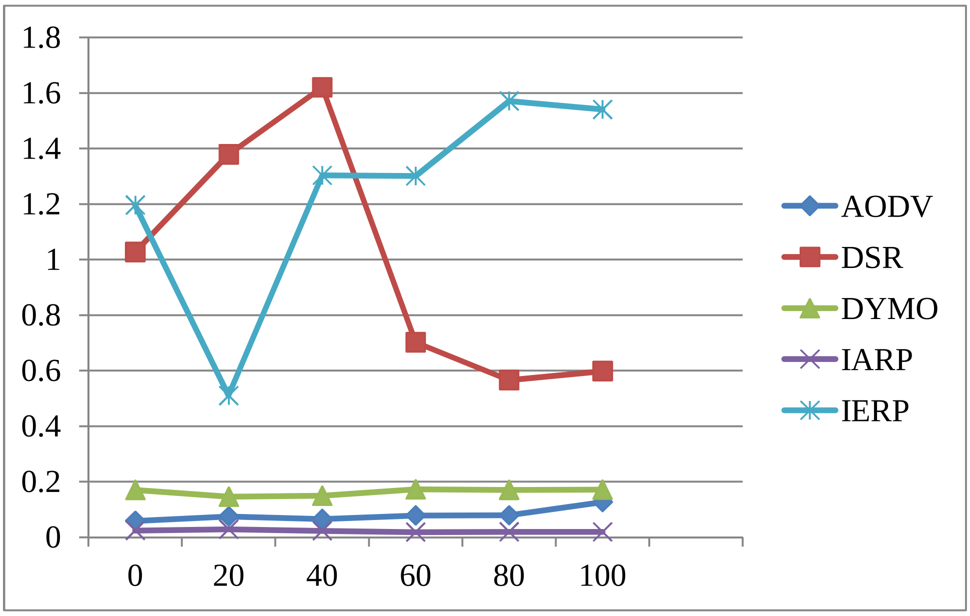

Figure 6.3: Jitter (seconds) as a function of the pause time

6.6.4 Graphical Representation of Packet Delivery Ratio (PDR)

PDR is the ratio of total packets received by the receiving nodes to the total packets sent by the sending nodes. The better PDR offers the most complete and correct routing path in the networks. This metric is very important because it evaluates the route discovery ability of any protocol.

*Packet Delivery Ratio (PDR) [in %] = (Received Packets/ Sent Packets) * 100*

Figure (6.4) demonstrates that the AODV acquired the highest PDR value, and the DYMO nearly follows it. DYMO has satisfactory PDR value. Here, reason is same as like in the case of throughput. Further, it is also observed that the IARP has a lower PDR value, but higher than the IERP, which has lowest PDR value among all the routing protocols.

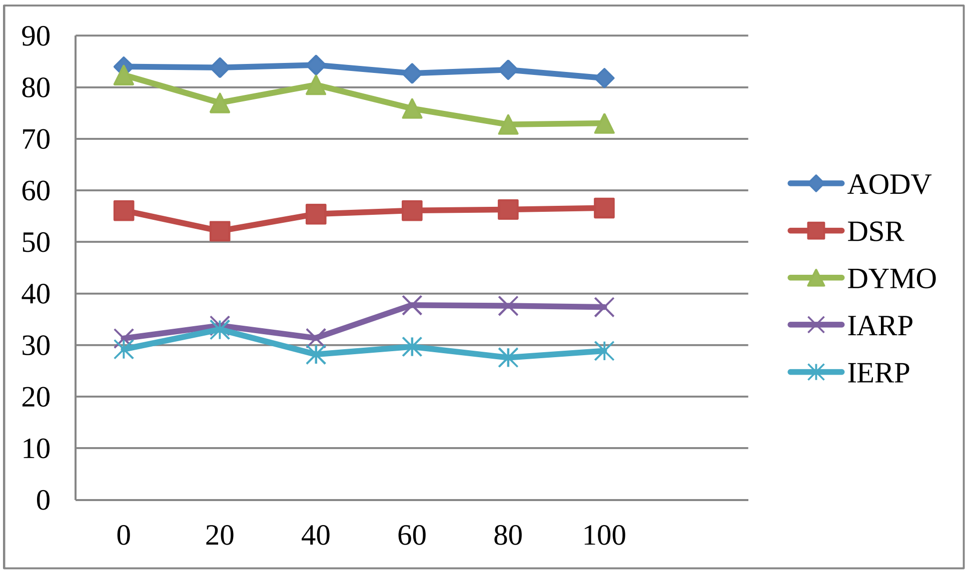

Figure 6.4: PDR as a function of the pause time

6.6.5 Results Discussion of QoS Metrics

The above-discussed results have been summarized in the tabular form that is shown in table (6.2).

Table 6.2: Comparative performance analysis in tabular form

Performance metrics	Throughput	End-to-End delay	Jitter	PDR
Highest	AODV	IERP	IERP	AODV
High	DYMO	DSR	DSR	DYMO
Medium	DSR	DYMO	DYMO	DSR
Low	IARP	AODV	AODV	IARP
Lowest	IERP	IARP	IARP	IERP

From the table, one may observe that all purely on-demand routing protocols like AODV, DSR, & DYMO have outperformed than ZRP components (IARP & IERP that are hybrid routing protocols, basically), in terms of throughput and PDR. Since AODV, DSR, & DYMO are using on-demand nature because of that less number of control overhead packets in the network. Hence, the minimum number of packets gets dropped in these cases. Therefore, the throughput and PDR are better for these on-demand routing protocols. It may also be seen that the IERP and IARP deliver the worst performance (in terms of throughput & PDR). It may be due to the limited proactive and reactive features in IERP and IARP. Moreover, IARP gives the best performance in terms of end-to-end delay and jitter than the other remaining routing protocols, and the performance is almost constant throughout the variation in pause time. The reason may be due to some degree of the nature of proactive maintenance within routing zones, which makes it more and more robust to the changes in the network topology. And also, the route discovery process becomes easier due to this nature. Furthermore, in this case, the route breakage issues are also minimized because of multiple-hop paths concept within the routing zone. After IARP, AODV routing protocol performs satisfactorily in terms of end-to-end delay & jitter, and here performance is also constant throughout the range of pause time. The possible cause may be AODV have a mechanism to adopt the topology changes quickly in the network. One may also notice that the DSR performance is worse in the case of end-to-end delay, and jitter that are shown in figures (6.2) and (6.3). It is possibly happening due to the idea of source routing (source routing protocol has a higher delay because here route discovery process takes a longer time since every intermediate node tries to extract information before forwarding the reply). Also, the DSR performance becomes poorer at low values of pause time than the higher values. It may be due to the slow response to the fast changes in network topology, hence jitter is higher at lower values of pause time. As well, the route discovery process becomes difficult due to the highly dynamic nature of network at lower values of pause time. Thus, the higher end-to-end delay is observed in this case also.

Therefore, overall it can be said that the AODV performs better than all other remaining routing protocols for throughput and PDR throughout the range of pause time, and also second best for the end-to-end delay and jitter. Beside the above fact, the results may vary from other similar studies due to the difference in simulation setup and different parameter conditions. Although in general, the results obtained by this chapter are very similar to the other research results done for above routing protocols.

6.7 Conclusion

This chapter evaluates the performance of different routing protocols with the help of four different performance metrics (i.e. QoS metrics) that are throughput, end-to-end delay, jitter, and packet delivery ratio (PDR). Here, the comparative performance analysis has been done in the varying pause time environment. From the above discussion, this chapter concludes that the AODV gives better throughput and PDR than the other remaining routing protocols throughout the range of variation of pause time. Although, it also performs satisfactorily in terms of end-to-end delay and jitter performance metrics, after IARP. The reason behind the best performance of AODV may be the lesser number of control overhead packets because of on-demand nature. Also, another reason may be the quick response to the route breakage and topology changes in the network promptly. DYMO also performs satisfactorily for pause time variation after AODV. Here, it can be noted that the IARP and IERP are proactive and reactive components of the ZRP respectively and have limited proactive and reactive features. Hence, their performance is poorer than the other remaining routing protocols, i.e. AODV, DSR, & DYMO. However, the best one in terms of end-to-end delay and jitter is observed by IARP because of some features of the proactive maintenance that makes it more suitable towards the network topology changes. Moreover, the reason for the best performance is also a concept of the multiple-hop paths within the routing zone.

Chapter 7 finally summarizes the present thesis and also includes the conclusion of all chapters. Moreover, chapter 7 is also pointing out the scope of future work.