CHAPTER 4

IN AODV ROUTING: COMPARATIVE STUDIES FOR CBR & VBR TRAFFIC UNDER THE INFLUENCE OF ROUTE MAINTENANCE PARAMETERS

4.1 Introduction

Since the mobile Internet applications flourish greatly in the recent years, hence it is absolutely important and interesting to find the way to guarantee the QoS in topology-varying ad-hoc network environment, especially for VBR traffic. VBR is more realistic than CBR as it includes multimedia traffic as well as other types of traffic. Therefore, in this chapter, the performance of the AODV routing protocol has been analyzed and compared to two different traffic generators: Constant Bit Rate (CBR) and Variable Bit Rate (VBR). In order to evaluate and to compare the performance of the AODV routing protocol under CBR and VBR traffic generator, again the route maintenance parameters (ART & DPC) have been taken into account. Along with the above, the created scenario in this network is subjected to IEEE 802.11 MAC protocol under random waypoint topology for a fixed Network Load Density (NLD), i.e. number of nodes. This chapter makes the evaluation and comparison of AODV routing performance based on three QoS parameters; throughput, average end-to-end delay, and average jitter. Again, D-plot is used here to prepare the QoS graphs. Moreover, this chapter also measures the degree at which the number of Active Nodes (ANs)/SD pairs (i.e. number of nodes that are actively participating in communication at any instant) will affect the QoS parameters for both considered traffics. The above considerations are presented, discussed and simulated using QualNet7.1 simulation software. The simulation objective and overview, simulation environment and simulation results are discussed in further sections. Two publications based on this part of thesis work and another one is communicated as follows;

- **Sachin Kumar Gupta** and R.K. Saket, "Effect of ART, DPC and ANs on the Performance of AODV Routing," *10th International Conference on Industrial and Information Systems (ICIIS),* **IEEE**, Faculty of Engineering, University of Peradeniya, **Sri Lanka**, Dec 2015, 77-81.
- **Sachin Kumar Gupta** and R.K. Saket, "Analyzing the Outcome of Route Maintenance Parameters with VBR Traffic on Stability of AODV Routing for a Realistic Scenario in MANET using QualNet," *International Conference on Telecommunication Technology and Management (ICTTM),* **Emerald India**, Bharti School of Telecommunication Technology and Management, **IIT Delhi**, Apr 2015.
- **Sachin Kumar Gupta** and R.K. Saket, "Analytical study for evaluating an optimal ART & DPC in AODV routing for VBR traffic," *Wireless Personal Communications*, Springer, **(SCI, IF=0.97)**.

4.2 Simulation Objective and Overview

It is well known that the ad-hoc networks run in a dynamic environment where network topology changes constantly and quickly. In this network, joining the new nodes and leaving old nodes happens automatically and arbitrarily. Thus, routing algorithms (in this case AODV) should be robust in order to adapt such behavior as they affect the network performance. As in the AODV routing, route maintenance parameters are one of the paramount factors. Hence, their choice of default value may play an important role in order to provide the stable routing in such environment. Moreover, the QoS parameters are the key element for observing any routing protocol performance. From the SOTA section (1.4.6), it is clear that some available studies carried out comparative studies between various routing protocols. However, they were limited to CBR and TCP traffic models, and very few included the route maintenance parameters but only for CBR traffic. Therefore, this chapter presents the comparative study between CBR and VBR traffic under the influence of route maintenance parameters like ART and DPC. In addition, this chapter also tries to point out an optimal relation between route maintenance parameters (ART & DPC) and both traffic generators (CBR & VBR) in which AODV network performs best in terms of QoS metrics (i.e. provides stable routing).

Here, the QualNet simulation tool has been used to study the network performance under CBR and VBR traffic generators. Moreover, to create the network, 60 nodes are spread randomly over a constant area size of 1000mX1000m and the nodes are moving according to the random waypoint mobility model with a minimum speed of 1 m/s to the maximum speed of 10 m/s. Among 60 nodes, three different SD pairs (8, 12, and 16) have randomly been chosen as traffic generators. During the simulation, each node starts its journey from a random spot to a randomly chosen destination. Once the destination is reached, the node takes rest for a period of time in a second, called “pause time” and other random destinations are chosen after this pause time. Here, the pause time value is 30 seconds, and the above process repeats throughout the whole simulation. In order to obtain the best results, the scenario simulation is run for the number of times for 180 seconds, and their average value is taken to plot the graphs. Same results are being obtained for almost all the time.

This chapter conducts mainly two different simulation studies for the substantial understanding of the network behavior under the above-considered scenario:

- Analysis for variable ART at fixed “NLD & SD pair”
- Analysis for variable SD pair at fixed “NLD & ART”

4.3 Simulation Environment

The various simulation parameters at different layers of the network have been chosen as per the table (4.1) and (4.2) to create the simulation scenario. In this case, the ART value has significantly been changed from its default value (i.e. from 1 to 5 in a regular interval of 1 second), and the DPC value is considered as (3, 4, 5, 6, 7). Along with the above, three different values of the ANs/SD pair are chosen as (8, 12, and 16).

Table 4.1: Simulation parameters at physical layer

Radio_Type	PHY802.11b
Antenna_Height	1.5 m
Antenna_Efficiency	0.8
Antenna_Model	Omni directional
Path_Loss_Model	Two ray
Packet_Reception_Model	PHY802.11b
Number of Channels	1 (2.4GHz) Ad-hoc mode
Channel Bandwidth	11 Mbps

The above parameters could be setup through the scenario properties of QualNet.

Table 4.2: Simulation parameters at other layer and general parameters

MAC Layer	
Mac_Protocol	802.11
Network Layer	
Subnet Channel	Wireless
Network Protocol	IPv4
Routing Protocol	AODV
Application Layer	

Applications	CBR, VBR
Packet Size	1024 Bytes
Packet Interval Time (CBR)	0.1 s
Packet Mean Interval Time (VBR)	0.1 s
General Parameters	
Node Placement	Randomly
Terrain Size	1000 m X 1000 m
NLD	60
ANs/SD pair	8, 12, 16
ART	1, 2, 3, 4, 5 (in s)
DPC	3, 4, 5, 6, 7
Mobility Model	Random waypoint
Pause Time	30 s
Minimum Speed	1m/s
Maximum Speed	10 m/s
Simulation Time	180 s
Transmission Range	200 m
Transmission Power	15 dbm

4.4 Simulation Results

Extensive simulation has been carried out to observe and to compare the performance of the AODV routing protocol for CBR and VBR traffic generators by varying the considered route maintenance parameters. The observation and comparison of the performance for created scenario are done with the help of QoS metrics. Here, the results have been analyzed in two ways by varying ART and SD pair. Therefore, two different simulation studies are conducted for better understanding of the network behavior. One is the “analysis for variable ART at fixed “NLD & SD pair” and another one is the “analysis for variable SD pair at fixed “NLD & ART”.

While changing the DPC value for variable ART and variable SD pair for the created scenario, and running the simulation upto 180 seconds, different values of throughput, average end-to-end delay, and average jitter have been carried out by using QualNet. With the help of these obtained values, various graphs are plotted that are shown and discussed in further coming sub-sections. Moreover, the figures (4.1) and (4.2) are showing snapshots of X-Y & 3-D view, respectively, for VBR traffic under the wireless subnet for a simulation topology of 60 mobile nodes.

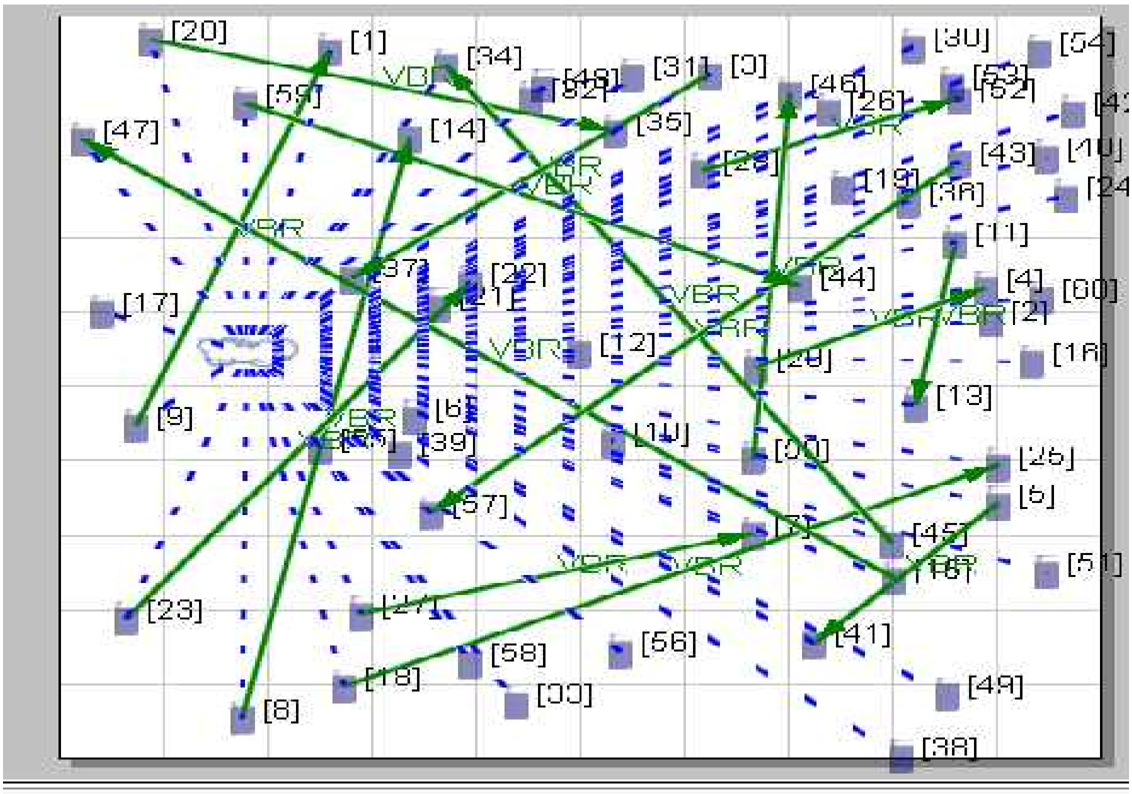

Figure 4.1: Snapshot of 60 nodes in QualNet scenario for VBR traffic (X-Y view)

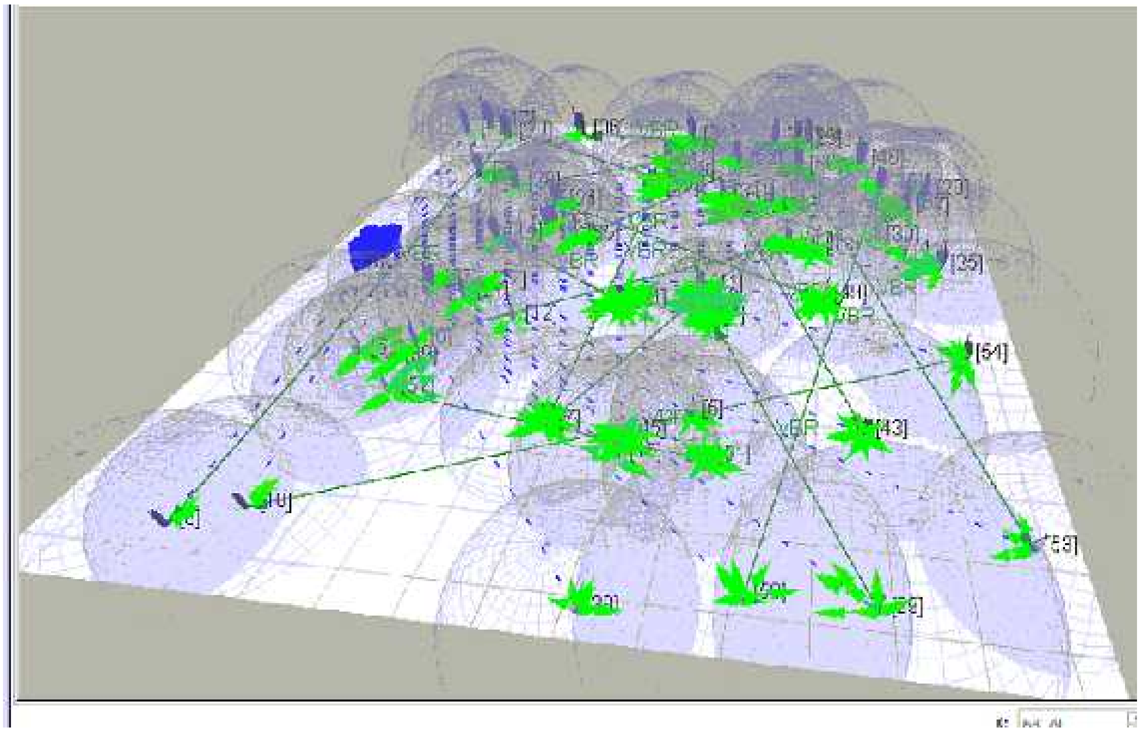

Figure 4.2: Snapshot of 60 nodes in QualNet scenario for VBR traffic (3-D view)

4.4.1 Analysis for variable ART at fixed "NLD & SD Pair"

In this case, the value of NLD and SD pair are kept constant at 60 and 12, respectively. After that, the analysis is begun for the various QoS metrics in a varying DPC environment where DPC value is taken from 3 to 7 at a regular interval of 1 (i. e. 3, 4, 5, 6, 7) for different values of ART. In this scenario, in order to analyze the results, the value of ART has significantly been varied from its default value (3 seconds). In other words, the analysis is initiated with the ART value (1 & 2) that is less than from its default value, and later on, the analysis is extended for the ART value (4 & 5) that is greater than from its default value. Thus, it can be observed that how the AODV routing protocol behaves under CBR & VBR traffic when ART value is varied from its default value (i.e. ART<3 & ART>3).

4.4.1.1 Graphical Analysis of Throughput for CBR & VBR Traffic

This sub-section shows the throughput graphs that have been plotted for various ART values with DPC on the X-axis and throughput on Y-axis for CBR and VBR traffic generators. In other words, it can be said that the values of the throughput are getting compared to CBR and VBR traffic generators with the DPC for different values of ART.

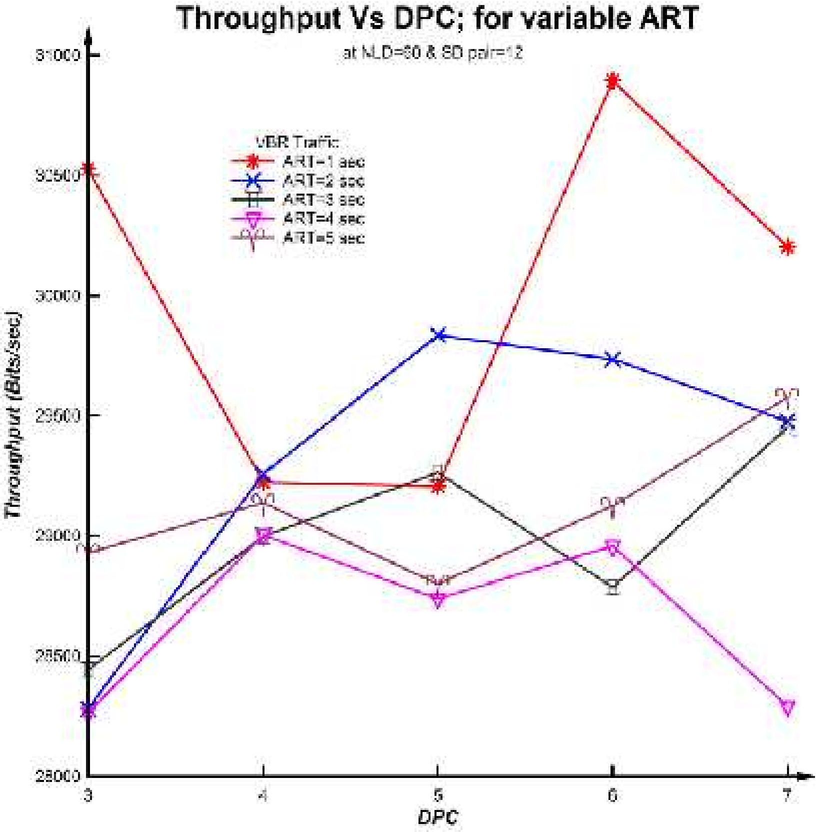

Figure 4.3: Throughput Vs DPC; for variable ART (VBR Traffic)

Figure (4.3) demonstrates the throughput vs DPC for variable ART during VBR traffic generator. From the figure, it can be observed that except ART=1, for all values of ART, initially the total number of throughputs is getting increased in some cases (for ART=4 & 5) till at DPC=4 and in some cases (for ART=2 & 3) till DPC value at 5. Also, almost for all values of ART at very higher DPC, throughput again starts to decrease. Initially, as DPC value increases, the number of alternative routes also increases. Hence, the throughput values are increased. Later on, the poor performance is noticed, it may be due to increasing in memory overheads than alternative routes. Thus, the successful delivery of packets is getting reduced. In addition, it could also be noted that the higher ART (4 & 5) values give an overall lower throughput performance than other lower values of ART (1, 2, 3). It might be possible because of holding the memory for a longer time, hence creating more overheads. Moreover, the packets are also being sent out on invalid routes. Thus, more packets get dropout. Therefore, throughput values are getting reduced at higher values of ART. From this graph, one can see that a curve ART=1 delivers the highest throughput at DPC=6.

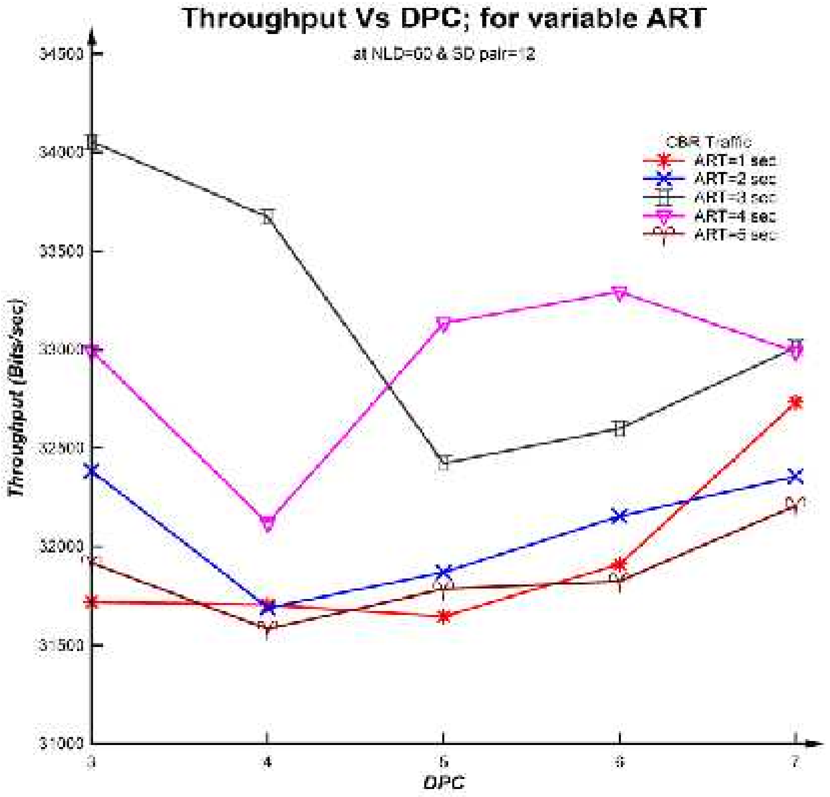

Figure 4.4: Throughput Vs DPC; for variable ART (CBR Traffic)

Figure (4.4) shows the throughput performance with DPC at different values of ART for CBR traffic generator. From the figure, it can be noticed that as ART value increases from 1 to 3, overall throughput values are also getting increased. Whereas, at higher ART values (4 & 5), the throughput values start to decrease. In other words, it can be said that the best performance has been seen at ART=3 (i.e. at its default value) for CBR traffic. For ART<3, the throughput performance is poor; it may be due to node holds the route state information for a very short time after it has been used, which causes a node to repeat the route discovery process most of the time after each use of the route while a valid route is still there. Moreover, at higher ART values (i.e. ART>3) the throughput performance is again experienced poor; it may be due to sending the packets on an invalid route. Hence, initiation of the RERR message occurs instead of a new route discovery process. In addition, it can also be observed that initially as DPC value increases, the performance gets reduced. The reason for that may be the unavailability of the alternative routes with an increase in DPC value. Later on, performance starts to rise with an increase in DPC value; it may be due to the availability of the alternate routes.

4.4.1.2 Graphical Analysis of Average End-to-End Delay for CBR & VBR Traffic

This sub-section illustrates the various delay graphs that have been plotted for variable ART with DPC on the X-axis and average end-to-end delay on Y-axis for different traffic generators: CBR and VBR (i.e. the values of the average end-to-end delay are getting compared to CBR and VBR traffic generators at various values of ART).

Average end-to-end delay vs DPC graph for variable ART (VBR traffic) is shown in figure (4.5). From the figure, one can notice that again the best delay performance is observed for ART=1 at DPC value of 6. Moreover, as ART value starts to increase, the network performance becomes worst. It may be possible due to the invalid route in the routing table. Hence, the consequence is an initiation of the RERR message instead of new route discovery process. Thus, the packet gets delayed to reach the destination. It may also be observed from the figure (4.5) that at lower DPC values, a very high delay is experienced in all the cases. Moreover, at higher values of DPC except the curve ART=1, again high delay is experienced for all ART values as compared to the middle range of DPC. For DPC<4, network performance is poor in terms of delay because of route unavailability for the successful transmission of the packets. In addition, for DPC>6, again the performance is degraded due to memory occupation by routing table for a longer time, thus creating more overheads.

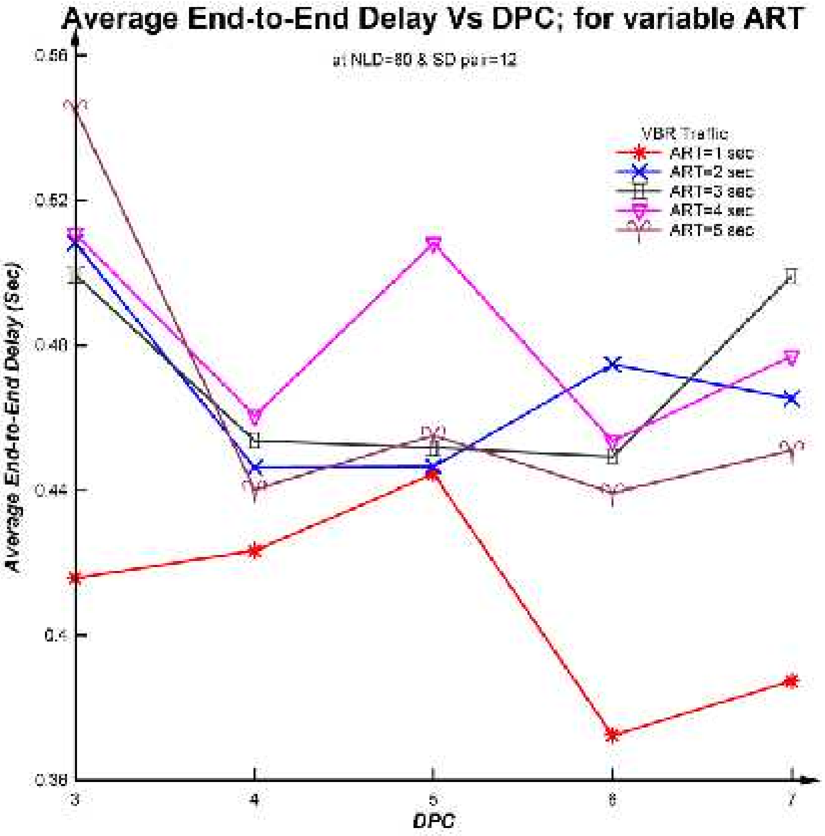

Figure 4.5: Average end-to-end delay Vs DPC; for variable ART (VBR Traffic)

Figure (4.6) demonstrates the delay graph, but for CBR traffic generator. From the figure, it may be observed that the curve ART=3 at DPC=3 gives the best network performance. In both the cases, for ART<3 & ART>3, the AODV network gets overall high delay as compared to ART=3. The reason for that may be again initialization of the new route discovery process while a valid route is still there, and sent out the packets to an invalid route instead of the new route discovery process, respectively. However, in the case of CBR traffic generator, for all ART values, initially the delay increases with an increase in DPC value. It may be possible because of the increase in overheads than alternative routes.

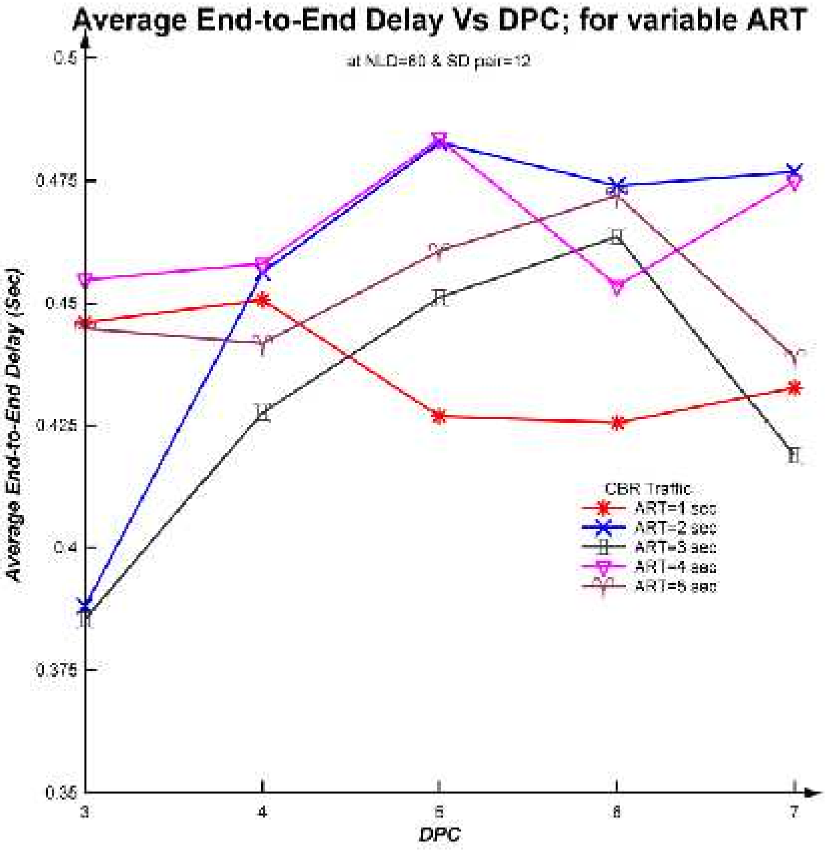

Figure 4.6: Average end-to-end delay Vs DPC; for variable ART (CBR Traffic)

4.4.1.3 Graphical Analysis of Average Jitter for CBR & VBR Traffic

Here, various jitter graphs are presented that have been drawn by D-plot for some ART values with DPC on the X-axis and average jitter on Y-axis for both considered traffic generators (i.e. the values of the average jitter are getting compared to CBR and VBR traffic generators for different values of ART).

Figure (4.7) illustrates the average jitter at different values of ART for VBR traffic generator. The network with VBR traffic generator gives the worst performance (in terms of jitter) at higher ART values. Here, reason is same as in the case of throughput and average end-to-end delay. Except the curve ART=1, for all other ART curves, initially, network performance improves until DPC values of 4 & 5. Later on, the poor performance is experienced almost for all ART. Moreover, its analytical values are uncertain. The reason for quality degradation at higher DPC values may increase in route breakage despite of alternative routes. It may be due to higher traffic particularly at this time interval. At the same time, a different characteristic is given by curve ART=1, and it offers the lowest jitter throughout the range of DPC as compared to other ART curves.

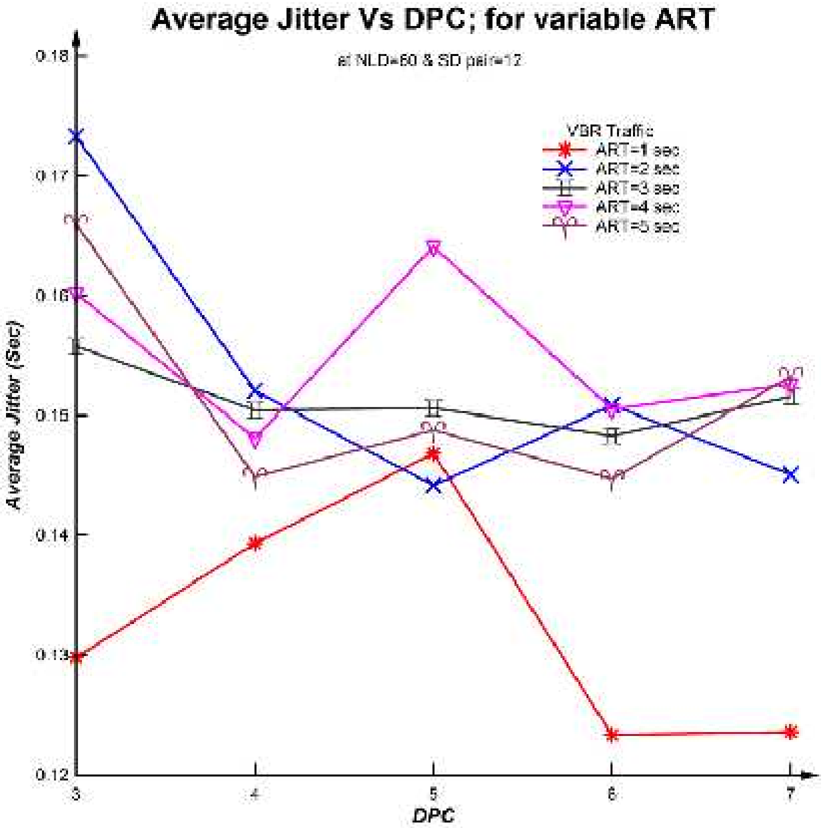

Figure 4.7: Average jitter Vs DPC; for variable ART (VBR Traffic)

Average jitter graph for CBR traffic is shown in figure (4.8). From the figure, it may observe that curve ART=3 gives the overall minimum jitter than other ART values. And, in this case as DPC value increases, jitter value is also increased. The reason for that may be an increase in route breakage with a DPC value because of heavy traffic, particularly. One can also see that the overall higher jitter is experienced for ART<3 & ART>3. Here, reason is same like figure (4.6). Moreover, for ART (1 & 2), as DPC value increases, these curves give better performance. It may be due to an increase in routes' stability as DPC value increases, so there is no variation in the packets arriving time. However, for ART (3 & 4), poor performance is observed with an increase in DPC value. Whereas, the analytical value of curve ART=5 is entirely uncertain and gives the highest jitter. Here, the reason for overall highest jitter may be an abrupt change in ART value from its default.

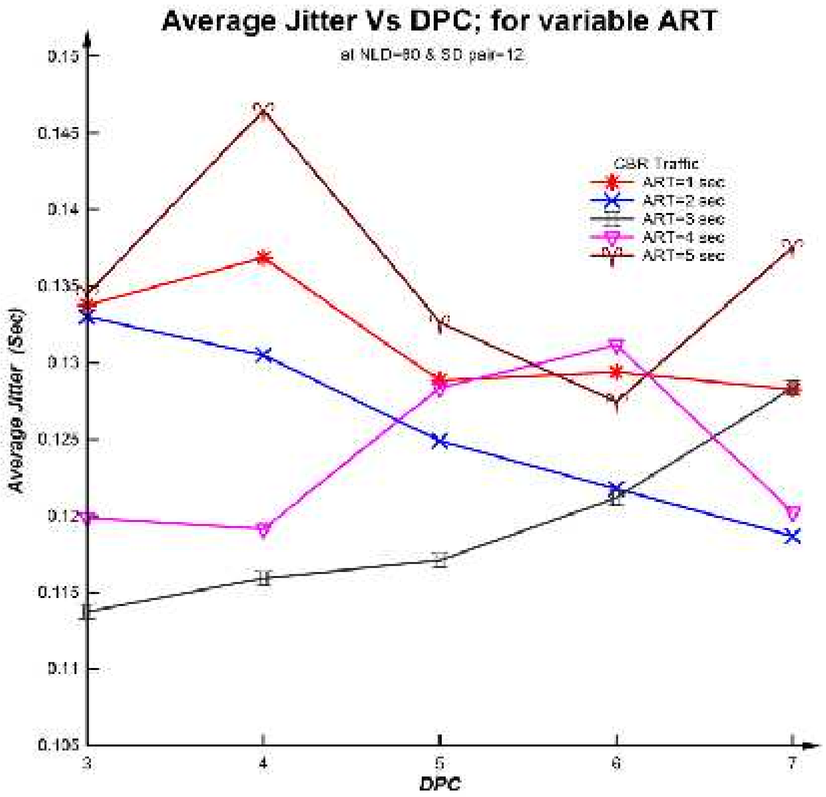

Figure 4.8: Average jitter Vs DPC; for variable ART (CBR Traffic)

4.4.2 Analysis for variable SD Pair at fixed "NLD & ART"

This simulation scenario has been conducted to observe and to compare the AODV network performance for CBR and VBR traffic generators in the variable SD pair environment while a value of NLD and ART is kept constant over a fixed network size. Here, NLD=60, ART=3 seconds, and three different values of the SD pair (8, 12, and 16 out of 60 nodes) have been considered to create the network scenario. The reason for taking ART=3 is that as it is the default value. Again, in this case, QoS metrics are used to observe the AODV performance for both traffic generators.

4.4.2.1 Graphical Analysis of Throughput for CBR & VBR Traffic

In this sub-section, the throughput graph is depicted. It is plotted for the variable SD pair with DPC on the X-axis and throughput on Y-axis for CBR and VBR traffic generators (i.e. in this graph throughput values are getting compared to CBR and VBR traffic generators in the variable SD pair environment).

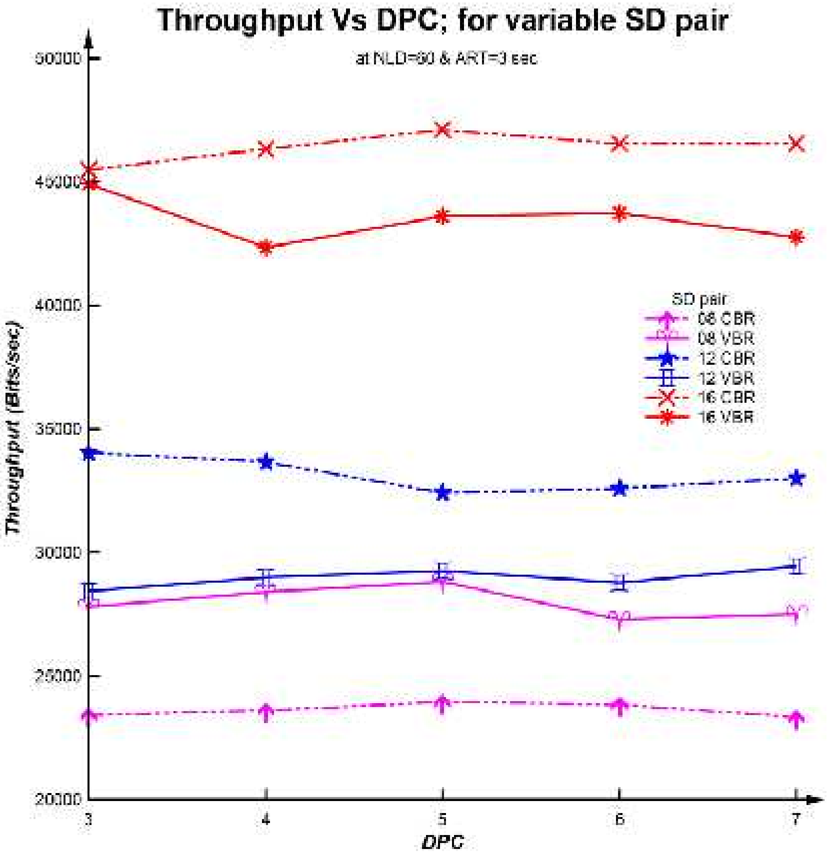

Figure 4.9: Throughput Vs DPC; for variable SD pair (CBR & VBR)

From (4.9) delineates the throughput graph on DPC for three different SD pairs. Actually, this figure makes the comparison of throughput values for CBR and VBR traffic generators. From the figure, one may observe as the number of SD pair increases in a particular area, the obtained throughput value also increases in both the cases (i.e.

CBR & VBR traffic). The reason behind that may be an increase in numbers of generating data packets with an increase in SD pairs (actually, with an increase in SD pair, the number of clients is also grown in the network) and hence, more packet gets successfully transmitted over the channel in a particular time unit. It is expected that after some amount of SD pairs (increase in the SD pair like more than 50% or 60% out of total NLD), the performance may start to degrade because of heavy traffic congestion in the network due to more control overhead packets, and thus more packets get dropout. In addition, it may also be noticed that for CBR traffic, the obtained amounts of total throughput values are always greater than the VBR traffic in all SD pairs. It might be possible because this simulation study has been conducted at the default value of ART (i.e. ART=3 seconds). And from the section (4.4.1), it is clear that the CBR traffic has outperformed than VBR at near default value of ART. Moreover, in the case of VBR traffic throughput values are always lower than CBR, it may be due to the variable nature of bit rate. Hence, accurate synchronization is required every time to transfer the data between a particular source and destination nodes. In other words, there is always a synchronization problem between a particular source and destination nodes.

4.4.2.2 Graphical Analysis of Average End-to-End Delay for CBR & VBR Traffic

Here, the average end-to-end delay for CBR & VBR traffic generators is shown in figure (4.10) for the variable SD pair with DPC on the X-axis and average end-to-end delay on Y-axis.

From the figure, it is evident that except for curve of 16 SD pair, all other curves acquire overall higher delay in case of VBR than CBR. For VBR traffic, it may be due to the large distance between a particular source and destination nodes (particularly, at 8 & 12 SD pair). Therefore, there is the difficulty in the route discovery process, and also tuning problem appears more between source and destination nodes. Hence, delay values are higher in these cases. Moreover, the overall network performance improves with an increase in the SD pair for both traffic generators. The reason for that may be the route discovery process becomes easier with an increase in the SD pair towards a particular client.

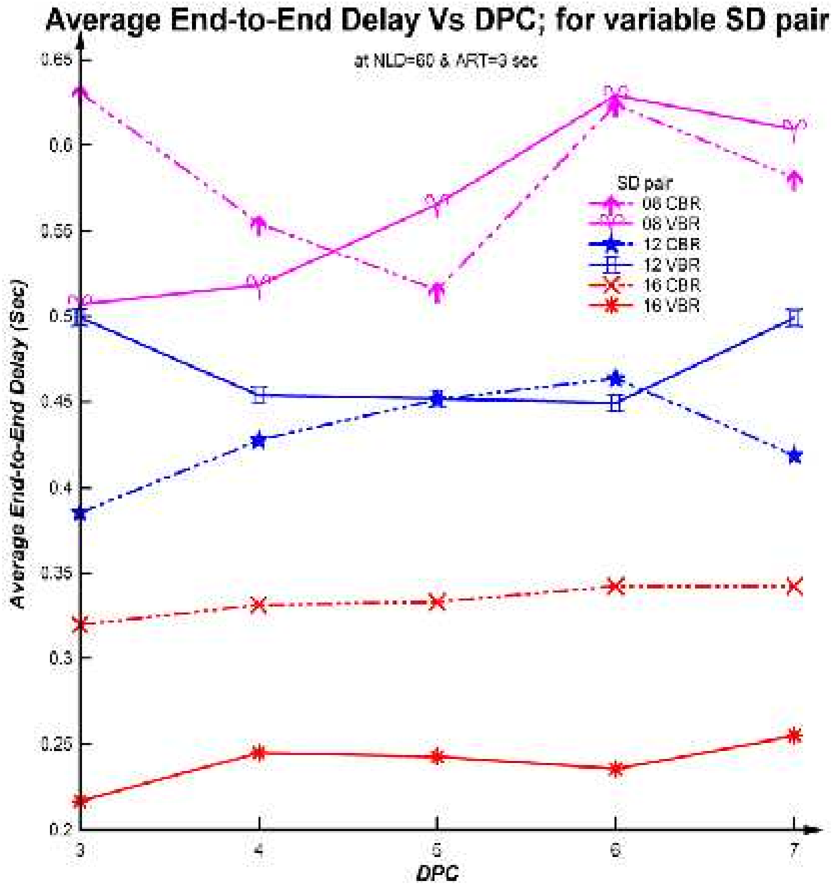

Figure 4.10: Average end-to-end delay Vs DPC; for variable SD pair (CBR & VBR)

4.4.2.3 Graphical Analysis of Average Jitter for CBR & VBR Traffic

In this sub-section, the average jitter for CBR & VBR traffic generators has been discussed in figure (4.11), and a jitter graph has been plotted for variable SD with DPC on the X-axis and average jitter on Y-axis.

From the figure, it can be seen, for 8 SD pair both traffic generators give almost same jitter, and these jitter values are almost constant throughout the range of DPC (i.e. in terms of average jitter, the same performance is observed for both traffic generators at lower SD pair). Moreover, lower SD pair acquires the minimum jitter than other SD pairs (12 & 16). As the SD pair increases, the performance in terms of jitter becomes worst in both traffic generators. The reason for the poor performance may be the increase in traffic congestion with an increase in SD pair, which leads the more frequent route breakage in the network. It may also be observed that overall CBR traffic has outperformed than VBR traffic in all the cases of SD pairs. Here, the reason is same as like in the case of throughput and average end-to-end delay.

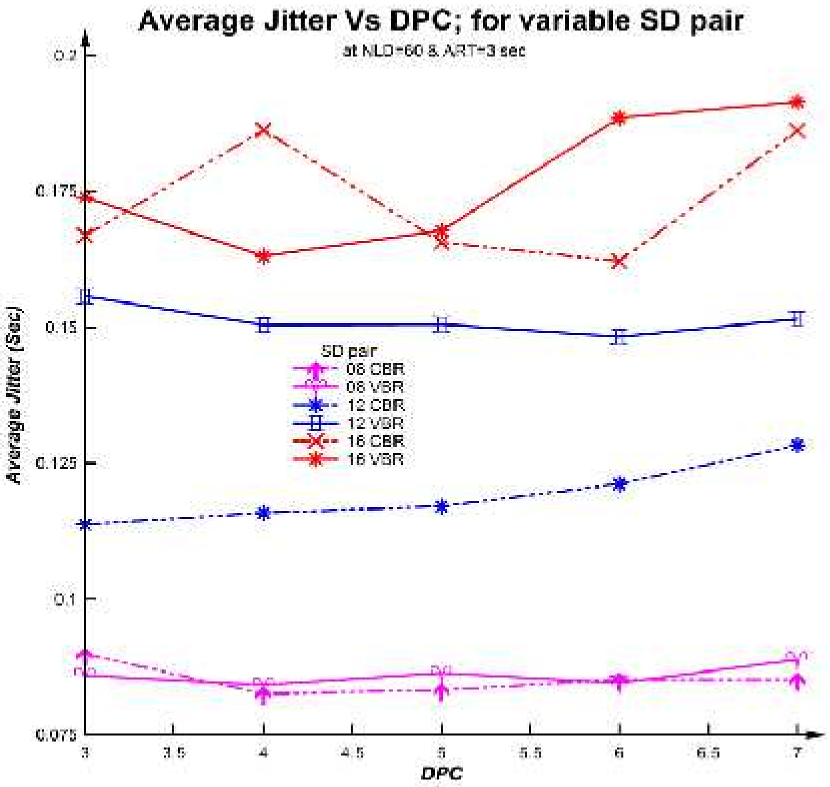

Figure 4.11: Average jitter Vs DPC; for variable SD pair (CBR & VBR)

4.5 Conclusion

Here, the performance of the AODV routing protocol based network has been analyzed and compared to CBR & VBR traffic generators by considering the route maintenance parameters. For the analysis and comparison study, the value of the route maintenance parameters has significantly been varied from their default value. Basically, this chapter tries to get an optimal relation between traffic generators (CBR

& VBR) and route maintenance parameters (ART & DPC) in which network performs well (i.e. gives the stable routing). Since in real time applications, most of the time, traffic is variable. Hence, it is indispensable to conduct the simulation-based comparison study between CBR and VBR traffic generators in order to observe the differences.

This chapter conducts two different simulation studies: one is for variable ART at fixed “NLD & SD pair” and the second one is for variable SD pair at fixed “NLD & ART” for both traffic generators in order to have better understanding of the network behavior. The main reason to do the first simulation study is to determine how the AODV behavior changes in the varying ART environment under different traffic generators that have been discussed in depth in the section (4.4.1). The curve ART=1 at DPC=6 gives the best performance in terms of QoS metrics for VBR traffic, whereas in the case of CBR traffic best performance is observed by the curve ART=3 at DPC=3 (i.e. best one is at the default value of ART). Hence, it can be stated that whenever traffic is variable, there is no need to hold route state information for a longer time because it creates more memory overheads. While for constant traffic, the value of ART is suggested at near about its default value. In CBR traffic, for ART<3, the worst performance is noticed because of the new route discovery process while a valid route is still there. In addition, again for ART>3, the poor performance is experienced in the network due to the packets sent to an invalid route. Hence, initiation of the RERR message instead of a new route discovery process takes place. Moreover, it can also be concluded that almost for all QoS metrics overall CBR performance is better than VBR. The reason for the poor performance of VBR may be due to the variable nature of traffic where each time synchronization is needed between the particular source and destination nodes.

The second simulation study that has been talked about in the section (4.4.2) concludes that the network performance increases with an increase in the SD pair in terms of throughput and average end-to-end delay for both traffic generators. It may be due to the enhancement in generating the data packets from the client and the route discovery process becomes easier with an increase in SD pair, respectively. However, it is expected that after a particular increase in the SD pair (like more than 50 % of total NLD), the performance will start to decrease because of a large number of control overhead packets in the network in a given area (i.e. network size is constant here). Whereas in the case of jitter, the performance decreases with an increase in the SD pair because it leads frequent link breakage in the network. Moreover, this section also concludes that the overall CBR has outperformed than VBR almost for all SD pairs. It might be possible because this simulation study has been conducted at the default value of ART, and CBR traffic performs better at near the default value of ART. Moreover, the requirement of synchronization may also be a reason for the poor performance of VBR traffic.

From the above discussion, it is suggested that the choice of the default value of ART and DPC depends on the type of traffic generators (i.e. their default values are application dependent). And, of course, the selection of their proper default values according to the applications may greatly increase the network performance (i.e. may provide stable routing). Moreover, also in this way the memory overheads can be reduced.

As the combined study between the various determining factors and route maintenance parameters has not been carried out yet. Therefore, in chapter 5, an attempt is made to analyze how AODV routing performance is influenced, when various determining factors like mobility, transmission range, NLD and ANs/SD pairs are taken into account along with the route maintenance parameters.