CHAPTER 3

ART & DPC ON THE PERFORMANCE OF AODV ROUTING FOR CBR TRAFFIC GENERATOR BY USING NS-3 & QUALNET

3.1 Introduction and Objective

As it is obvious from the section (1.4.6); state of the art (SOTA), most of the time researchers' concern is mobility of nodes, total number of nodes within the network area, and size of the network etc while few have also considered ART for the study of ad-hoc networks but not chosen DPC. Therefore, this chapter is showing its interest in analyzing how the performance of the AODV routing protocol is influenced by variation in the route maintenance (ART and DPC) parameters from its default value. Here, the CBR traffic generator has been provided among mobile nodes. In this chapter, the two different simulation studies have been conducted under different simulation tool in order to have the substantial understanding of the network behavior in AODV routing. The first one is by using NS-3 and the second one uses QualNet.

3.2 AODV Performance Observation for Constant Scenario by using NS-3

Here, the ability of AODV routing protocol reaction is tested on the random waypoint topology for a constant scenario by using NS-3. It is subjected to AODV routing performance with IEEE 802.11 MAC protocol for a fixed number of nodes. Here, in order to measure the performance of AODV routing protocol, two different QoS parameters are considered that are net throughput and Packet Delivery Ratio (PDR). From the results, it is evident that the performance of ad-hoc network varies with the change in route maintenance parameters. The simulation overview, simulation environment and simulation results are discussed in further sections. Two publications based on this part of thesis work are as follows:

- **Sachin Kumar Gupta**, Rohit Sharma and R.K. Saket, "Effect of variation in active route timeout and delete period constant on the performance of AODV protocol," *International Journal of Mobile Communications (IJMC), Inderscience publishers, 2014*, 12(2), 177-191, **(SSCI, IF = 1.221) (Citations = 4).**
- **Sachin Kumar Gupta**, Rohit Sharma, R.K. Saket and Ravi Prakash Diwedi, **"**Simulation and analysis of reactive protocol around default values of route maintenance parameters via NS-3," *International Conference on Information Systems and Computer Networks (ISCON),* **IEEE**, Mathura, India, Mar 2013, 155-160.

3.2.1 Simulation Overview

The open-source network simulation tool called network simulator-3 (NS-3) has been used to study and analyze the AODV routing protocol performance. This simulation study is mainly interested to get the net throughput & PDR for different values of ART & DPC and compare it with its default value. Here, the simulation environment has been conducted with the LINUX operating system. The whole simulation study is divided into two parts, one is to create the nodes (that may be a cell phone, internet or any other device) that is a NS-3 output. It is called Network Animator (NetAnim) which shows the movement of nodes and the communication between various nodes at different conditions. In other words, it can be said that the Newtonian allows the user to visualize the movement as well as the interaction of mobile nodes. The second part is a graphical analysis of trace (.tr) file. Trace files contain the traced events that can be further processed to understand the performance of the network.

Figure (3.1) depicts the overall process of how a network simulation is conducted under NS-3. The output files such as trace files have to be parsed to extract useful information. The parsing can be done using the *awk* command (in UNIX and LINUX, it is necessary to use gwak for the windows environment) or P*erl* script. The results can be analyzed using Matlab or D-plot.

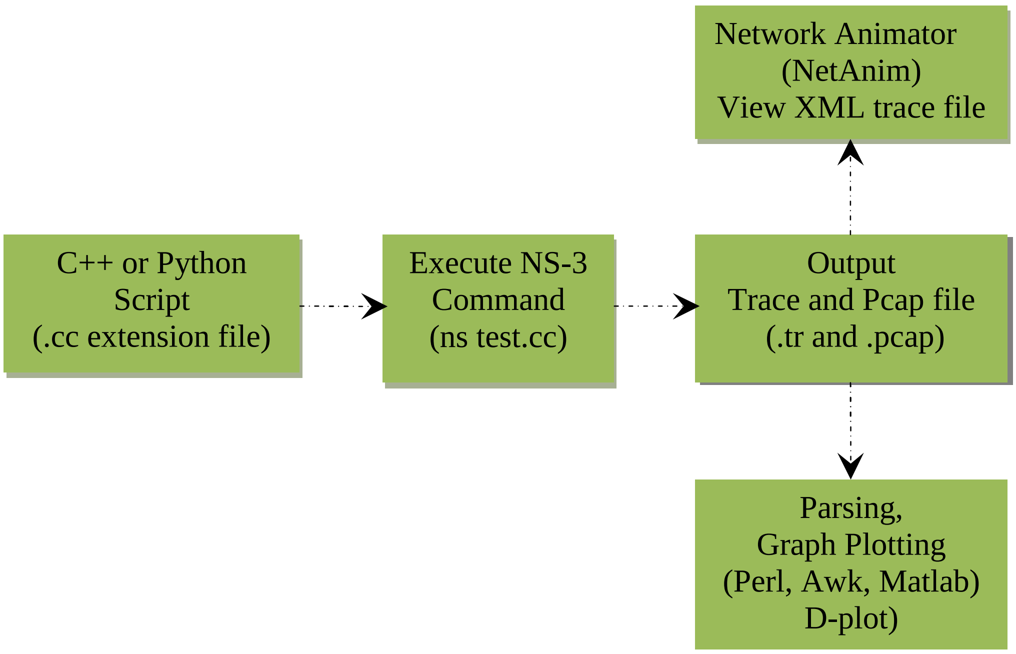


Figure 3.1: Overview of simulation under NS-3

3.2.2 Simulation Environment

The various parameters for simulation environment have been considered as per table (3.1). Here, the ART is taken as the values 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 6.0, 8.0, 10.0 (in sec) and for each value of ART, the value of DPC is taken as 3, 4, 5, 6, 7.

3.2.2.1 Scenario

- Topology of 1000*1000 meters is taken for simulation.
- Nodes are being generated randomly at random position.
- Nodes are generated at random time as if few nodes are entering into the topology.

- Nodes are moving at constant random speed between 1 m/s to 10 m/s due to Random Waypoint Model.
- Antenna model used is Omni Antenna.

3.2.2.2 Node Characteristics

- Link_Layer_Type: Logical_Link (LL)
- MAC_Type: 802_11
- Queue_Type: Drop_Tail
- Network_Interface_Type: Wireless
- Channel_Type: Wireless

Table 3.1: Simulation parameters

Parameter	**Value**
Routing_Protocol	AODV
Active_Route_Timeout (ART)	3 s (default)
Delete_Period_Constant (DPC)	5 (default)
Packet_Reception_Model	PHY802.11b
Channel_Bandwidth	11 Mbps
Terrain Size	1000 m X 1000 m
Number of Nodes	50
Node Placement	Random
Mobility Model	Random waypoint
Maximum Propagation Distance	200 m
Node Speed	1.0 m/s – 10.0 m/s
Node Pause	1 s
Data Payload	512 Bytes/packet
Packet Inter-Arrival Time	0.25 s or 4 Packets/s

Data Rate	2KBps
No. of Source/Sink	10
Transmission Power	7.5 dbm
Simulation Time	200 s

3.2.3 Simulation Results

While changing the ART & DPC route maintenance parameters and running the simulation upto 200 seconds, different values of net throughput & PDR are generated as the .cc file in NS-3 that are listed in the table (3.2).

Table 3.2: Values of net throughput & PDR for different values of ART & DPC

ART	DPC	Net Throughput	PDR
0.5	3	10.13504	0.494875
0.5	4	11.09504	0.54175
0.5	5	12.40064	0.6055
0.5	6	10.54464	0.514875
0.5	7	11.26912	0.55025
1.0	3	10.13504	0.494875
1.0	4	11.09504	0.54175
1.0	5	12.40064	0.6055
1.0	6	10.54464	0.514875
1.0	7	11.26912	0.55025
1.5	3	11.8912	0.580625
1.5	4	10.54464	0.514875
1.5	5	11.56096	0.5645
1.5	6	11.1616	0.545

1.5	7	9.62816	0.470125
2.0	3	10.54464	0.514875
2.0	4	11.06944	0.5405
2.0	5	10.46528	0.511
2.0	6	12.7872	0.624375
2.0	7	6.49472	0.317125
2.5	3	11.56096	0.5645
2.5	4	10.46528	0.511
2.5	5	13.39136	0.653875
2.5	6	11.7504	0.57375
2.5	7	11.33312	0.553375
3.0	3	11.1616	0.545
3.0	4	12.7872	0.624375
3.0	5	11.7504	0.57375
3.0	6	11.74272	0.573375
3.0	7	10.81856	0.52825
4.0	3	12.7872	0.624375
4.0	4	11.5072	0.561875
4.0	5	11.20768	0.54725
4.0	6	11.07968	0.541
4.0	7	10.07872	0.492125
6.0	3	12.7872	0.573375
6.0	4	11.5072	0.541
6.0	5	11.20768	0.294875
6.0	6	11.07968	0.544125

6.0	7	10.07872	0.51825
8.0	3	11.07968	0.541
8.0	4	10.81344	0.528
8.0	5	10.0736	0.491875
8.0	6	10.304	0.503125
8.0	7	11.23328	0.5485
10.0	3	6.03904	0.294875
10.0	4	10.0736	0.491875
10.0	5	9.8432	0.480625
10.0	6	10.75456	0.525125
10.0	7	10.84416	0.5295

3.2.3.1 Graphical Analysis of Net Throughput

Here, graphs have been plotted using D-plot for each ART value with DPC (as shown in table (3.2)) on the X-axis and net throughput on Y-axis. Net throughput indicates the rate of communication per unit time. It is the ratio between the number of packets sent and number of packets received in particular given time.

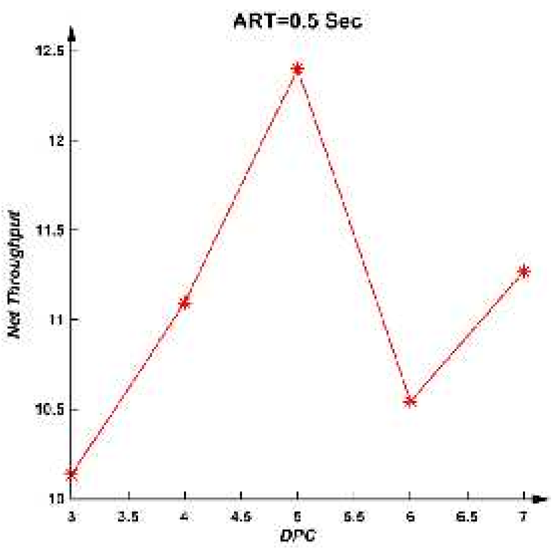


Figure 3.2: Net Throughput for ART=0.5

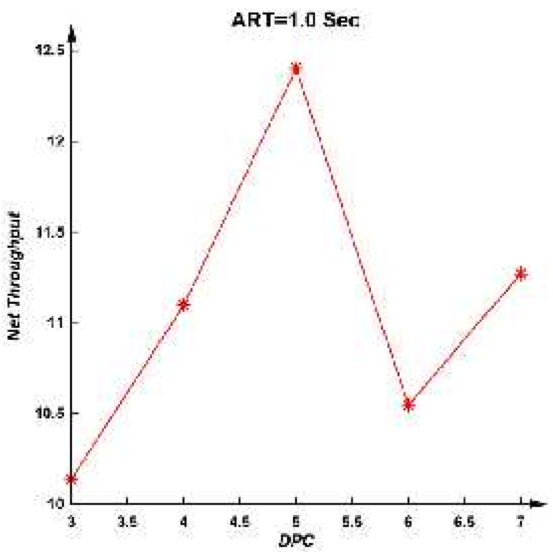


Figure 3.3: Net Throughput for ART=1.0

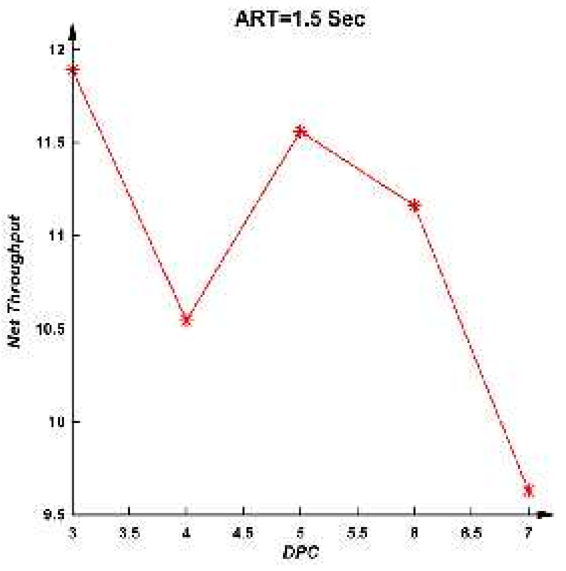


Figure 3.4: Net Throughput for ART=1.5

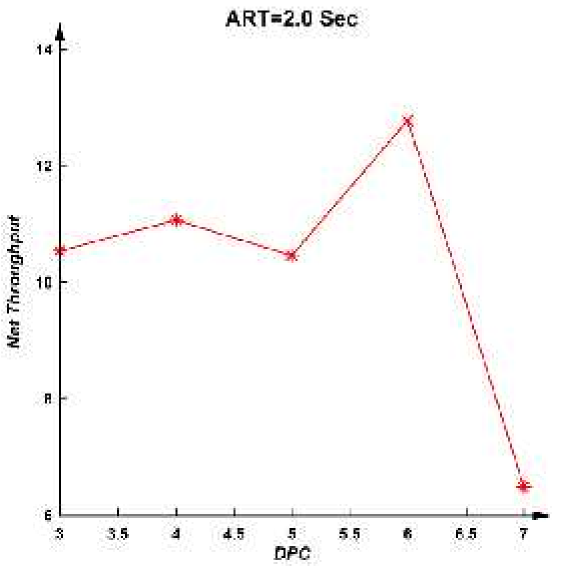


Figure 3.5: Net Throughput for ART=2.0

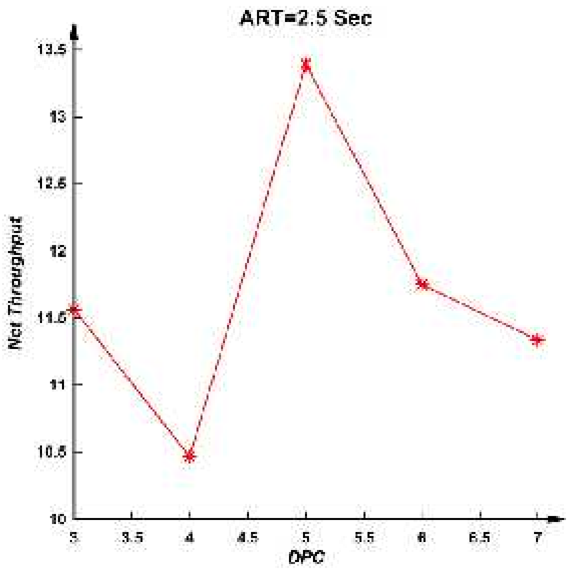


Figure 3.6: Net Throughput for ART=2.5

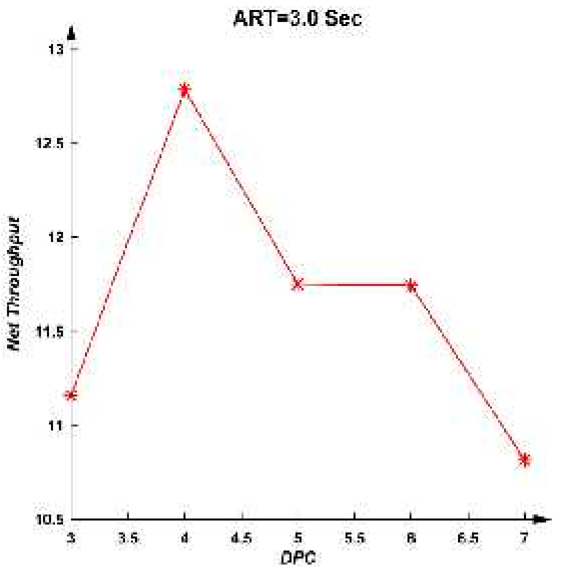
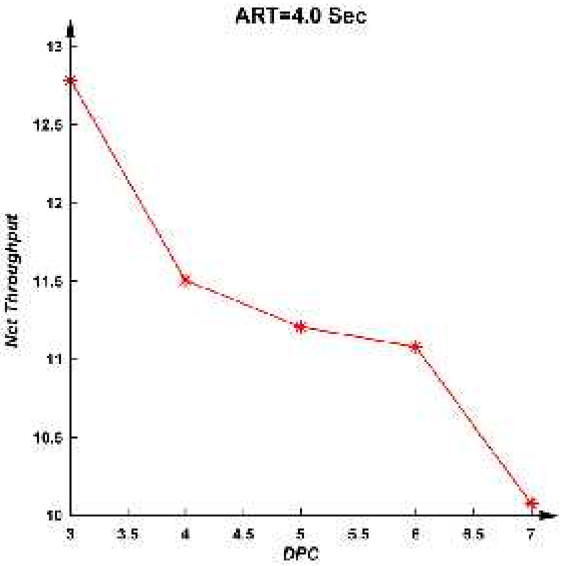


Figure 3.7: Net Throughput for ART=3.0



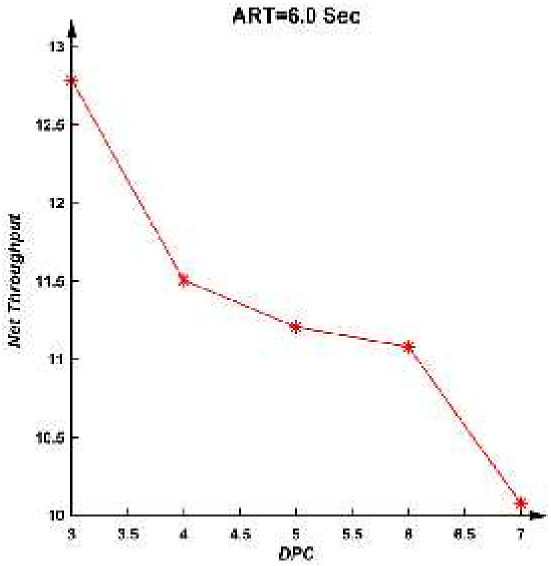
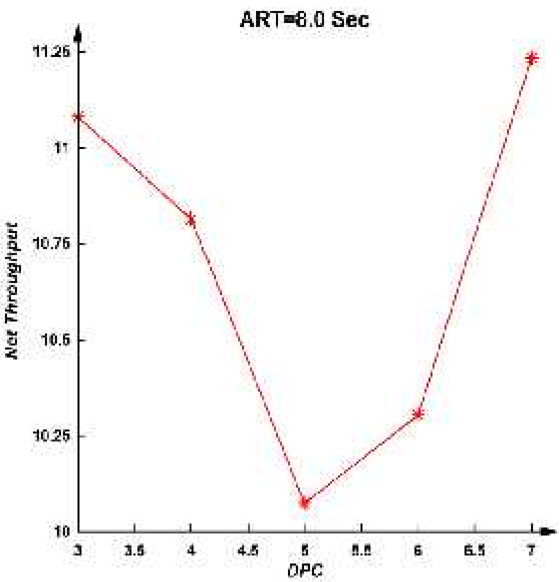


Figure 3.8: Net Throughput for ART=4.0   *Figure 3.9: Net Throughput for ART=6.0*



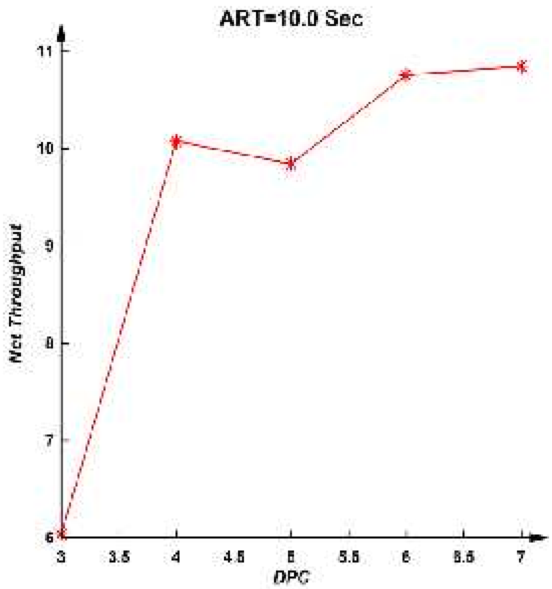


Figure 3.10: Net Throughput for ART=8.0   *Figure 3.11: Net Throughput for ART=10.0*

3.2.3.2 Graphical Analysis of PDR

Again, the graphs have been plotted using D-plot for each value of ART with DPC (as shown in table (3.2)) on the X-axis and PDR on Y-axis. PDR is the ratio of the total packets received by destination node to the total packets sent by the source node. The better PDR provides more absolute and accurate routing protocol.

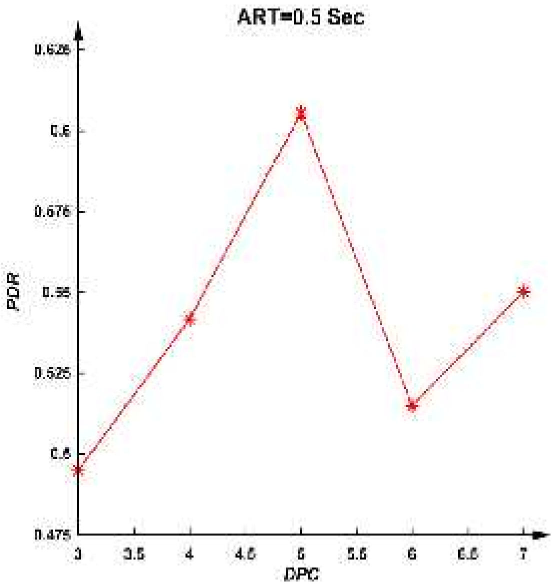


Figure 3.12: PDR for ART=0.5

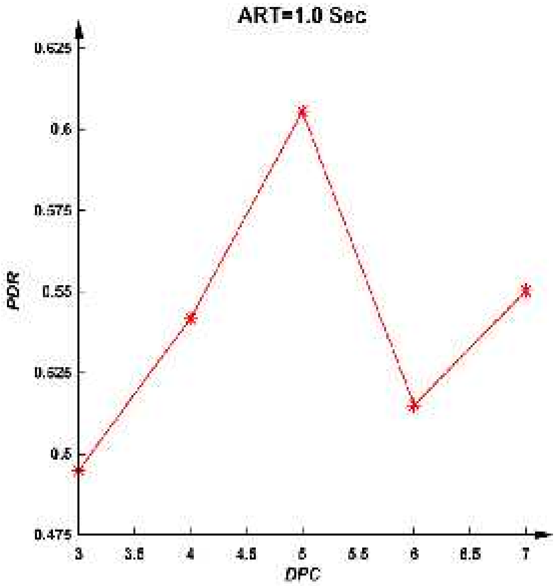


Figure 3.13: PDR for ART=1.0

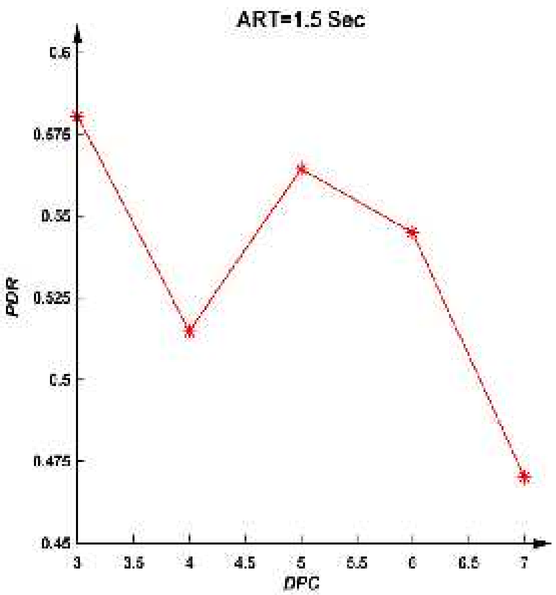


Figure 3.14: PDR for ART=1.5

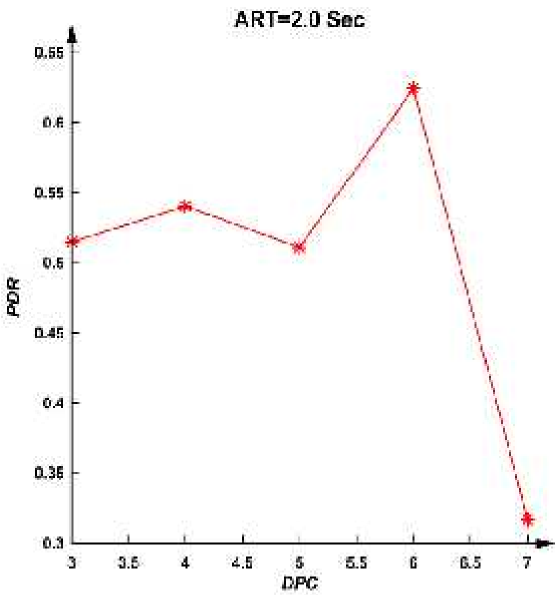


Figure 3.15: PDR for ART=2.0

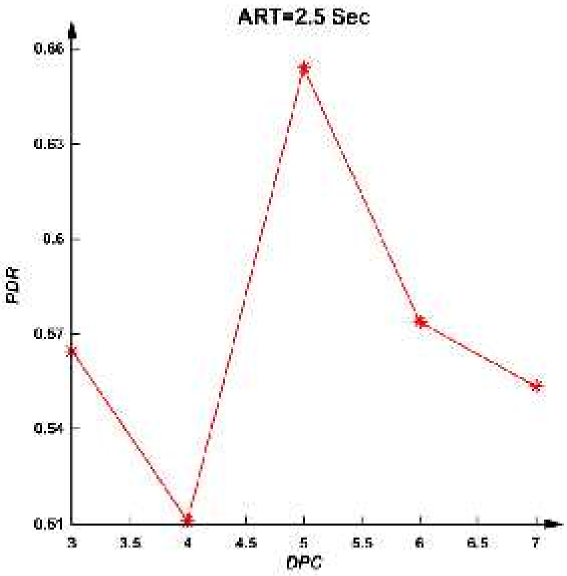


Figure 3.16: PDR for ART=2.5

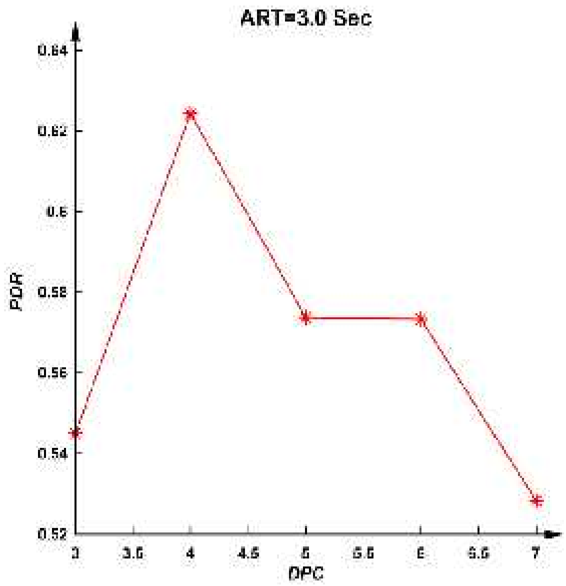


Figure 3.17: PDR for ART=3.0

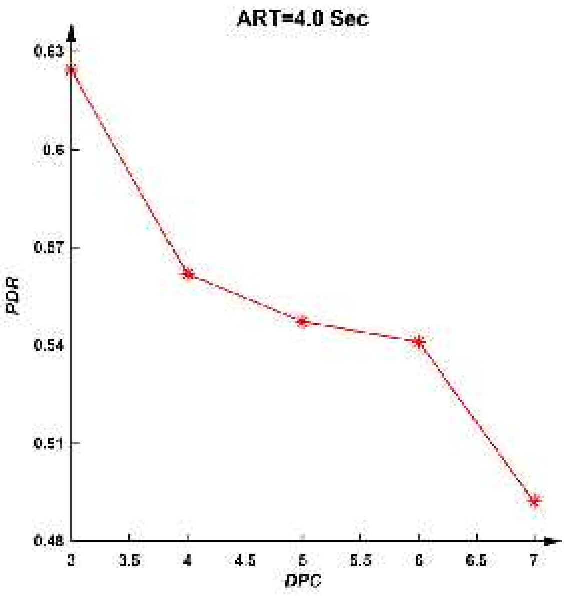


Figure 3.18: PDR for ART=4.0

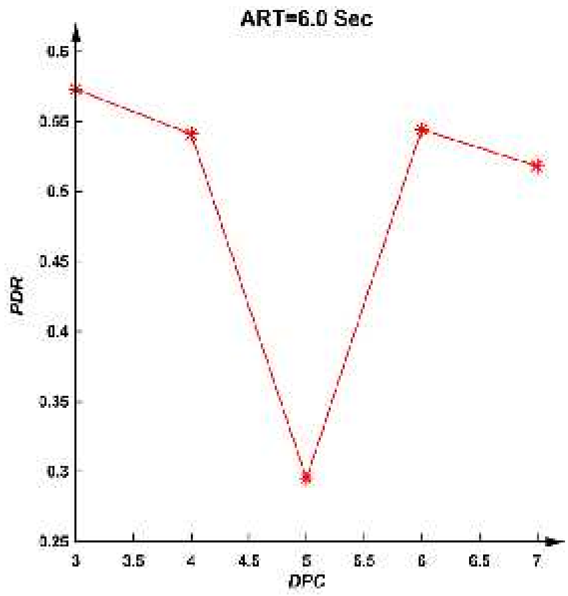
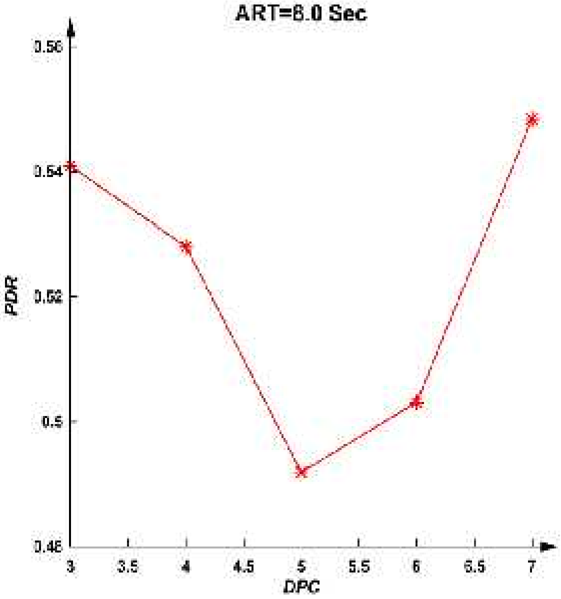


Figure 3.19: PDR for ART=6.0



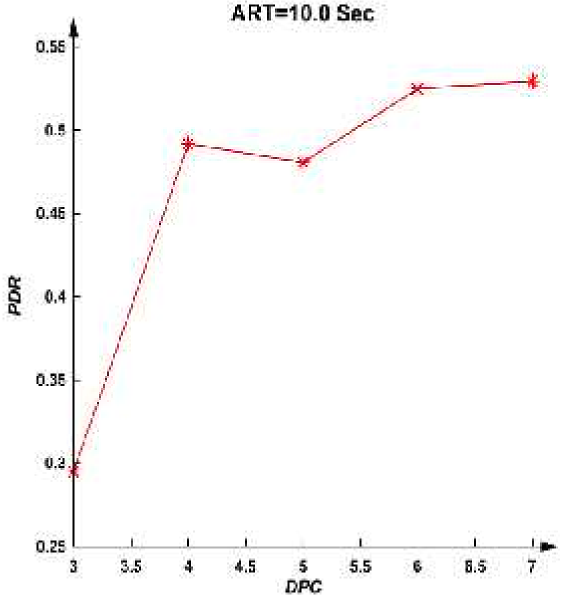


Figure 3.20: PDR for ART=8.0

Figure 3.21: PDR for ART=10.0

3.2.3.3 Analysis of Net Throughput and PDR for each ART

The analysis of these graphs as mentioned above (in section 3.2.3.1 & section 3.2.3.2) for net throughput and PDR is explained for each value of ART in the table (3.3).

Table 3.3: Observation & conclusion for net throughput & PDR for each ART value

ART Value (Sec)	Observation and Conclusion	Remarks
0.5 & 1.0	Network performs best at DPC=5 and for DPC<5, performance is increased. For DPC=6, it is decreased and again for DPC=7, it increases slightly as shown in figures (3.2) & (3.12). According to the formula of DP (section 2.6); for ART≤1, the network is governed by	The best performance is at DPC =5, Maximum PDR=0.6055 &

	hello interval (which is = 1 sec). So, DP is independent of ART and hence the plotted graphs are same for ART=1 & 0.5, as shown in figures (3.2), (3.3), (3.12), and (3.13). The reason of this poor performance for DPC<5 can be the unavailability of routes for the successful transmission of messages. For DPC>5, the performance degrades due to memory occupation by route table for a longer time thus creating more overheads.	Maximum Net Throughput = 12.40064
1.5, 2.0 & 2.5	For ART=1.5, the performance degrades up to a certain minimum value and then the performance increases as shown in figures (3.4) & (3.14). This behavior can be attributed to the fact that an increase in DPC can cause increase in overheads and hence the successful packet delivery decreases. But after a certain value the increase in DPC caused availability of alternate route despite the increase in overheads and hence the performance increased. For ART=2.0, the performance degrades as there is an increment of 'DPC' from 6 to 7 as shown in figures (3.5) & (3.15). This is due to the fact that the amount of overheads generated during this transition far exceeds the number of alternative routes available and hence the performance degrades sharply. For ART=2.5 at DPC=5 there is a local maxima i.e., in the immediate vicinity of DPC=5, the performance is	'ART' & 'DPC' combination for best Performance is 2.5 & 5.0, respectively. Maximum PDR = 0.65387, & Maximum Net Throughput = 13.39136

	best at DPC=5 as shown in figures (3.6) & (3.16). This clearly explains why DPC=5 is taken as default value. The rest of the graph show abrupt behavior, but commonality comes at DPC=5.	
3.0 & 4.0	These graphs show a monotonous decreasing behavior in the vicinity of the default value of DPC. The default value of ART is 3 & DPC is 5 but as we observed from the graph network performance is high if we take DPC=4 as shown in figures (3.7) & (3.17). This directly signifies that overheads at DPC=5 are more than overheads at DPC=4 but default values are taken so as to optimise performance in every aspect and hence it is taken as DPC=5 and ART=3. So, if we have to design a network in which performance is measured only on the basis of net throughput or PDR, then we can go for reducing the value of DPC in order to increase the performance.	'ART' & 'DPC' combination for best performance is 3.0 & 4.0, respectively. Maximum PDR=0.624375, & Maximum Net Throughput = 12.7872
6.0, 8.0 & 10.0	These graphs were plotted with the sole aim of studying the effect of abrupt change in ART as shown in figures (3.9), (3.10), (3.11), (3.19), (3.20) & (3.21). These graphs show a quite variation in the performance, as DPC is increased with the characteristic that the graph shows minima at DPC=5. Thus, it gives totally opposite result for AODV which is optimized for DPC=5. Hence, these abrupt changes in ART cause change in the	'ART' & 'DPC' combination for best performance is 6.0 & 3.0, respectively. Maximum PDR = 0.57337,

	behavior of AODV.	& Maximum Net Throughput = 12.7872

3.3 Conclusion

Here, the performance analysis of AODV protocol has been done by varying route maintenance parameters. ART & DPC are varied and the effect of variations on net throughput & PDR has been analysed graphically. The default value of ART & DPC is 3 seconds & 5, respectively. This analysis is initiated with a narrow range of ART (2, 3, 4) & DPC (4, 5, 6) and found that for ART=3 & 4, the net throughput {figures (3.7) & (3.8)} and PDR {figures (3.17) & (3.18)} decreases monotonously but for ART=2 seconds {figures (3.5) & (3.15)}, it has a local minima.

Therefore, the analysis is extended into the region around ART=2 to observe this deep phenomenon very closely. Now, the ART values are extended too far away from its default value in order to observe the effect of abrupt changing of ART on the network. Analysis has also been done for the different values of DPC just to observe network behavior as we go far from the default value of DPC.

So from this analysis, it is clear that if there is a change in the parameters far away from their default value, the performance becomes abrupt. Furthermore, even if one parameter is kept constant and another parameter is varied quite away from the default value, the network acted oppositely at the default value.

However, if the result is taken for network performance only on net throughput or PDR, the maximum performance of AODV is found for ‘ART’ & ‘DPC’ combination of 2.5 & 5.0, respectively, as shown in table (3.2) and figures (3.6) and (3.16).

The original default value of ART has been taken at 3 seconds in AODV algorithm developed by C. Perkins. Here, in this scenario, it is observed ART as 2.5 seconds for maximum performances. So, it is clear that as per this analysis ART value is 0.5 second less than the original default value, which results in less memory overheads.

3.4 AODV Performance Observation for Different SD Pair by using QUALNET

In this section, the performance of the AODV routing protocol has been tested under random waypoint topology for a constant scenario, but for different SD pairs and by using the QualNet simulation tool. Again, AODV routing performance is subjected to IEEE 802.11 MAC protocol for a fixed number of nodes. This section is mainly interested to observe the routing protocol performance by varying ART and DPC on four different QoS parameters that are throughput, average end-to-end delay, average jitter and percentage (%) of loss/drop packet. Again, the pictorial representation of analytical data for performance metrics is based on D-Plot. The simulation environment and simulation results are discussed in further sections. Based on this section one publication is there;

- **Sachin Kumar Gupta** and R.K. Saket, "Impact of ART and DPC in AODV Routing of MANET Environment," *Pensee Journal Paris, France*, 2014, 76(9), 408-423.

3.4.1 Simulation Environment

The various parameters at different layers of network that are used during this simulation study have been listed in the table (3.4). And, the default value of various route maintenance parameters of the AODV routing protocol is listed in table (2.1). In this case, the ART value is taken such as 0.5, 2.0, 3.0, 3.5 and 5.0 (in sec) and for each value of ART, the value of DPC is taken as 2, 3, 4, 5, 6, 7 and 8.

Table 3.4: Simulation parameters at different layers

Physical Layer	
Radio_Type	PHY802.11b
Antenna_Height	1.5m
Antenna_Efficiency	0.8
Antenna_Model	Omni directional
Path_Loss_Model	Two ray
No. of Channels	1 (2.4GHz) Ad-hoc mode
Channel_Bandwidth	11 Mbps
MAC Layer	
Mac_Protocol	802.11
Network Layer	
Subnet_Channel	Wireless
Network_Protocol	IPv4
Routing_Protocol	AODV
Application Layer	
Application	CBR
Packet_Size	512 Byte
Packet Inter-Arrival Time	0.05 s or 20 Packets/s
General Parameters for Scenario Creation	
Network Simulator (Version)	QualNet 7.1
Total Simulation Time	180 s
Terrain Size	1000 m X 1000 m
Number of Nodes	20
Number of SD pair	5, 7

Maximum Propagation Distance	200 m
Transmission Power	15 dbm
Node Placement	Randomly
Device Type	Human
Mobility Model	Random waypoint
Pause Time	30 s
Minimum Speed	0 m/s
Maximum Speed	10 m/s
Consider ART	0.5, 2, 3, 3.5, 5 (in sec)
Consider DPC	2, 3, 4, 5, 6, 7, 8

3.4.2 Simulation Results

While changing the value of ART & DPC for the created scenario and running the simulation upto 180 seconds, different values of throughput, average end-to-end delay, average jitter and percentage (%) of drop (loss) packet for 5 & 7 SD pair have been carried out by using QualNet that are listed in table (3.5). Moreover, the snapshots of X-Y & 3-D view under the wireless subnet for a simulation topology of 20 devices have been shown in figure (3.22) & (3.23), respectively.

Table 3.5: 5 and 7 SD pair; values of throughput, average end-to-end delay, average jitter, and loss packet for different values of ART & DPC

5 SD PAIR					
ART (Sec)	**DPC**	**Throughput (Bits/sec)**	**Average End_to_End Delay (Sec)**	**Average Jitter (Sec)**	**Loss Packet**
0.5	2	33512.424	0.16148608	0.012486452	0.662
0.5	3	34088.244	0.1411124	0.018812474	0.657833333
0.5	4	35028.484	0.22382158	0.012654648	0.646222222
0.5	5	35028.484	0.1224337	0.013568504	0.649833333

0.5	6	35028.484	0.22439908	0.01351513	0.654833333
0.5	7	35028.484	0.22439908	0.012610074	0.653277778
0.5	8	34363.604	0.13679374	0.013144484	0.653277778
2.0	2	34398.824	0.1772606	0.020477914	0.641166667
2.0	3	32824.524	0.11489818	0.016394226	0.640222222
2.0	4	33251.224	0.1180188	0.015624196	0.634777778
2.0	5	33969.524	0.10923432	0.015028788	0.635444444
2.0	6	33969.524	0.10923432	0.015028788	0.636333333
2.0	7	33981.804	0.10649812	0.014809334	0.638111111
2.0	8	33981.804	0.10649812	0.014809334	0.640222222
3.0	2	34320.164	0.10735736	0.020428186	0.653833333
3.0	3	34618.164	0.13986824	0.016910454	0.647833333
3.0	4	35720.167	0.16867828	0.017069634	0.631444444
3.0	5	35250.164	0.1777538	0.017069634	0.642555556
3.0	6	34856.724	0.1776604	0.012007194	0.642555556
3.0	7	34264.764	0.16762982	0.012007194	0.642555556
3.0	8	34197.664	0.16651358	0.013974814	0.649888889
3.5	2	35083.264	0.08350184	0.013298068	0.645944444
3.5	3	34121.544	0.16838086	0.016287452	0.647777778
3.5	4	34450.904	0.13842938	0.015429482	0.650666667
3.5	5	33703.964	0.16129694	0.015761208	0.643944444
3.5	6	33966.084	0.16089684	0.01626224	0.645055556
3.5	7	34015.644	0.1606927	0.016427454	0.649555556
3.5	8	34375.944	0.15956352	0.017943605	0.654888889
5.0	2	33163.684	0.194205	0.018240814	0.66
5.0	3	33058.264	0.19587864	0.018083034	0.654222222
5.0	4	32612.784	0.19631408	0.018517994	0.654788889
5.0	5	32650.744	0.19449734	0.017911294	0.652888889
5.0	6	33036.124	0.19999744	0.019049974	0.657777778

5.0	7	33219.283	0.18925728	0.09095297	0.659444444
5.0	8	33236.964	0.19225586	0.017974454	0.659777778

7 SD PAIR

ART (Sec)	DPC	Throughput (Bits/sec)	Average End_to_End Delay (Sec)	Average Jitter (Sec)	Loss Packet
0.5	2	43221.67143	0.136726343	0.025658657	0.549603175
0.5	3	43180.12857	0.219013714	0.027593443	0.547380953
0.5	4	41190.82857	0.103872271	0.022639571	0.555714286
0.5	5	40647.7	0.171004571	0.0276921	0.557023809
0.5	6	41962.84286	0.143261929	0.022395857	0.561904762
0.5	7	42873.1	0.1680994	0.024487086	0.561904762
0.5	8	42490.61429	0.1761994	0.023196614	0.573968254
2.0	2	42898.07143	0.177009129	0.023555586	0.549285714
2.0	3	43249.14286	0.148771086	0.022841871	0.548571429
2.0	4	43328.15714	0.091822571	0.020137986	0.547301587
2.0	5	42984.97143	0.123381514	0.019516327	0.549722222
2.0	6	41853.28571	0.098505214	0.020273514	0.562063492
2.0	7	42982.04286	0.095401557	0.019581029	0.549523809
2.0	8	42977.8	0.095622014	0.019709429	0.549563492
3.0	2	44277.55714	0.116998443	0.02196	0.565992064
3.0	3	44108.98571	0.117042771	0.023243229	0.549960318
3.0	4	44623.5523	0.086622229	0.017606014	0.54281746
3.0	5	44509.28571	0.128318486	0.022758857	0.540992064
3.0	6	44253.789	0.126548786	0.022872443	0.551428571
3.0	7	44131.594	0.134725414	0.023317886	0.550357143
3.0	8	43367.95714	0.131293443	0.022870943	0.553968254
3.5	2	41886.35714	0.222671886	0.026933971	0.556349206
3.5	3	42010.08571	0.1549979	0.023834014	0.551111111
3.5	4	42010.08571	0.1549979	0.023834014	0.550952381

3.5	5	42750.7	0.135977186	0.0233845	0.549523809
3.5	6	42271.11429	0.159566886	0.024832529	0.549484127
3.5	7	42874.25714	0.133879457	0.023284986	0.550138095
3.5	8	42207.38571	0.141573686	0.024321914	0.5499849206
5.0	2	41172.48571	0.162064414	0.022464471	0.560952381
5.0	3	41234.87143	0.159292614	0.022176114	0.557103175
5.0	4	40969.204	0.171300043	0.023140014	0.557103175
5.0	5	40872.97143	0.1820678	0.025787843	0.550277778
5.0	6	41342.768	0.181729286	0.0246292	0.554722222
5.0	7	41028.47143	0.138647614	0.022952586	0.548888889
5.0	8	41260.79	0.171436829	0.0257817	0.555753968

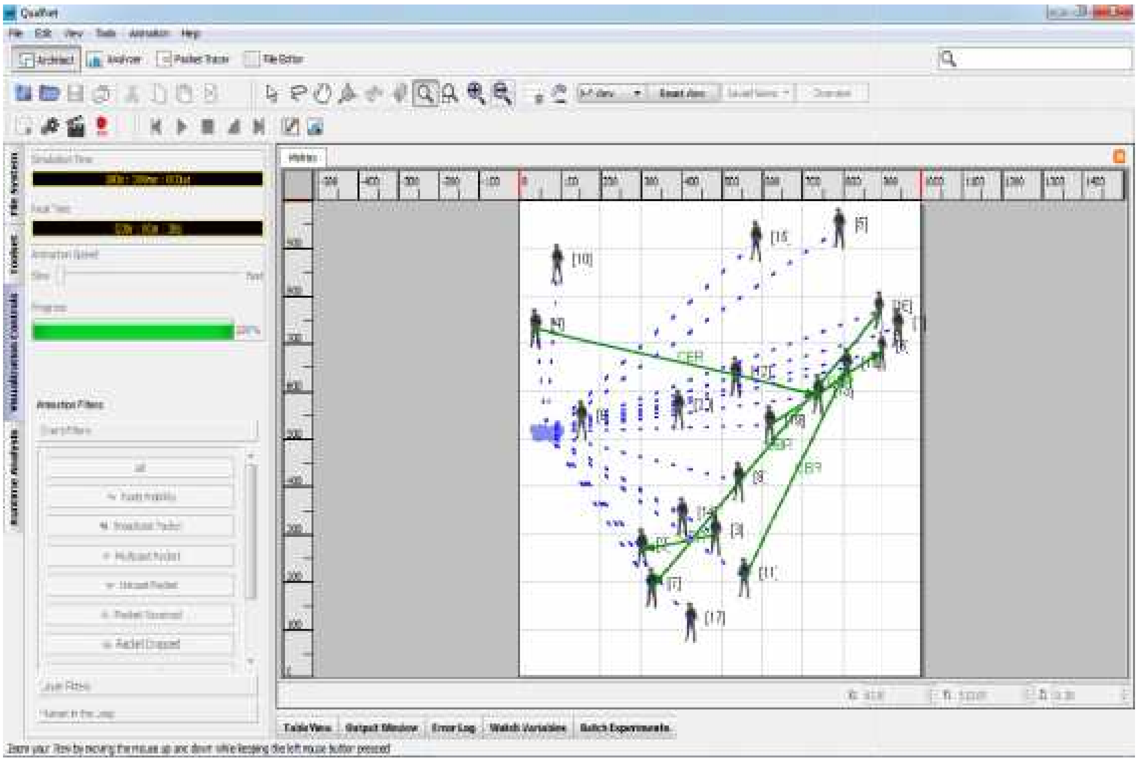


Figure 3.22: Snapshot of simulation topology for 20 human devices under wireless subnet (X-Y view)

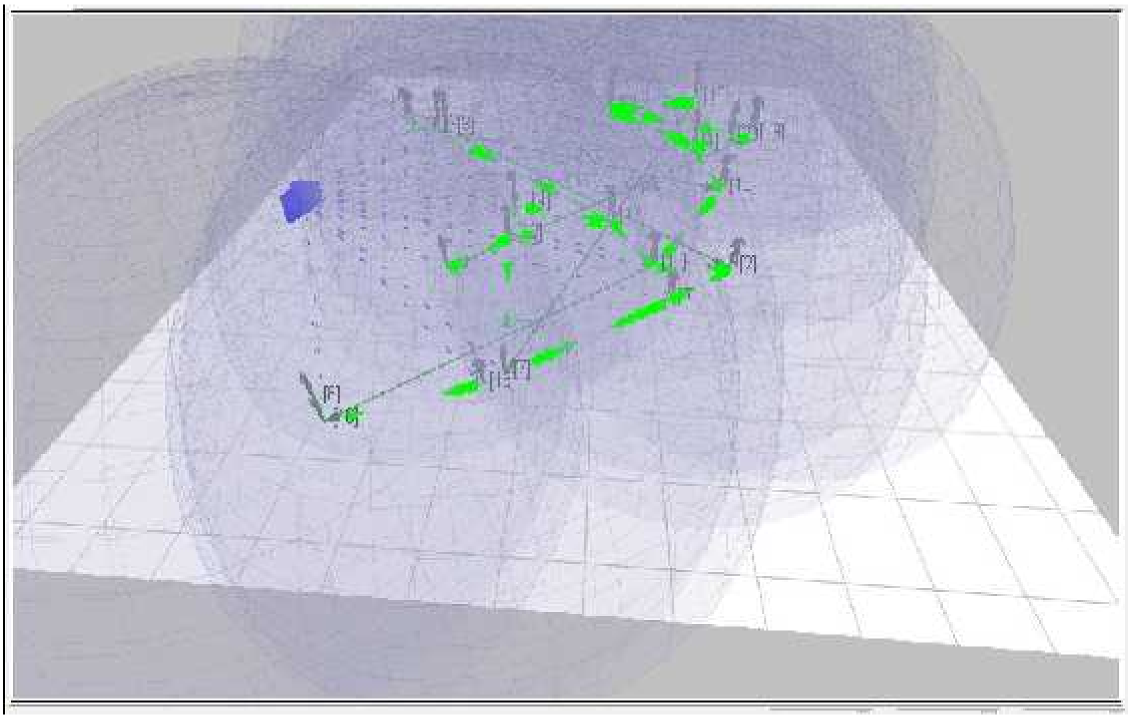


Figure 3.23: Snapshot of simulation topology for 20 human devices under wireless subnet (3-D view)

3.4.2.1 Graphical Analysis of Throughput

This sub-section shows the throughput graphs that have been plotted for each ART value with DPC (as shown in table (3.5)) on the X-axis and throughput on Y-axis.

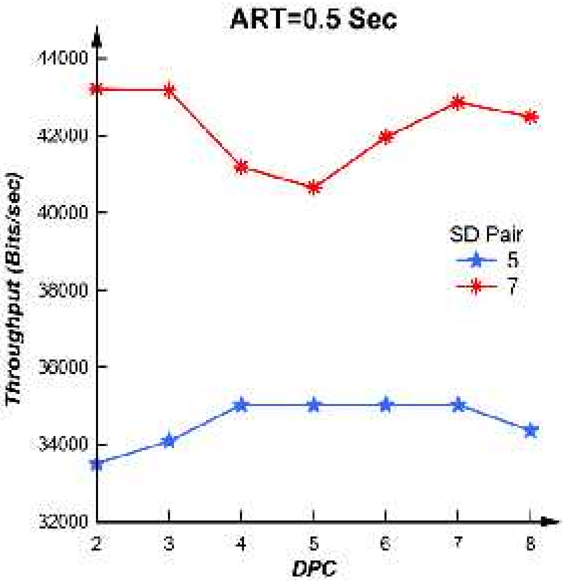


Figure 3.24: Throughput for ART=0.5

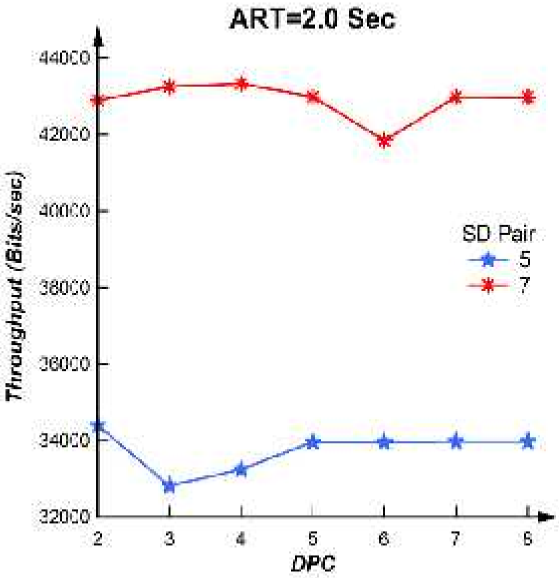


Figure 3.25: Throughput for ART=2.0

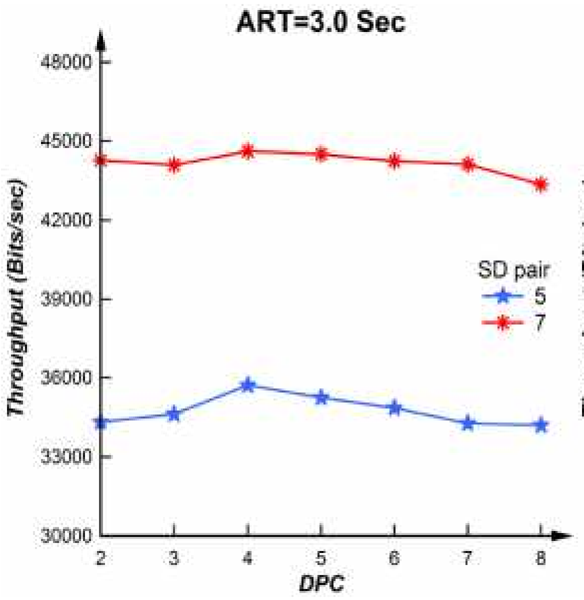


Figure 3.26: Throughput for ART=3.0

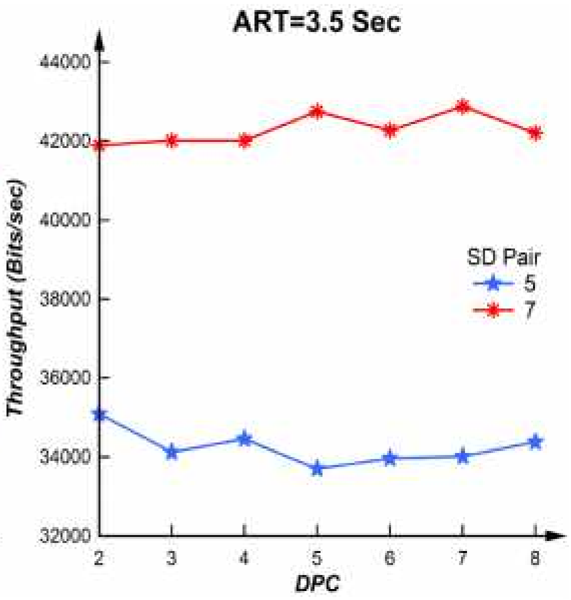


Figure 3.27: Throughput for ART=3.5

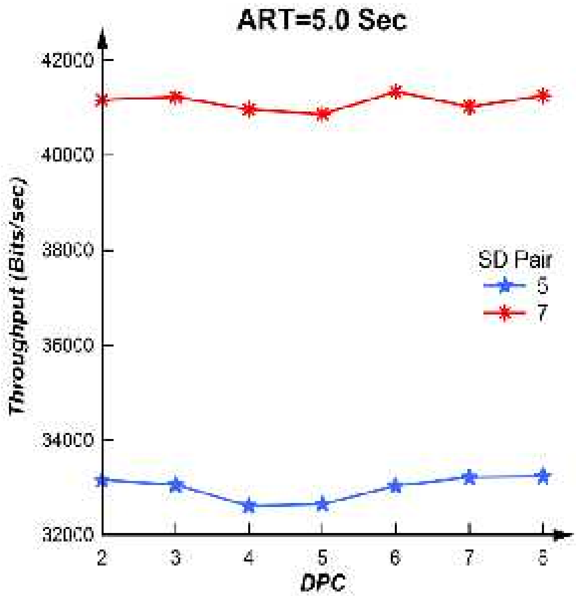


Figure 3.28: Throughput for ART=5.0

3.4.2.2 Graphical Analysis of Average End-to-End Delay

In this sub-section, graphs for the average end-to-end delay have been plotted for each ART value with DPC (as shown in table (3.5)) on the X-axis and average end-to-end delay on Y-axis. It is the average time taken by the packets to reach the destination point.

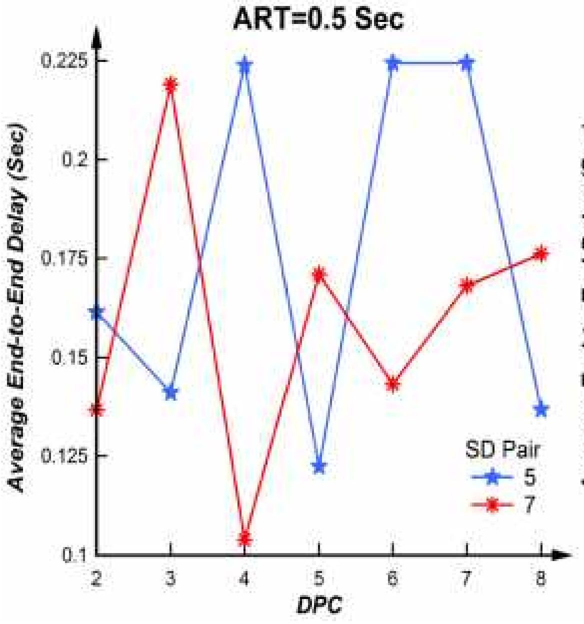


Figure 3.29: Average Delay for ART=0.5

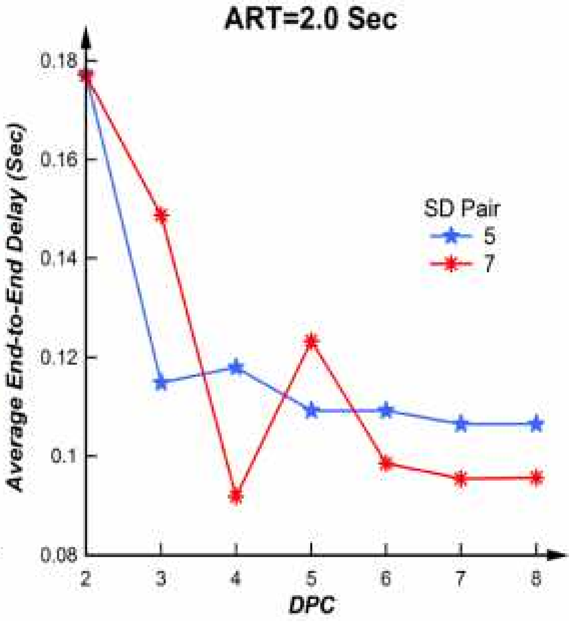


Figure 3.30: Average Delay for ART=2.0

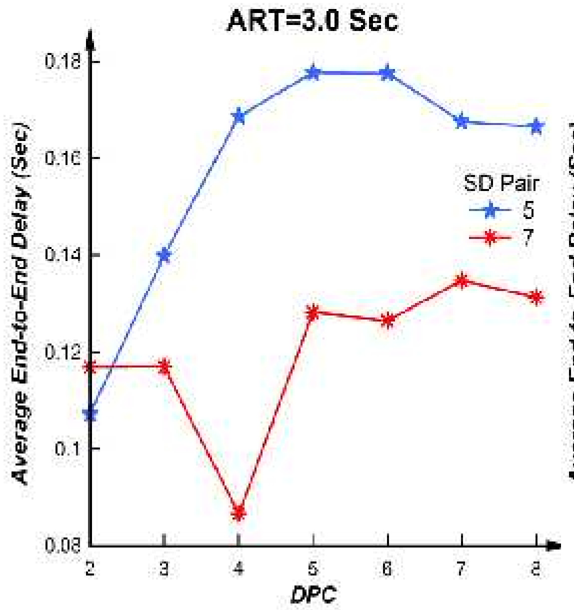


Figure 3.31: Average Delay for ART=3.0

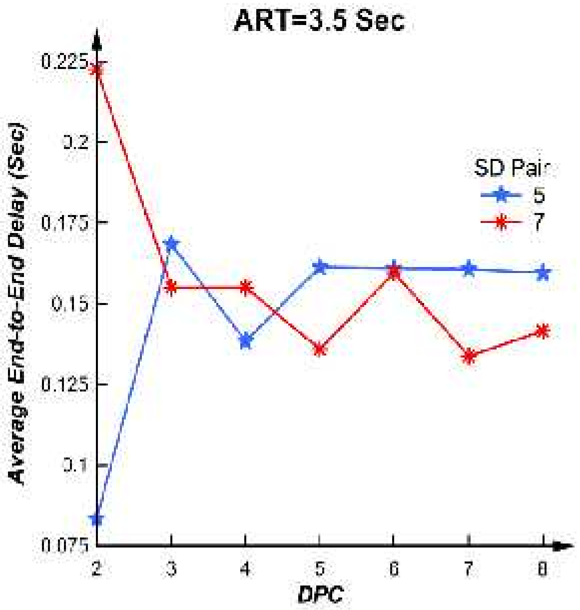


Figure 3.32: Average Delay for ART=3.5

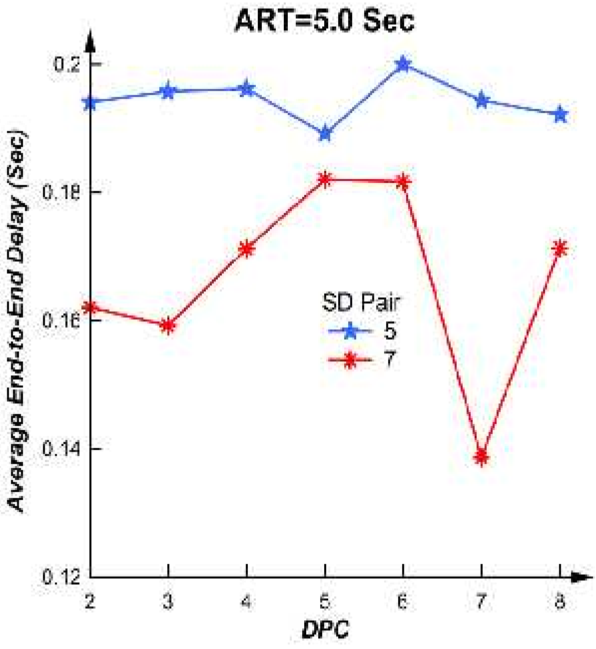


Figure 3.33: Average Delay for ART=5.0

3.4.2.3 Graphical Analysis of Average Jitter

Here, graphs have been plotted for each ART value with DPC (as shown in table (3.5)) on the X-axis and average jitter on Y-axis. Actually, it is the average displacement or variation in the time between packets arriving at the receiving point.

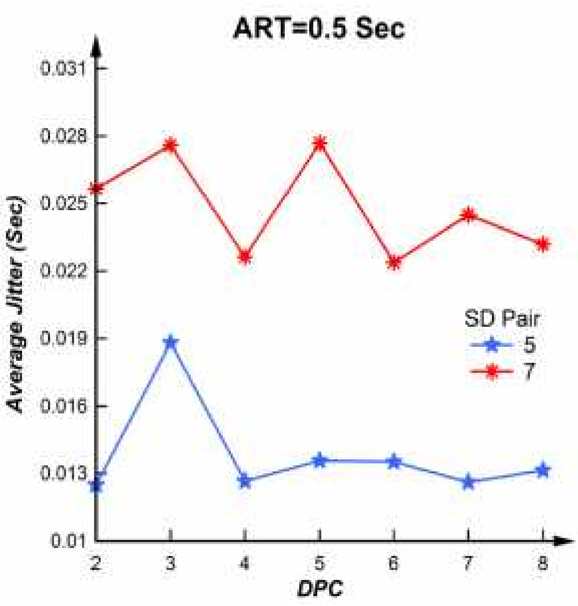


Figure 3.34: Average Jitter for ART=0.5

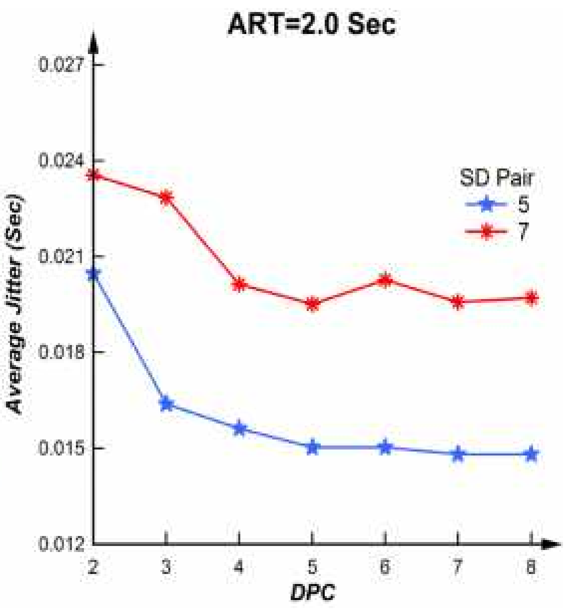


Figure 3.35: Average Jitter for ART=2.0

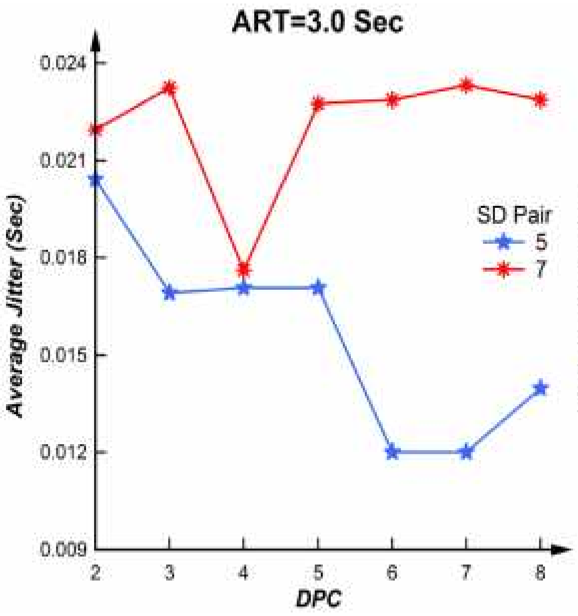


Figure 3.36: Average Jitter for ART=3.0

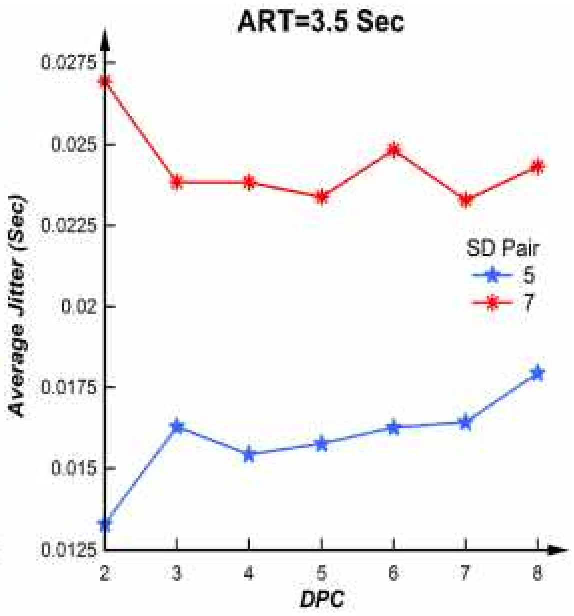


Figure 3.37: Average Jitter for ART=3.5

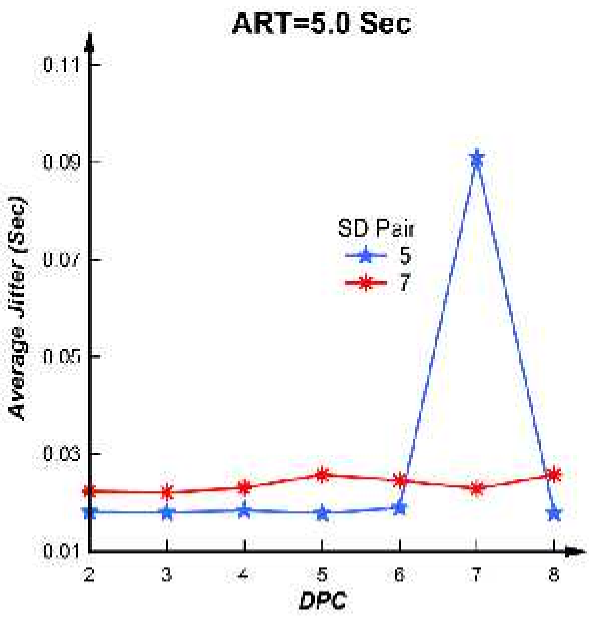
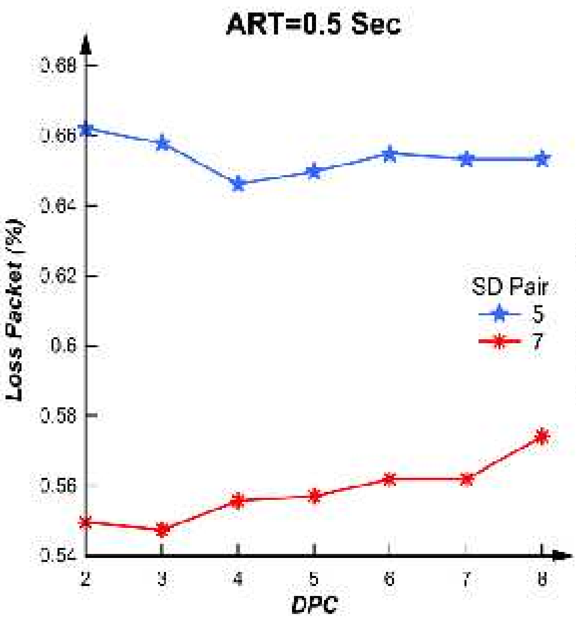


Figure 3.38: Average Jitter for ART=5.0

3.4.2.4 Graphical Analysis of Percentage (%) of Loss/Drop Packet

Here, graphs have been plotted for each value of ART with DPC (as shown in table (3.5)) on the X-axis and Percentage (%) of Loss/Drop Packet on Y-axis. It is the measurement of the percentage of total packets dropped with respect to packets sent during the whole simulation.



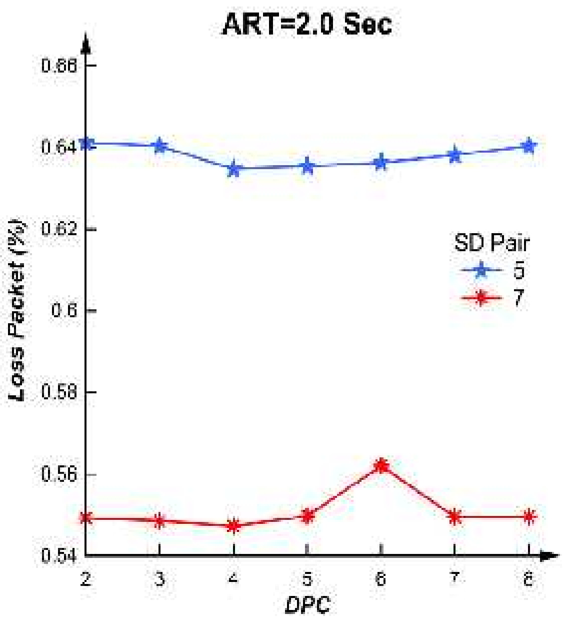
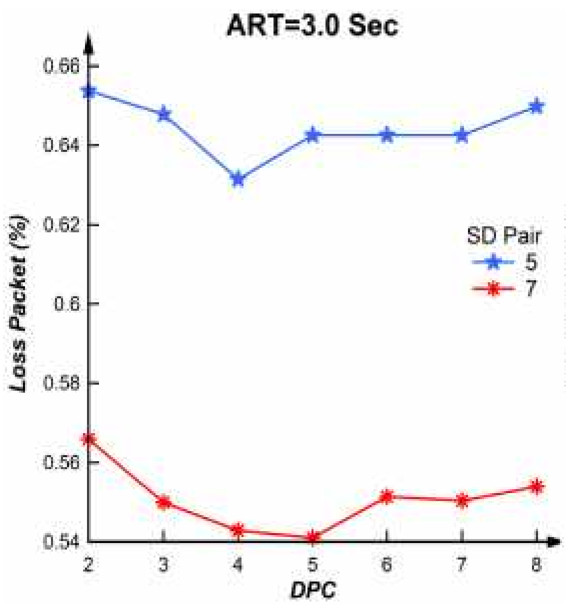


Figure 3.39: % of Loss Packet for ART=0.5Figure 3.40: % of Loss Packet for ART=2.0



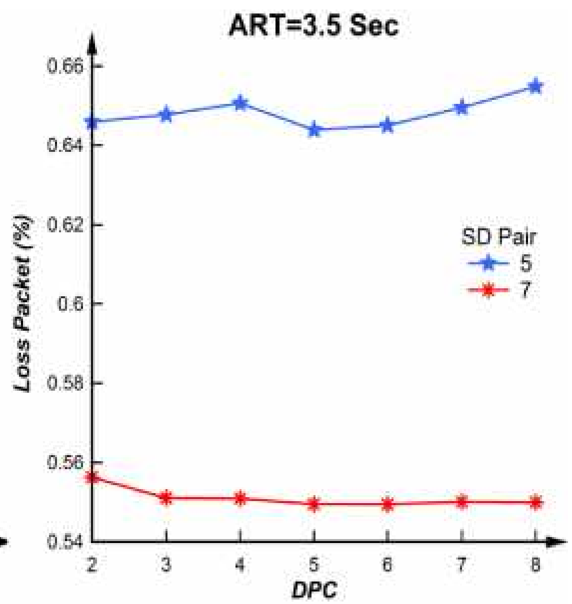


Figure 3.41: % of Loss Packet for ART=3.0Figure 3.42: % of Loss Packet for ART=3.5

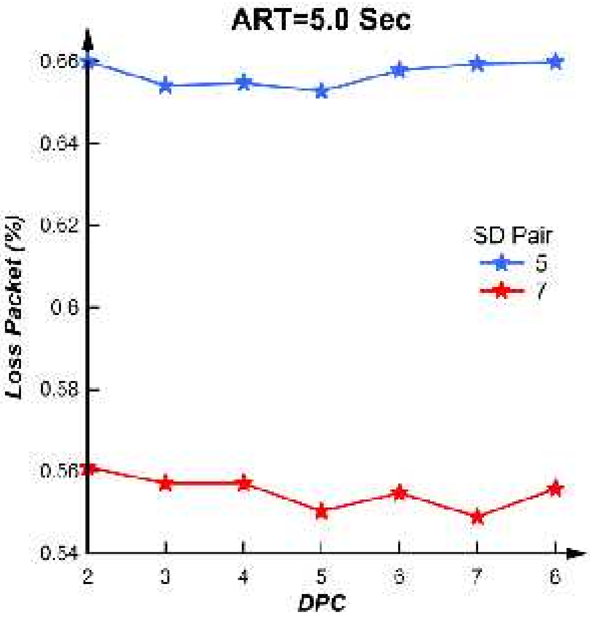


Figure 3.43: % of Loss Packet for ART=5.0

3.4.2.5 Analysis of QoS Metrics for each ART

The close analysis of these obtained graphs as mentioned above *(in sections 3.4.2.1, 3.4.2.2, 3.4.2.3, & 3.4.2.4)* for QoS metrics; throughput, average end-to-end delay, average jitter and percentage (%) of loss/drop packet is clearly explained in the table (3.6) for each value of ART.

Table 3.6: Close analysis of QoS metrics graphs for each ART value

ART Value (Sec)	Analysis of QoS Metrics 1. Throughput	Remarks
0.5	In case of 5 SD pair, throughput increases from 2 to 4, then almost constant from 4 to 7 and slightly it degrades from 7 to 8 values of DPC, as shown in figure (3.24). The reason for poor performance for DPC<4 can be the unavailability of route for successful transmission of packets. For DPC>7, performance degrades due to memory occupy in the routing table is longer thus creating more overheads. For 7 SD pair, the network gives the best performance at DPC=2 because routes are easily available to deliver data and worst performance at DPC=5, because overheads are more than the available of alternate routes. 7 SD pair gives a best	For 5 SD pair, Maximum Throughput (35028.484 bits/sec) is observed at DPC= 4 to 7. & For 7 SD pair, Maximum Throughput (43221.67 bits/sec) at DPC=2.

	throughput performance than 5 SD pair, because the data generated from clients is more and is successfully transmitted over the channel.	
2.0	For 5 SD pair, up to a certain value of DPC<3 performance degrades, then it starts to increase as shown in figure (3.25). This behavior can be attributed to the fact that the increase in DPC caused an increase in overheads and hence delivery of successful packet is decreased. However, after a certain value of DPC, availability of alternate routes is more despite the increase in overheads and hence the performance is increased. Almost same situation is in the case of 7 SD pair, here it degrades between 4 to 6, then increases between 6 to 7, reason is same as 5 SD pair.	For 5 SD pair, Maximum Throughput (34398.82 bits/sec) at DPC=2. & For 7 SD pair, Maximum Throughput (43328.15 bits/sec) at DPC=4.
3.0 & 3.5	At ART=3, for 5 SD pair, network performance slightly increases for DPC<4 then gradually decreases until DPC=8. The best performance is seen at DPC=4 because as its value increases, alternate routes are easily available and hence overhead reduces. Therefore, the performance is better for this DPC value. Later on, as the value of DPC increases from 4 to 8, overheads are more than alternate routes hence performance degrades. For 7 SD pair, performance is almost constant between 2 to 7 then slightly decreases from 7 to 8 that can be seen in figure (3.26). At ART=3.5, for 5 SD pair, initially for DPC<5 performance degrades. Thereafter, performance starts to increase gradually until 8. Whereas for 7 SD pair, initially performance is increased until DPC=5. Moreover, for higher values of DPC, performance is very unpredictable. Hence, it is clear, why the default value of ART has been taken 3. The above could be noticed from figure (3.27).	For 5 SD pair (ART= 3), Maximum Throughput (35720.167 bits/sec) at DPC=4. (ART=3.5), Maximum Throughput (35083.26 bits/sec) at DPC=2. & For 7 SD pair (ART = 3), Maximum Throughput (44623.55 bits/sec) at DPC=4. (ART = 3.5), Maximum Throughput (42874.25 bits/sec) at DPC=7.
5.0	The main aim for this ART value is to see the effect on AODV performance, if value is taken so far away from its default. As shown in figure (3.28), for both 5 & 7 SD pairs graph shows minima at DPC=4 & 5. Thus, it gives totally opposite result for AODV that is optimized for 5. For 5 SD pair network provides the best performance at 8. Whereas for 7 SD pair best performance is observed at 6.	For 5 SD pair, Maximum Throughput (33236.96 bits/sec) at DPC=8. & For 7 SD pair, Maximum Throughput (41342.768 bits/sec) at DPC=6.
For 5 SD pair, the best network performance can be concluded from above throughput		

analysis, for ART=3 at DPC=4 (35720.1670 bits/sec). For 7 SD pair, it is for ART=3 at DPC=4 (44623.5523 bits/sec).		
ART Value (Sec)	**2. Average End-To-End Delay**	**Remarks**
0.5	For 5 SD pair, the network gives the best performance (i.e. minimum delay) at DPC=5 and provides maximum delay at DPC=6 to 7. Delay is less at DPC=5 because at this particular time, distance between client and server is less. Later on, performance is worst for DPC=6 to 7 because the routes are easily available, but the channel is not free. In case of 7 SD pair, minimum delay is observed at DPC=4 because alternate routes are easily available for data transmission and maximum delay is at DPC=3 because during this time duration alternate routes are not available. The above can be seen from figure (3.29).	For 5 SD pair, Minimum Avg. Delay (0.1224 sec) is observed at DPC=5. & For 7 SD pair, Minimum Avg. Delay (0.1038 sec) at DPC=4.
2.0	From figure (3.30), it is clear that for 5 SD pair, the network provides maximum delay at DPC=2 then starts to decrease and provides minimum delay at DPC=7 to 8. Here, initially delay is high due to less number of alternate routes, but later on alternate routes are increased as DPC value increases. Again, for 7 SD pair, the network gives maximum delay at DPC=2 then starts to decrease and provides minimum delay at DPC=4. Again, same reason is here as for 5 SD pair. However, at this particular value (DPC=4), network gives its best performance because the traffic is less and hence route discovery and transmission process becomes easily possible.	For 5 SD pair, Minimum Avg. Delay (0.1064 sec) is observed at DPC=7 to 8. & For 7 SD pair, Minimum Avg. Delay (0.0918 sec) at DPC=4.
3.0	For 5 SD pair, the network gives minimum delay at DPC=2 then starts to increase until DPC=5. For DPC=5 to 6, it is constant after that again, it starts to degrade until DPC=8. For 7 SD pair, the network provides minimum delay at DPC=4 and starts to increase for DPC>4, this can be seen from figure (3.31). Here, the 5 SD pair result is very different from 7 SD pair. For 5 SD pair, initially delay increases as DPC increased because channel becomes worst in terms of traffic in spite of the availability of alternate routes. However, later on due to easily available of free channel, propagation of data is easily possible. Whereas for 7 SD pair, the result is best at DPC=4 due to less overheads.	For 5 SD pair, Minimum Avg. Delay (0.1073 sec) is observed at DPC=2. & For 7 SD pair, Minimum Avg. Delay (0.0866 sec) at DPC=4.
3.5	For 5 SD pair, the network gives its best	For 5 SD pair,

	performance at DPC=2 with minimum delay and provides its maximum delay at DPC=3. For 7 SD pair, network shows its worst performance at DPC=2 then continuously performance is increased until DPC=5. Here, the best performance can be seen from the figure (3.32) at DPC=7. In case of 5 SD pair, the initial traffic load is less so performance is best. Whereas in case of 7 SD pair initial traffic load is high due to less number of availability of alternate routes. However, later on, as availability of alternate routes is increased, performance is also increased.	Minimum Avg. Delay (0.0835 sec) is observed at DPC=2. & For 7 SD pair, Minimum Avg. Delay (0.1338 sec) at DPC=7.
5.0	For 5 SD pair, the network provides better performance at DPC=7 with minimum delay. Whereas for 7 SD pair, it also gives its best performance at DPC=7. In case of delay, AODV behavior is again unpredictable, if its ART value is taken far away from its default. In both cases, it gives the worst performance at DPC=5 that could be seen from figure (3.33).	For 5 SD pair, Minimum Avg. Delay (0.1892 sec) is observed at DPC=7. & For 7 SD pair, Minimum Avg. Delay (0.1386 sec) at DPC=7.
For 5 SD pair, the best network performance can be concluded from above delay analysis, for ART=3.5 at DPC=2 (0.0835 sec). For 7 SD pair, it is for ART=3 at DPC =4 (0.0866 sec).		
ART Value (Sec)	**3. Average Jitter**	**Remarks**
0.5	For 5 SD pair, the best performance in terms of jitter is observed at DPC=2 and worst performance at DPC=3. Moreover, it is almost constant during interval 4 to 8. The above can be realized through the figure (3.34). The worst performance at DPC=3 is due to frequent route breakage towards destination & heavy traffic in the network. Later on, performance is quite good because of the stability of routes is increased as DPC value increases. Hence, there is no variation in the packets arriving time. For 7 SD pair, best performance is seen at DPC=6 and worst at DPC=5. However, at this moment (i.e. DPC=5), the number of alternate routes is there, but performance is degraded due to heavy congestion in the network. Hence, route breakage becomes quite common.	For 5 SD pair, Minimum Avg. Jitter (0.01248 sec) is observed at DPC=2. & For 7 SD pair, Minimum Avg. Jitter (0.02239 sec) at DPC=6.
2.0	From figure (3.35), it can be easily realized that for this ART value in both cases, the network shows almost the same behavior as DPC value increases. I.e. quality of performance increases with an increase in DPC value. Again, same reason is here as for the higher DPC value of ART=0.5.	For 5 SD pair, Minimum Avg. Jitter (0.01480 sec) is observed at DPC=7 to 8. &

		For 7 SD pair, Minimum Avg. Jitter (0.01951 sec) at DPC=5.
3.0	For 5 SD pair, again network shows the same behavior somewhat like ART=2. Here, the performance also gets improve with an increase in DPC value. In this case, best one has been seen at DPC=6 to 7. This can be observed from figure (3.36). Whereas for 7 SD pair, the network delivers minimum jitter at DPC=4. For both cases, initially network presents worst behavior. The reason for that is the unavailability of alternate routes and hence may contention in the network.	For 5 SD pair, Minimum Avg. Jitter (0.01200 sec) is observed at DPC=6 to 7. & For 7 SD pair, Minimum Avg. Jitter (0.01760 sec) at DPC=4.
3.5	For this ART value, especially in the case of 5 SD pair, the network exhibits totally opposite behavior than other lower values of ART. Here, initially performance is good. Later on, performance becomes worst as DPC value increases. The minimum jitter is noticed at DPC=2 and maximum is at DPC=8, which is shown in figure (3.37). The reason for poor performance may be increased in route breakage with an increase in DPC value. For 7 SD pair, network behavior is almost same as a previous one. Here, worst performance is observed at DPC=2.	For 5 SD pair, Minimum Avg. Jitter (0.01329 sec) is observed at DPC=2. & For 7 SD pair, Minimum Avg. Jitter (0.02328 sec) at DPC=7.
5.0	Here, for 7 SD pair, the network gives almost same performance throughout all DPC values. In case of 5 SD pair, performance is similar like 7 SD pair until DPC=6, but network behavior is changed abruptly during interval 6 to 8 that is shown in figure (3.38). The main reason for this abrupt behavior between this time interval may be more frequent route changes towards the destination.	For 5 SD pair, Minimum Avg. Jitter (0.01791 sec) is observed at DPC=5. & For 7 SD pair, Minimum Avg. Jitter (0.02217 sec) at DPC=3.
For 5 SD pair, the best network performance can be concluded from above jitter analysis, for ART=3.0 at DPC=6 to 7 (0.012 sec). For 7 SD pair, it is for ART=3 at DPC =4 (0.01760 sec).		
ART Value (Sec)	**4. % of Loss Packet**	**Remarks**
0.5	For 5 SD pair, the minimum % of loss packet is observed at DPC=4 and for 7 SD pair it is at DPC=3 that could be seen from figure (3.39). For 5 SD pair, % of loss packet is decreased until a DPC value of 4. After that, it is slightly increased. However, in case of 7 SD pair, as the value of DPC increases, % of loss packet also increases. It	For 5 SD pair, Minimum % of Loss Packet (0.64622) is observed at DPC=4. & For 7 SD pair,

	happened possibly because of signal degradation increases over the network medium due to multi-path fading or distance as DPC value is increased.	Minimum % of Loss Packet (0.5473) at DPC=3.
2.0	From figure (3.40), it is clear that for 5 SD pair, % of loss packet is almost constant throughout all values of DPC. In both cases, the minimum % of loss packet is observed at DPC=4. In 7 SD pair, % of loss packet is slightly higher at DPC=6. The reason of poor performance may be the channel congestion at a particular time.	For 5 SD pair, Minimum % of Loss Packet (0.6347) is observed at DPC=4. & For 7 SD pair, Minimum % of Loss Packet (0.5473) at DPC=4.
3.0	Here, the best performance for 5 SD pair is seen at DPC=4 and worst at DPC=2. Whereas, in case of 7 SD pair, the best one is at DPC=5 and the worst one is at DPC=2. From figure (3.41), it can be observed that for both cases worst performance is given at DPC=2. The reason for degradation of performance at this moment may be a severe delay in overall transmission. Therefore, more packets get dropouts.	For 5 SD pair, Minimum % of Loss Packet (0.6314) is observed at DPC=4. & For 7 SD pair, Minimum % of Loss Packet (0.5409) at DPC=5.
3.5	From figure (3.42), for both cases, the % of loss packet is almost constant throughout the range of DPC. The best performance is observed at DPC=5 & 6 for the 5 & 7 SD pair, respectively. At a particular time duration, the performance becomes worse, it may be because of the buffer is already completely filled when packet arrives. Hence, more packets get dropouts.	For 5 SD pair, Minimum % of Loss Packet (0.6439) is observed at DPC=5. & For 7 SD pair, Minimum % of Loss Packet (0.5494) at DPC=6.
5.0	For 5 SD pair, the best performance may be seen at DPC=5 and the worst one is at DPC=2. Whereas in case of 7 SD pair, the best one is at DPC=7 and worst one could be noticed at DPC=2. The above can be observed from figure (3.43). Here, again the reason is same as for ART=3.	For 5 SD pair, Minimum % of Loss Packet (0.6528) is observed at DPC=5. & For 7 SD pair, Minimum % of Loss Packet (0.5488) at DPC=7.
For 5 SD pair, the best network performance can be concluded from above % of loss packet analysis, for ART=3.0 at DPC=4 (0.63144). For 7 SD pair, it is for ART=3.0 at DPC =5 (0.54099).		

3.5 Conclusion

In this section, again, performance evaluation of the AODV routing protocol has been done by varying route maintenance parameters, but different SD pairs have been taken into account. However, for this purpose QualNet simulation tool is used here. The impact of variations of ART and DPC is analyzed in a graphical manner on different QoS parameters: throughput, average end-to-end delay, average jitter, and percentage of loss packet. The various considered ART value is 0.5, 2.0, 3.0, 3.5, & 5.0 and for each ART value, the value of DPC has been varied from 2 to 8 in a regular unit interval. This section conducts the simulation experiment two times for two different SD pairs (5 & 7), where network density is kept constant, and its value is 20.

The impact of this variation phenomenon of ART and DPC has deeply and closely been analyzed on AODV routing, which is tabulated in the table (3.6). From the above analysis that is tabulated in table (3.6), it is clear that if the parameter value is changed far away from its default value, then network shows abrupt behavior. Even if one parameter is kept constant and the other is varied quite away from its default value, the network exhibits odd behavior than its normal one.

The best network performance in terms of throughput is observed for ART=3 at DPC=4 for both SD pairs. In case of average end-to-end delay, best one is for ‘ART=3.5 at DPC=2’ & for ‘ART=3 at DPC=4’ for 5 and 7 SD pair, respectively. Here, analytical values are uncertain in both cases. It is also found that minimum jitter for ‘ART=3 at DPC=6 to 7’ & for ‘ART=3 at DPC=4’ for 5 & 7 SD pair, respectively. Here, analytical values are again uncertain like delay for both cases. Moreover, the best one in both cases of percentage of loss packet is observed for ART=3 but DPC value is different (i.e. 4 & 5, respectively).

It is analyzed that ART=3 gives the best performance to all QoS metrics excluding delay for 5 SD pair, here, it is 3.5 seconds. Whereas, the best one is found at different DPC value. DPC value is less than its default value for all other QoS parameters but not including jitter, which results in less memory overheads. Moreover, it could also be seen from all above mentioned graphs that 7 SD pair has outperformed except jitter. In other words, in the case of jitter, 5 SD pair gives better results, this might be feasible because of less traffic in the network and hence route breakage is less here. From the above discussion, it can be said that the QoS metrics are constrained to each other. Hence, the selection of the default values of ART & DPC may depend on the user choice as per requirement of QoS.

Chapter 4 presents the comparative study between CBR & VBR traffic generators under the influence of the various route maintenance parameters. Since in real-world applications, mostly the traffics are variable. Hence, it is absolutely necessary to conduct the simulation-based comparison study between CBR & VBR traffic generators in order to observe the performance differences.