Chapter Four

Simulation results and discussion

4.1 Simulation scenario:

Based on literature review [10], and virtual classroom environment within an area of 50 m * 50 m and 25 students, performance metrics have been considered can be seen from Table 4-1 and Table 4-2:

Table 4-1 performance metrics of virtual classroom

Performance metric	Value
Data rate	500 kbps
queue size	50 packet
packet size	70 byte
PDF	85%
Packet loss number	595
delay	0.5 ms
jitter	0.00 ms
throughput	0.00
Number of nodes access the main	7
Total byte	235410

Table 4-2 performance metric of previous study.

Performance metric	Value
queue size	50 packet
packet size	512 byte
Packet loss	235 packet
delay	0.02247 s
throughput	82.799 Kbps

In this case 22 users attempts to access the main node concurrently, only 7 user access the main node with unacceptable performance metrics, to see results for this simulation please refer to Appendix B.

Figure 4-1 display the delay over time at node 6 when 22 nodes access node 6 at the same time.

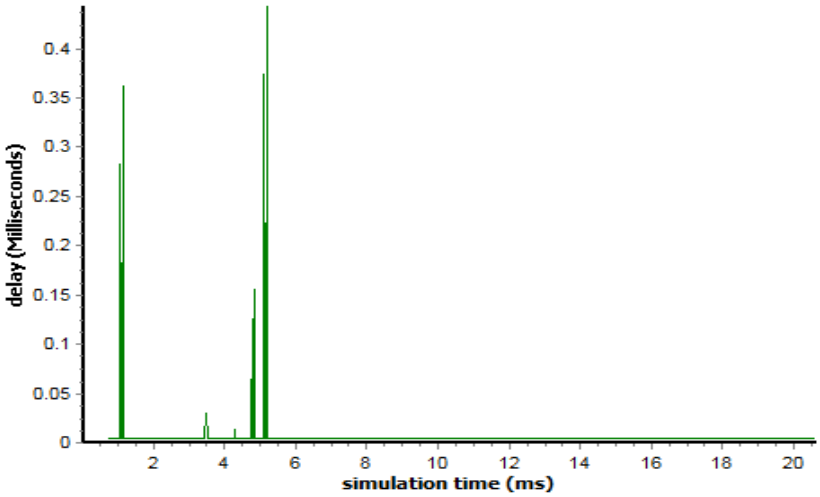


Figure 4-1: Delay over time at node 6

All nodes start contact node 6 at 0.7 ms, at this time delay is 0.27 ms as shown in Figure 4-1.

Figure 4-2 display the value of delay, jitter, and throughput when 22 node access the main node concurrently.

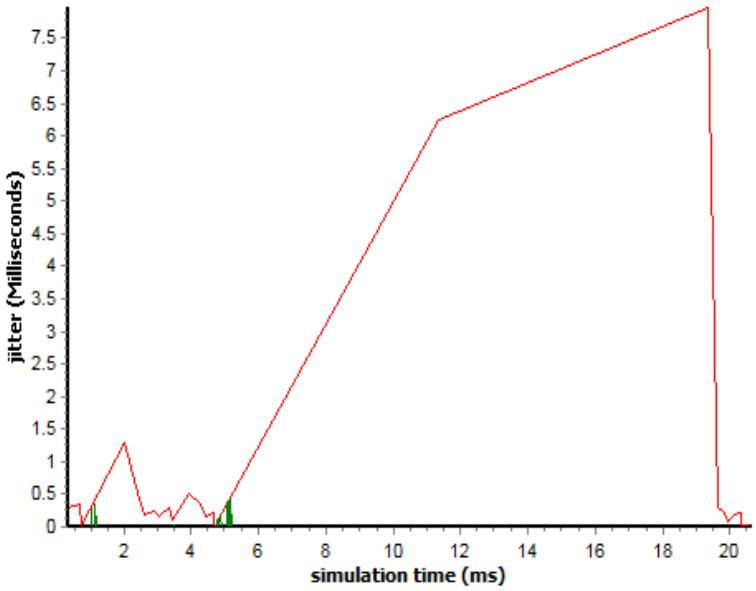


Figure 4-2: jitter over time at node 6

The Jitter is 0.4 ms when all node access the main node concurrently.

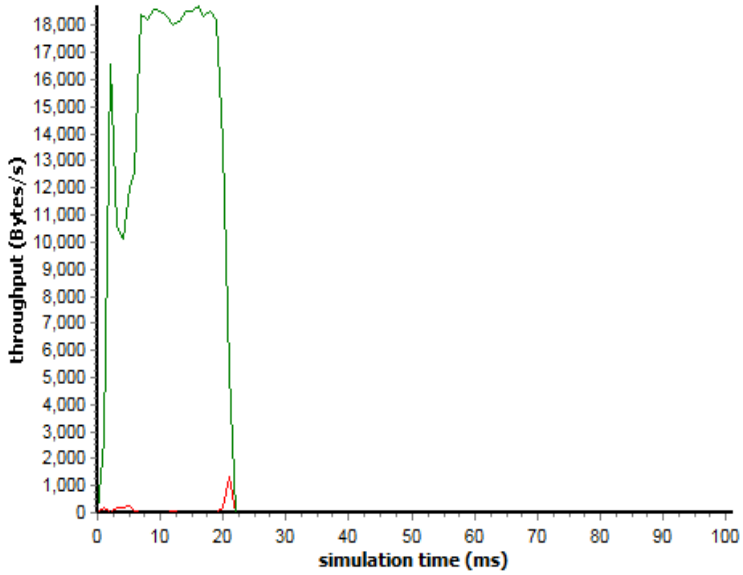


Figure 4-3: throughput over time at node 6

when more than two node attempt to access the main node concurrently, the number of packets loss is high and the number of PDF is low in addition some of these node lost the connection with the main node .

Figure 4-3 display the value of throughput when 22 node access the main node concurrently .In this study an attempts has been made to optimize theses performance metric, and increase number of users access the main node concurrently with acceptable value of performance metrics.

Tests on packet size, Queue size and data rate are applied to determine optimal value for packet size, queue size and data rate. Every experiment will be run 100 s in total.

4.2 SIMULATION RESULT AND DISCUSSION

4.2.1 Data Rate

In this set of simulations, a group of data rates ranging from 500 kbps to 10 kbps is applied for all nodes in the network including the main node, you can find the TCL script for this simulation in appendix A.

The term bandwidth used by people who discussed the topic in the field of QoS aware routing protocols means data rate but not the physical bandwidth with the unit of Hertz. In this thesis the term bandwidth that people usually misused is modified to data rate with the unit of bits per second.

4.2.2 Data Rate Test

Table 4-3 display the parameters of simulation environment where different group of data rate are tested.

Table 4-3 simulation environment 1

Parameter	Value
Simulator	Ns 2.34
MAC Type	802.15.4
Simulation Time	100 seconds
Channel Type	Wireless Channel
Routing protocol	AODV
Simulation Area	50 m * 50 m
Traffic Type	CBR
Interface queue length	50
Interface queue type	Drop Tail
Number of nodes	26
Packet size	70 byte
Data Rate	500 , 400, 300,200 ,100,50 ,20,10 Kbps

4.2.3 500 kbps Data Rate Test

In this case, 500 k of Data rate is tested to show the effect of this value on packet loss, PDF, delay, jitter and throughput.

Data rate = 500kbps for all nodes.

When data rate is 500K:

PDF = 1801/ 4308 * 100 = 41.8%.

Packet loss = 4308 – 1801 = 2507 packet.

To see results for this simulation please refer to Appendix B.

4.2.4 400 kbps Data Rate Test

Data rate = 400 kbps for all nodes.

Total packet sent to node 6 = 63 + 0+3809 = 3872 packet

PDF = 1631/ 3872 *100 = 42.1 %

Packet loss = 3872 – 1631 = 2241 packet

To see results for this simulation please refer to Appendix B.

4.2.5 300 kbps Data Rate Test

Data rate = 300 k.

PDF = 24/86 * 100 = 27.9 %.

Packet loss = 86 – 24 = 62 packet.

Total packet sent to node 6 =0+0+86 = 86.

To see results for this simulation please refer to Appendix B.

4.2.6 200 kbps Data Rate Test

Data rate = 200 k

Total packet sent to node 6 =298+6+0 = 304.

PDF = 130/304 *100 =42.7%

Packet loss = 304-130= 174 packet

To see results for this simulation please refer to Appendix B.

4.2.7 100 kbps Data Rate Test

Data rate = 100 K

Total packet sent to node 6 =571+6+0=578.

PDF = 257/578 *100 = 44.4%.

Packet loss = 578 - 257 = 330 packet.

To see results for this simulation please refer to Appendix B.

4.2.8 100 kbps Data Rate Test

Data rate = 50k

Total packet sent to node 6 =1459+0+0 = 0.

PDF = 691/1459 = 47.3%

Packet loss = 1459 –691 = 768 packet

To see results for this simulation please refer to Appendix B.

4.2.9 20 kbps Data Rate Test

Data rate =20k

Total packet sent to node 6 =158+0+5077=5235.

PDF = 4976/5235 * 100 = 95 %

Packet loss = 5235 – 4976 = 259 packet

To see results for this simulation please refer to Appendix B.

4.2.10 10 kbps Data Rate Test

Data rate =10k

Total packet sent to node 6 =1974+127=2101.

PDF = 1900/2101 * 100 =90.34%.

Packet loss = 2101-1900 = 201.

To see results for this simulation please refer to Appendix B.

From table 4-4 it to be noted that when the data rate is 500K the PDF is low and the packet loss is very high, based on this result data rate value has been decrease and different values ranging from 500k to 10k are tested, when the data rate is 20 k value of PDF and packet loss is improved as is show in table 4-4.

Table 4-4 Performance data of AODV protocol with respect to data rate

Data Rate(kbps)	PDF	Packet Loss(packet)	Total byte
500	41.8%	2507	126070
400	42.1 %	2241	114170
300	27.9 %	62	21000
200	42.7%	174	9100
100	44%	330	17990
50	47.3%	768	48370
20	95 %	259	348320
10	90.34|%	201	133000

The results presented in the Table 4-4 show that when the Data rate is high the PDF is low and the packet loss is high. This result also represented in the next chart as is show in figure 4-4.

Table 4-5: Performance data of AODV protocol with respect to data rate

Data Rate / kbps	PDF	Packet Loss/ packet	Overall byte
500 /50	30.77%	947	29470
400 /40	4.7 %	78	280
300 /30	81.6 %	1168	362460
200 /20	93.6%	238	246960
100 /10	63.78%	1936	238700

Table 4-5 represents the result of simulation when data rate value for the main node is 10 times the data rate value of client node.

Table 4-6: Performance data of AODV protocol with respect to data rate

Data rate /K	Delay /ms	Jitter /ms	Throughput b/s
20	0.015	0.012	3900
50	0.12	0.09	-
100	0.015	0.012	3900
400	0.065	0.05	-
500	0.14	0.08	-

Table 4-6 show the values of delay , jitter and throughput, when different values of data rate were tested , when the data rate is 20kbps the PDF is 95% and packet loss is 259 packet as shown in table 4-5. Delay is 0.015 ms , jitter is 0.012 ms and throughput is 3900 b/s as shown in table 4-5.

Based on the previous result and result in table 4-4 20kbps has been chosen as an optimal value of data rate .from table 4-6 100kbps also can be chosen as an optimal value of data rate but data rate value is depends on other parameter like packet size see table 4-8 when data rate is 100kbps and packet size is 70 PDF is 44%.

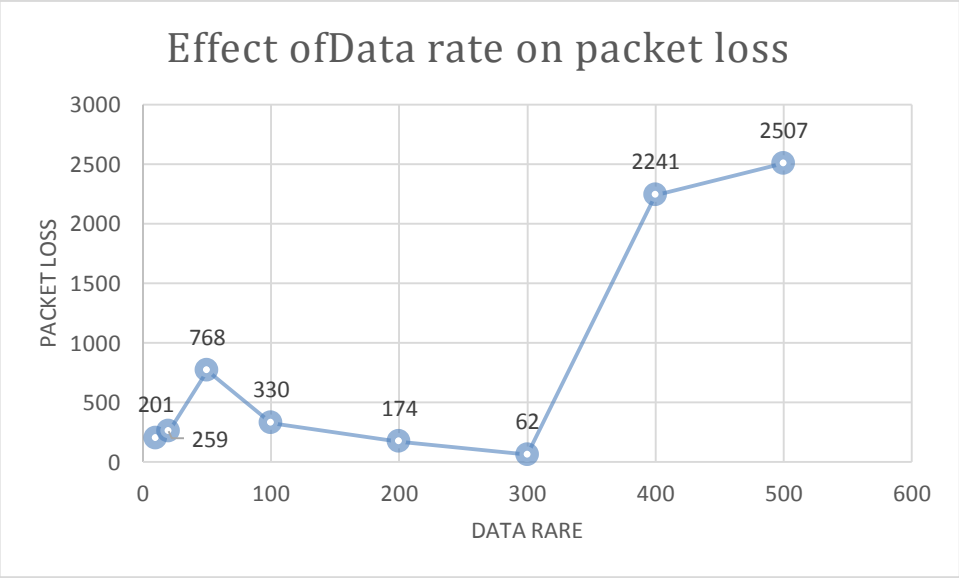


Figure 4-4: Effect of data rate on packet loss

Figure 4-4 represents the relationship between the Data rate and the packet loss, and show that the optimal value of the data rate is 20kbps.

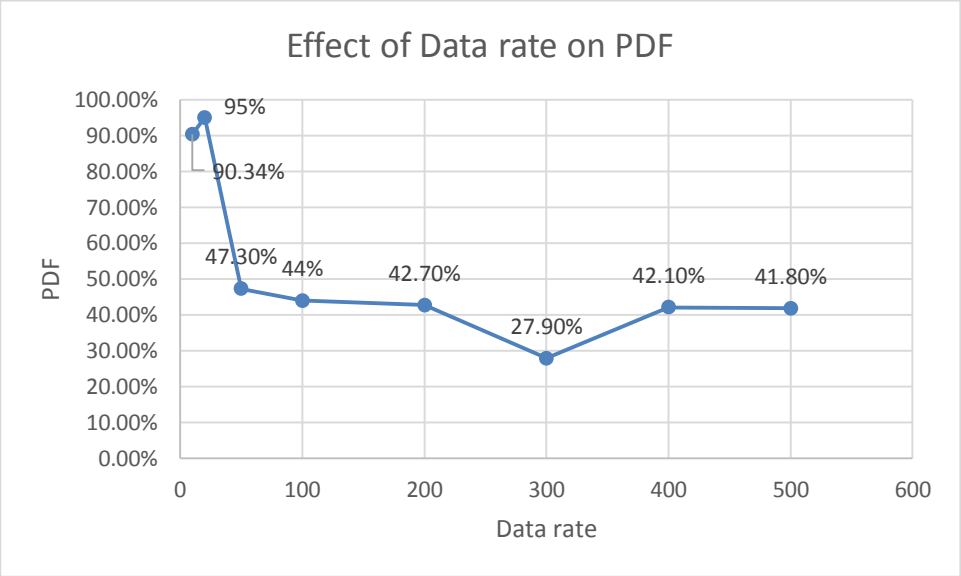


Figure 4-5: Effect of data rate on PDF

Figure 4-5 represents the relationship between the Data rate and the PDF, when the data rate is high, the PDF is low.

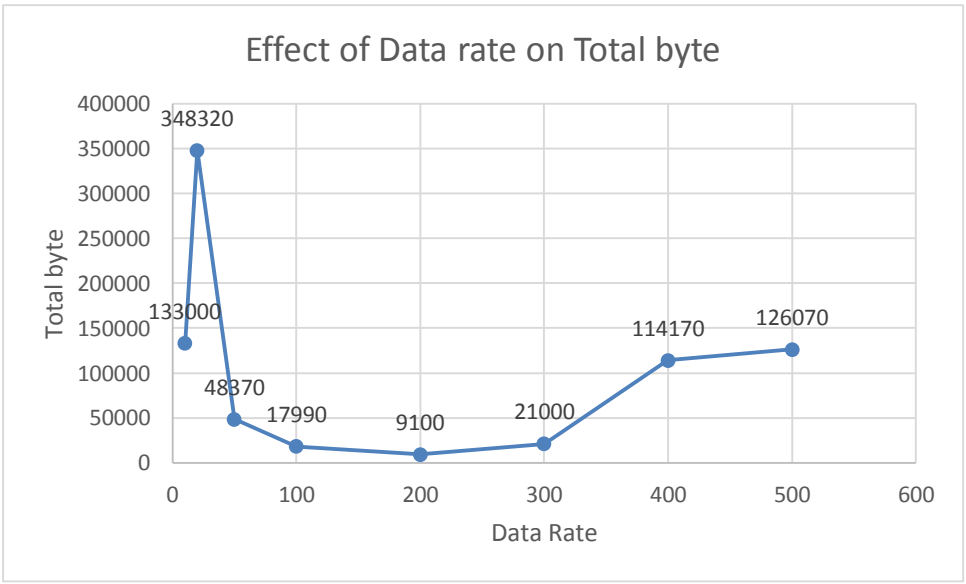


Figure 4-6: Effect of data rate on number of total byte

When the data rate for all nodes are 20 or 100k as can be seen from figure 4-7 the delay is 0.012 ms.

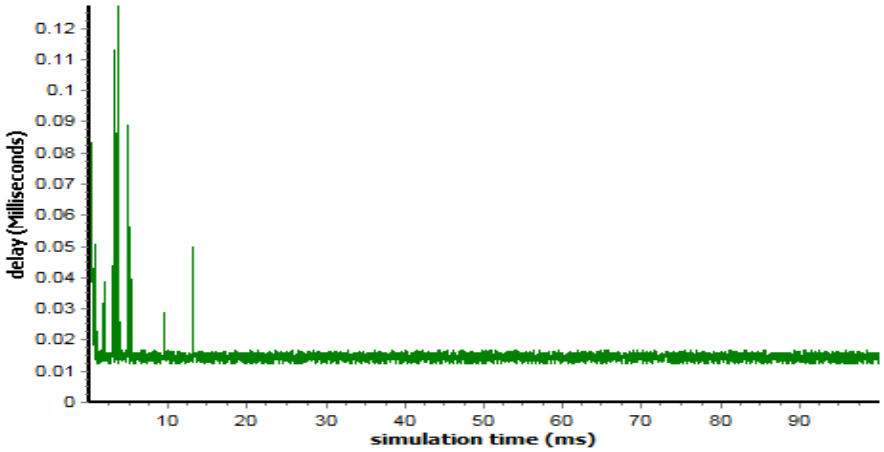


Figure 4-7: delay over time at node 6 when data rate =20, 100 kbps

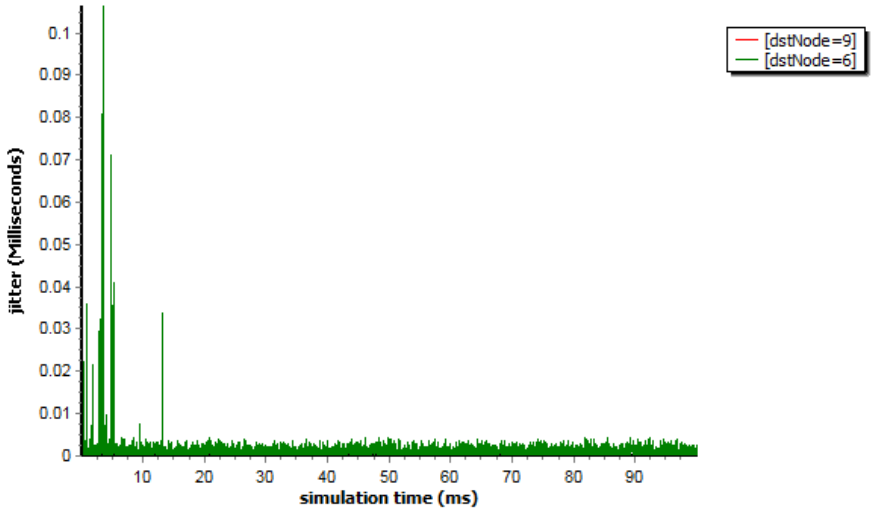


Figure 4-8: Jitter over time at node 6 when data rate =20, 100 kbps

When the data rate for all nodes are 20 or 100k as can be seen from Figure 4-8 the jitter is 0.012 ms.

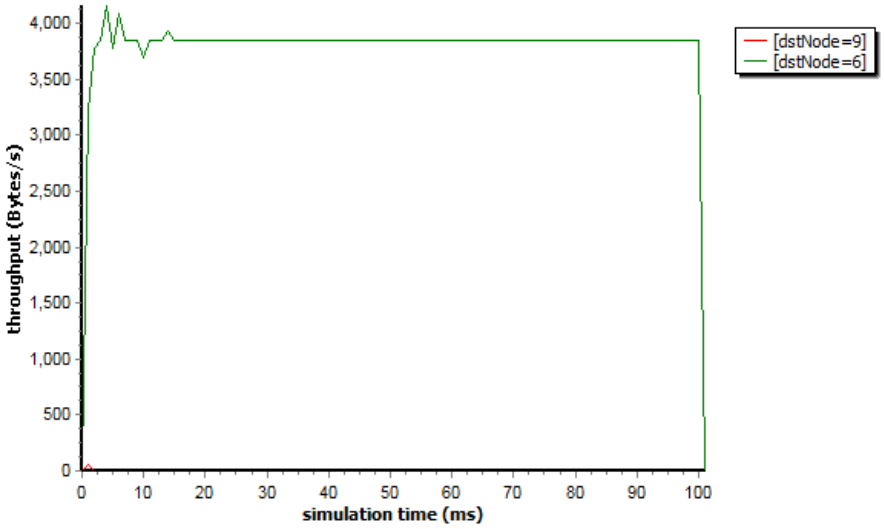


Figure 4-9: throughput over time at node 6 when data rate =20, 100 Kbps

Figure 4-9 show that when the data rate for all nodes are 20 or 100k the throughput is 3900 byte/s.

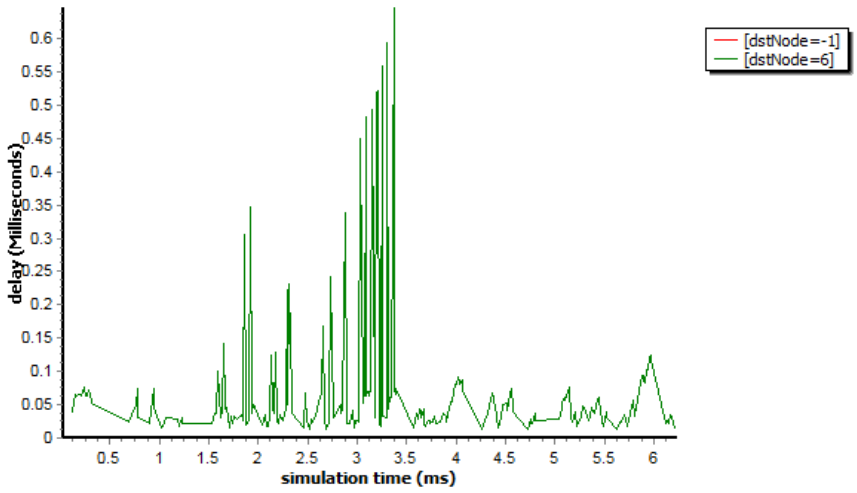


Figure 4-10: delay over time at node 6 when data rate =50 Kbps

Figure 4-10 shows the delay over time when the data rate is 50k. The delay is higher than the delay when the data rate were 20 and 100 kbps.

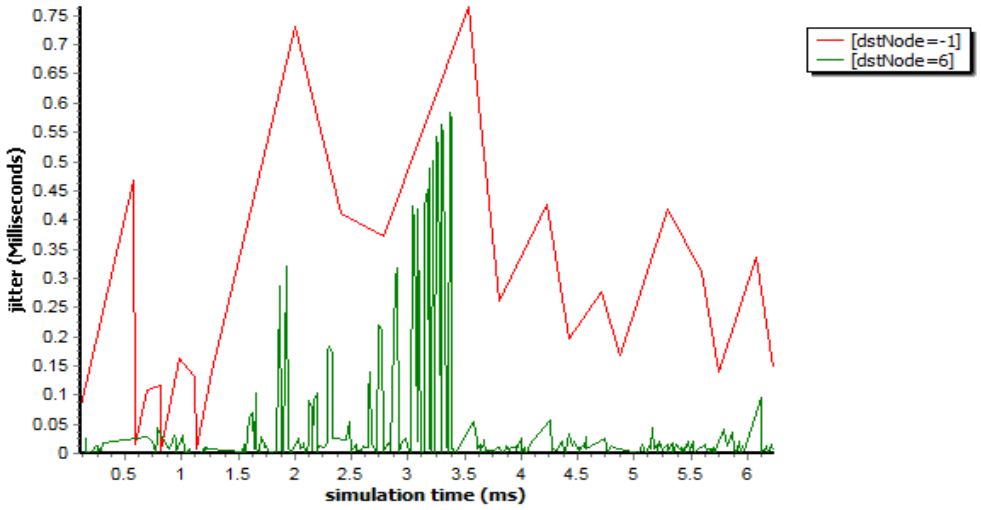


Figure 4-11: jitter over time at node 6 when data rate

Figure 4-11 shows the jitter over time at node 6 when the data rate is 50k. The jitter is higher than the jitter when the data rate were 20 and 100.

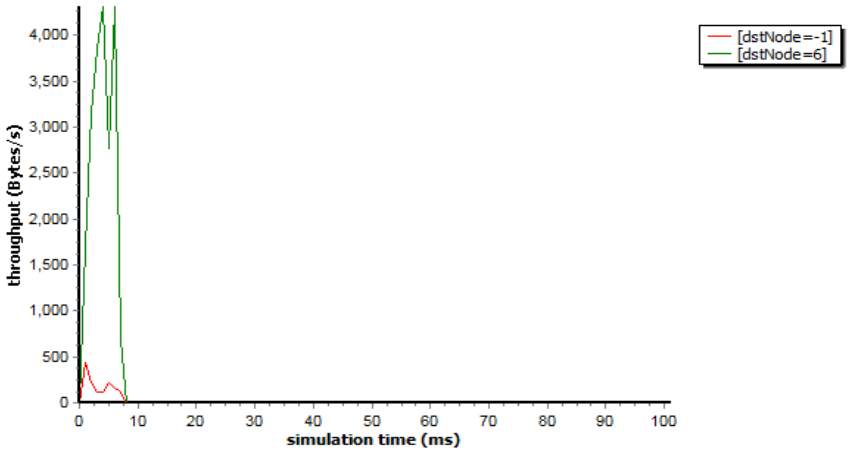


Figure 4-12 : throughput over time at the main node when data rate =50 Kbps

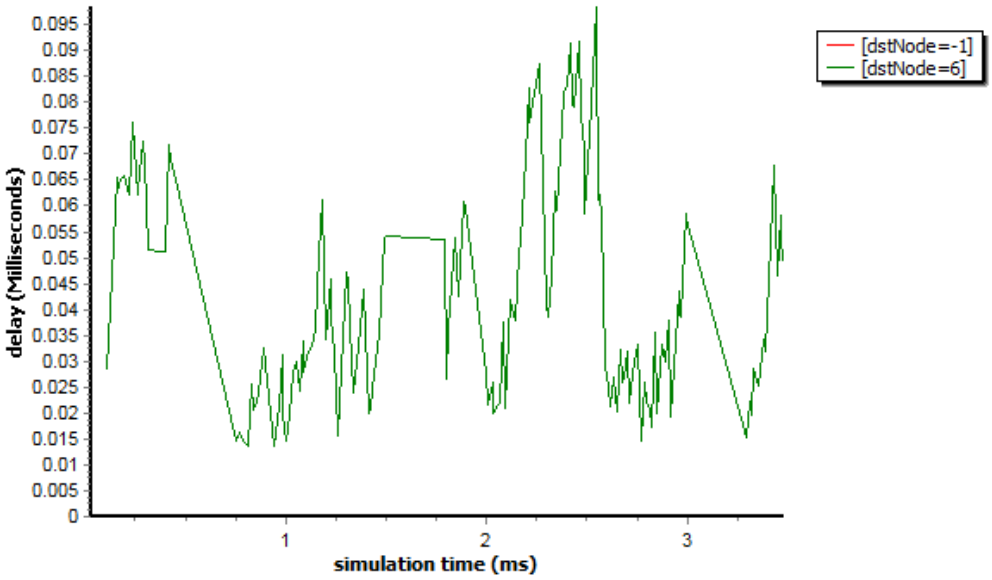


Figure 4-13 delay over time at node 6 when data rate = 400 kbps

Figure 4-13 shows the delay over time at node six when the data rate is 400k. The delay is lower than the delay when the data rate were 20k.

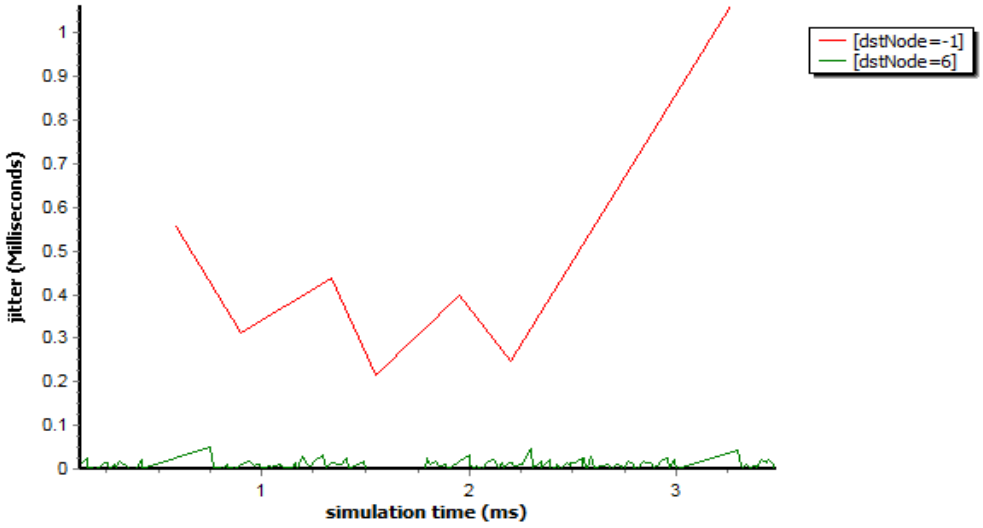


Figure 4-15: jitter over time at node 6 when data rate =400 Kbps

Figure 4-15 shows the jitter over time when the data rate is 400k. The jitter is less than the jitter when the data rate was 50k.

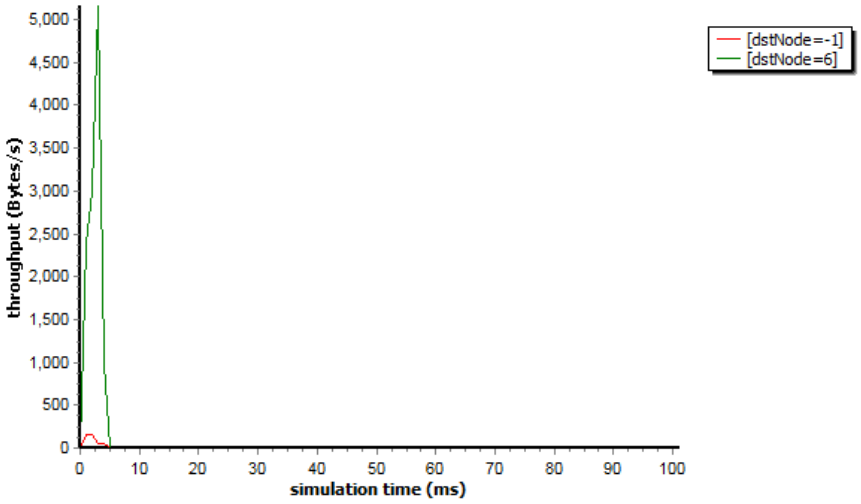


Figure 4-16: throughput over time at node 6 when data rate =400 Kbps

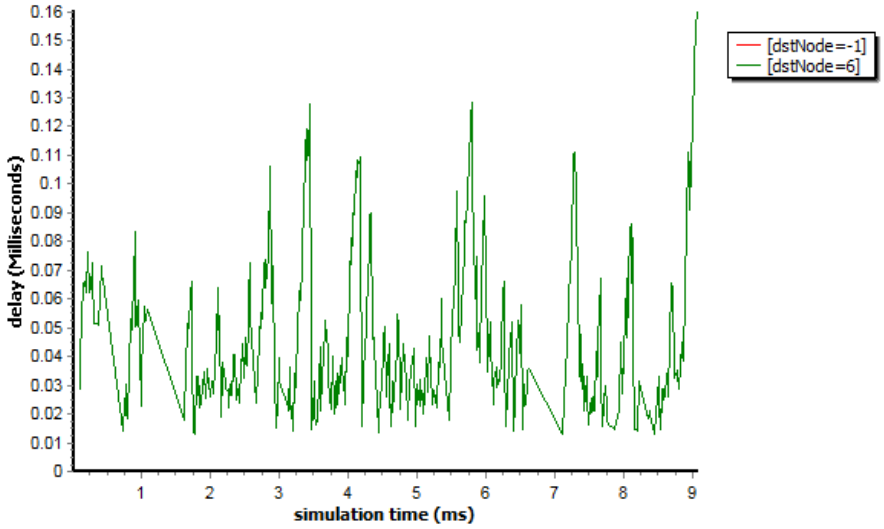


Figure 4-17: delay over time at node 6 when data rate = 500 kbps

Figure 4-17 show the delay when the data rate is 500k, the delay is 0.15ms.

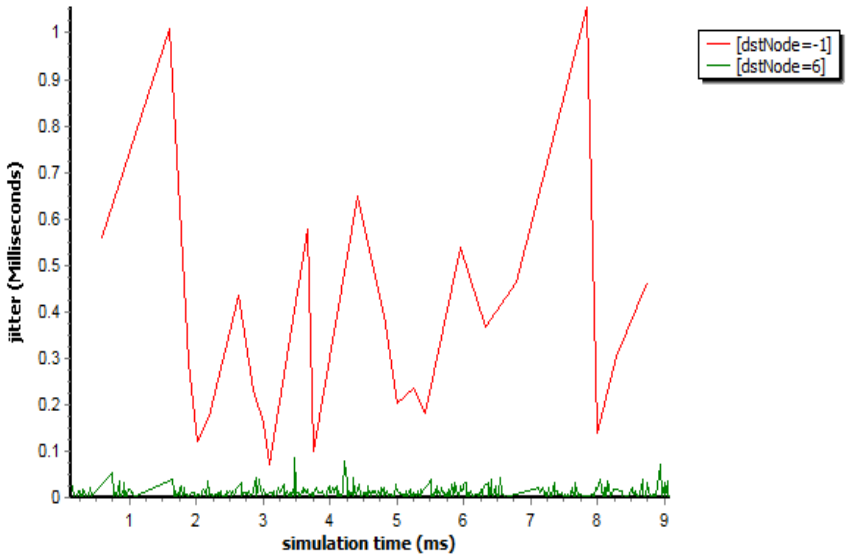


Figure 4-18 jitter over time at node 6 when data rate = 500 kbps

Figure 4-18 show the jitter value at node six when the data rate is 500k, the jitter is 0.08 ms.

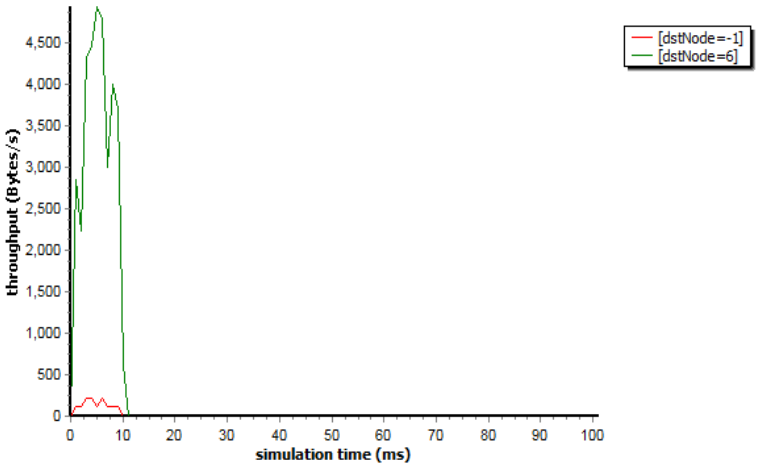


Figure 4-19: throughput over time at node 6 when data rate =500k

The values of delay, jitter and throughput are listed in table 4-6.Table 4-6 show that there is no clear effect on delay, jitter and throughput, even if different values of data rate were tested.

The minimum delay is 0.015 ms as shown in table. When the data rate is 20k, the maximum PDF is 92.9% and the minimum packet loss is 379 packet.

4.3 Packet Size Test

In this set of simulations, a group of packet size is ranging from 120 bytes to 50 bytes is applied. The data rate value is 20k depend on the result of case1. The TCL script for this simulation is in appendix A.

Table 4-7: simulation environment 2

Parameter	Value
Simulator	Ns 2.34
MAC Type	802.15.4
Simulation Time	100 seconds
Channel Type	Wireless Channel
Routing protocol	AODV
Simulation Area	50 m * 50 m
Traffic Type	CBR
Interface queue type	Drop Tail /
Number of nodes	26
Queue Length	50
Packet Size	120 ,100, 70,50 byte

4.3.1 120 byte Packet Size Test:

Packet size = 120.

Total packet sent to node 6 =0

PDF = 473/ 249073 * 100 = 0%

Packet loss = 100 % packet

To see results for this simulation please refer to Appendix B.

4.3.2 100 byte Packet Size Test:

Packet size =100

Total packet sent to node 6 =174+2542+0=2559 packet.

PDF = 2485 /2559 * 100= 97%.

Packet loss = 2559-2485 = 74 packet.

To see results for this simulation please refer to Appendix B.

4.3.3 70 byte Packet Size Test

Packet size =70

Total packet sent to node 6 =45+3582+0= 3627.

PDF = 3528/3627 * 100= 93.6%

Packet loss = 3627-3528=99.

To see results for this simulation please refer to Appendix B.

4.3.4 50 byte Packet Size Test

Packet size = 50

Total packet sent to node 6 = 13435.

PDF = 13134/13435 * 100 =97.7 %.

Packet loss = 13435-13134= 301 packet.

To see results for this simulation please refer to Appendix B.

The results presented in Table 4-8 show the value of PDF and packet loss, when different values of packet size are tested where data rate value is 20kbps.

Table 4-8 Performance data of AODV protocol with respect to packet size

Data rate	Packet size	PDF	Packet Loss	total byte
20kbps	50	97.7 %	379	656700
20kbps	70	93.6%	1239	246960
20kbps	100	97.7%	337	248500
20kbps	120	0%	100%	0
20kbps	64	66.2%	1805	226,650
20kbps	512	63.9%	534	485376

Table 4-9 show the values of PDF and packet loss, when different values of packet size are tested where data rate value is 100kbps.

Table 4-9 Performance data of AODV protocol with respect to packet size

Data rate	Packet size	PDF	Packet Loss
100K	50	0	100%
100K	64	37%	791
100K	70	44.5%	320
100K	100	32.1%	129
100K	120	0	100%
100K	512	61.12%	3127

In the next simulation, different group of packet size is tested where data rate of main node is equal to ten times the data rate of the client node.

Table 4-10 Performance data of AODV protocol with respect to packet size

Data rate /kbps	Packet size /byte	PDF	Packet Loss	Total byte
500 /50	50	47.3%	768	34550
500 /50	64	48.7%	3232	196800
500 /50	70	30.77%	947	29470
500 /50	120	0	100%	0
500/50	512	64%	1336	1222656

Table 4-11 Performance data of AODV protocol with respect to packet size

Data rate /kbps	Packet size /byte	PDF	Packet Loss	Total byte
400 /40	50	4.7%	78	200
400 /40	64	48.6%	2175	131648
400 /40	70	52%	157	11970
400 /40	120	0%	100%	0
400 /40	512	63.8%	1260	1138688

Table 4-12 Performance data of AODV protocol with respect to packet

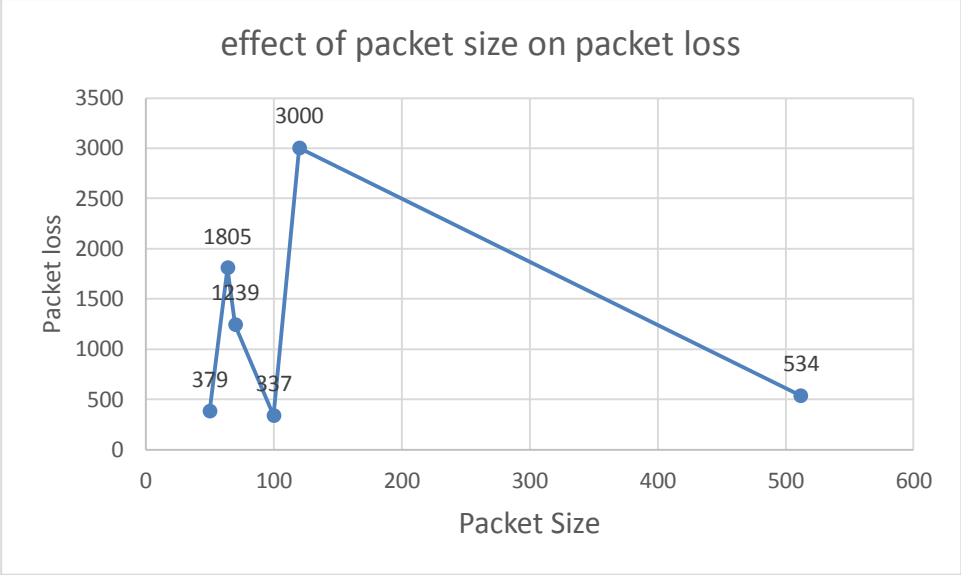
Data rate /kbps	Packet size /byte	PDF	Packet Loss	Total byte
300 /30	50	39.4%	369	1200
300 /30	64	51.5%	5195	353344
300 /30	70	81%	1168	362460
300 /30	120	0%	100%	0
300 /30	512	63.6%	804	719360

Table 4-13 Performance data of AODV protocol with respect to packet size

Data rate	Packet size	PDF	Packet Loss	Overall byte
200/20	50	97.7 %	379	656700
200/20	64	87.6%	540	244544
200/20	70	93.6%	1239	246960
200/20	100	97.7%	337	248500
200/20	120	0%	100%	0
200/20	512	91.24%	96	512000

Table 4-14 Performance data of AODV protocol with respect to packet size

Data rate	*Packet size*	*PDF*	*Packet Loss*	*Overall byte*
100/10	50	90%	1	450
100/10	64	68%	1557	212672
100/10	70	83.7%	33	11900
100/10	120	0%	100%	0
100/10	512	64%	365	334848



The sa Figure 4-20: Effect of packet size on packet loss 20

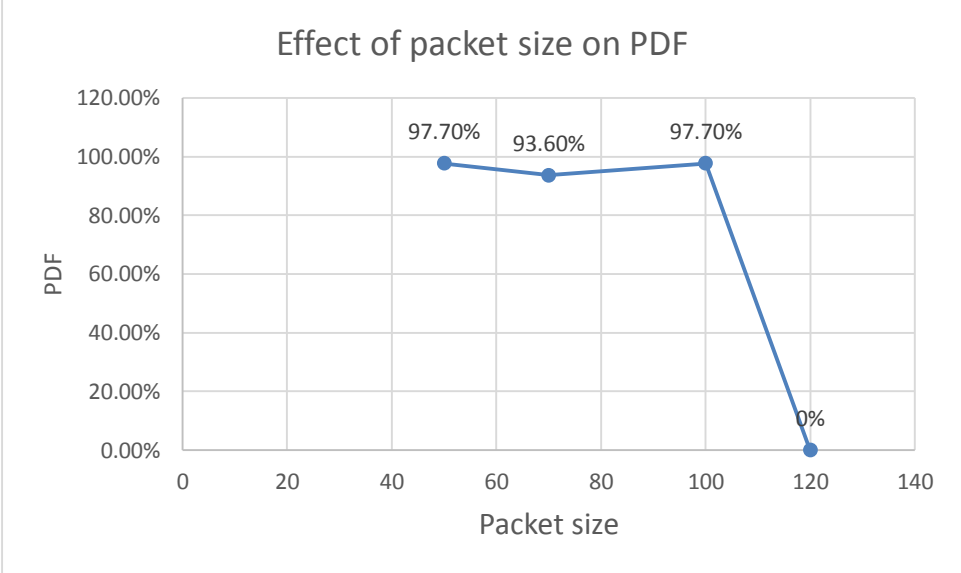


Figure 4-21: Effect of packet size on PDF

When the packet size is 120 byte, any packet received by node 6 has been dropped, because the data rate for node 6 is 20k only and the packet size is very large. To overcome this problem we will decrease the packet size, increase the queue size and increase the data rate value for the main node to 200k.

Figure 4-21 show the relationship between the packet size and PDF. When the packet size is low, the PDF is high. Depends on the results in this simulation the optimal value of packet size is 50 byte.

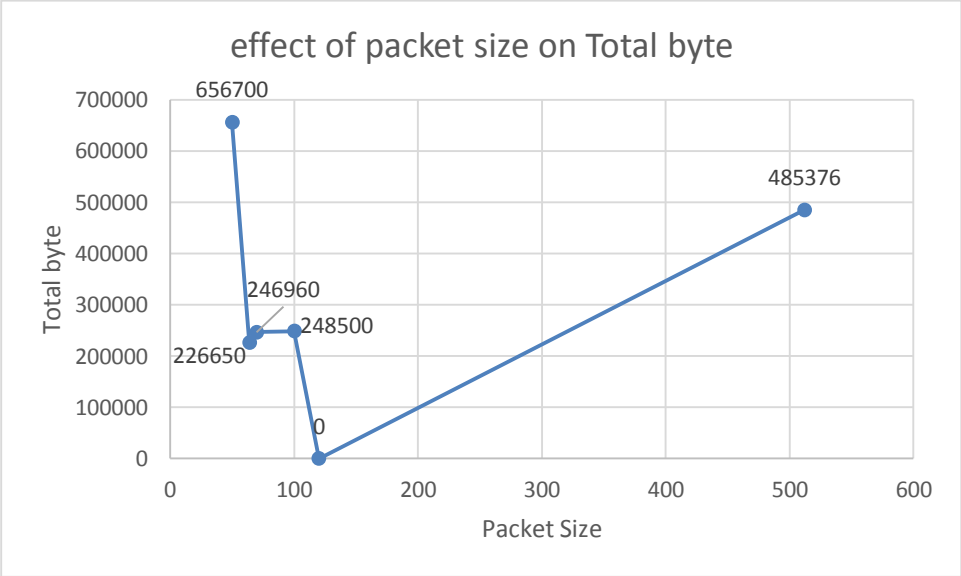


Figure 4-22: Effect of packet size on Total byte

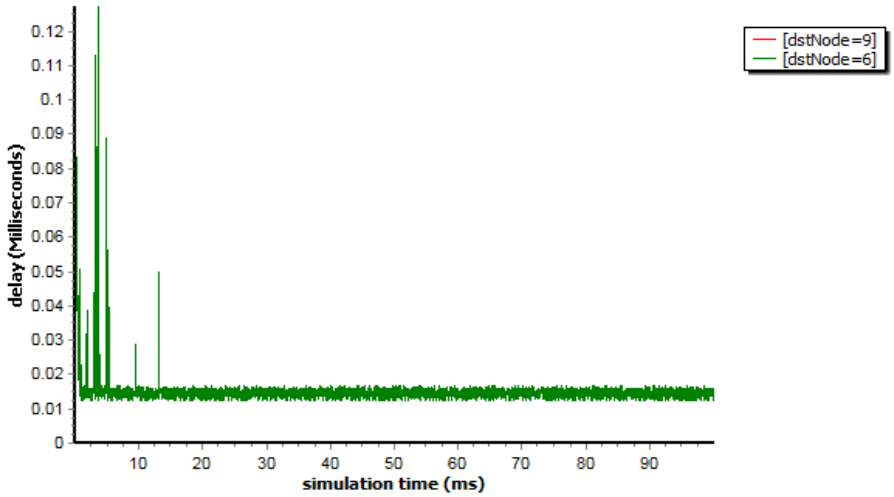


Figure 4-23: delay over time at node 6 when packet size = 50 byte.

Figure 4-23 show the delay at node 6when the packet size is 50 byte it is 0.015 ms

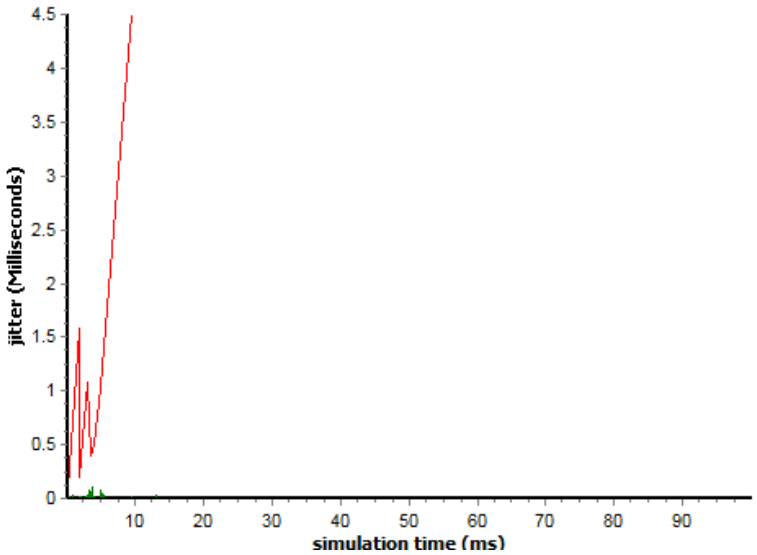


Figure 4-24: jitter over time at node 6 when pack size = 50 byte

Figure 4-24 show the jitter at node 6when the packet size is 50 byte it is about 0.0 ms.

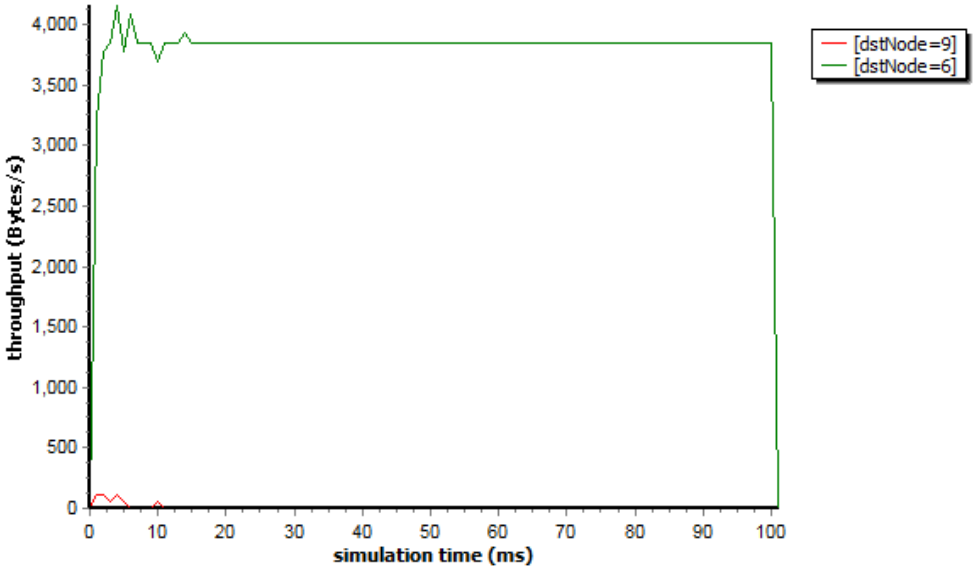


Figure 4-25 throughput over time at node 6 when pack size = 50

Figure 4-25 show the Throughput at node 6 when the packet size is 50 byte, which is 3900 bytes/s

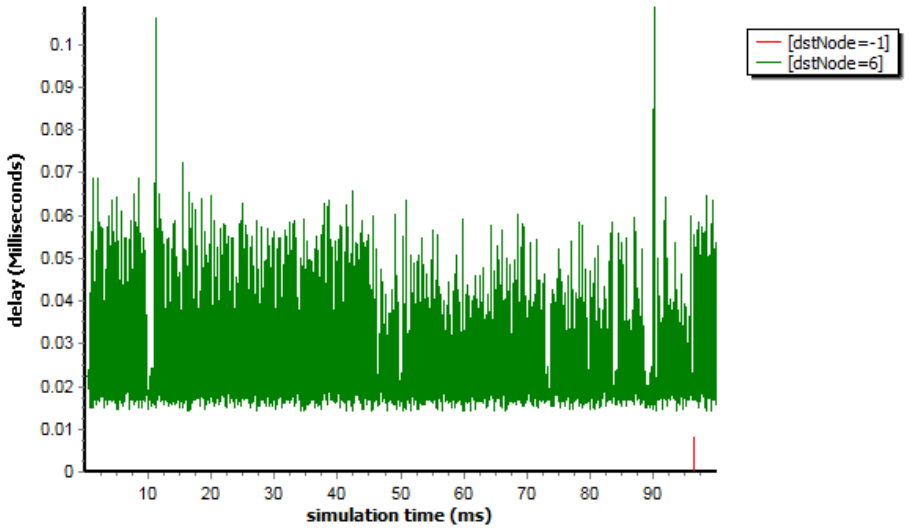


Figure 4-26: delay over time at node 6 when packet size = 70 byte

Figure 4-26 show the delay at node 6 when the packet size is 70 byte, the delay value is 0.059, which is less than the delay when the packet size is 50 byte.

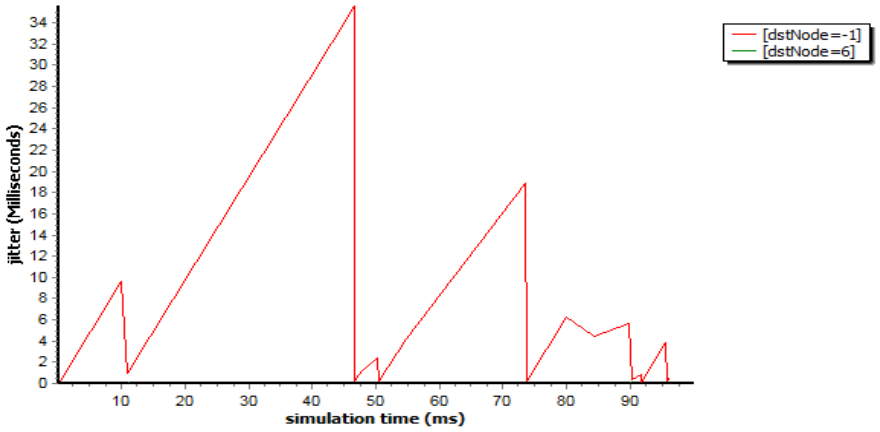


Figure 4-27 jitter over time at node 6 when packet size = 70

Figure 4-27 show the jitter at node 6 when the packet size is 70 byte, the jitter value is 0.0, which is less than the jitter when the packet size is 50 byte.

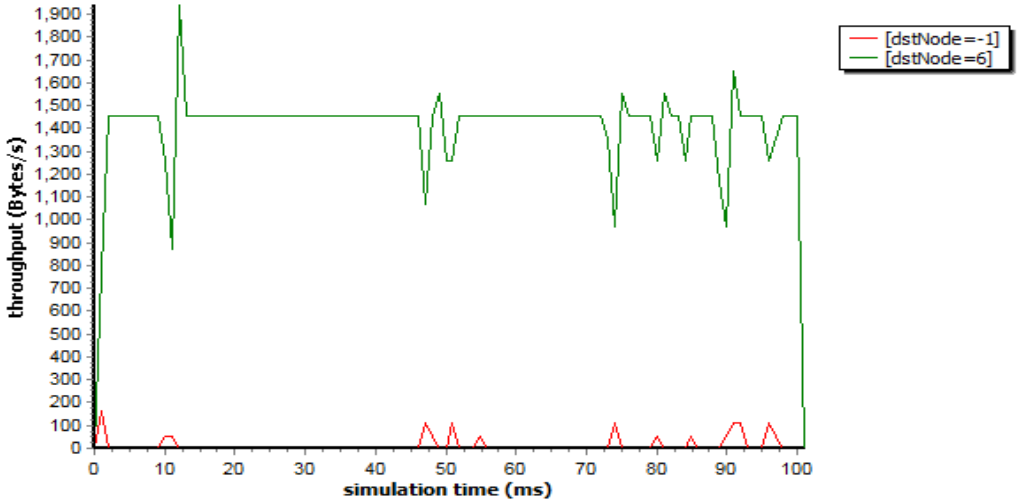


Figure 4-28: throughput over time at node 6 when packet size = 70byte

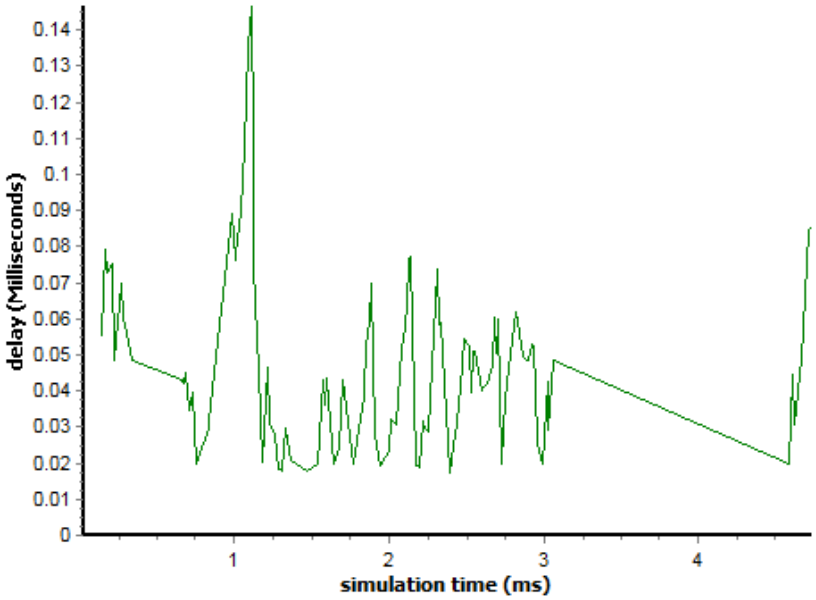


Figure 4-29: delay over time at node 6 when pack size = 100 byte

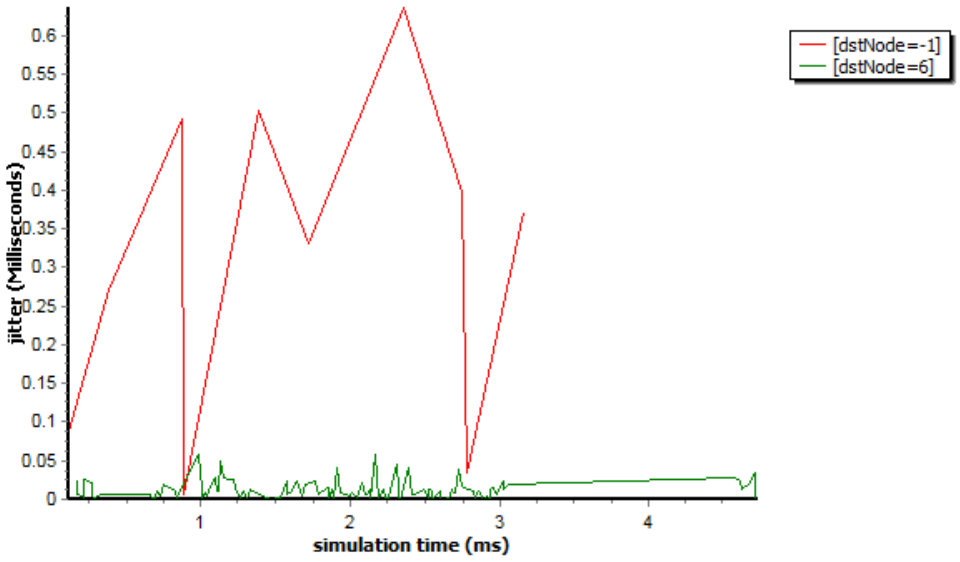


Figure 4-30: jitter over time at node 6 when pack size = 100 byte.

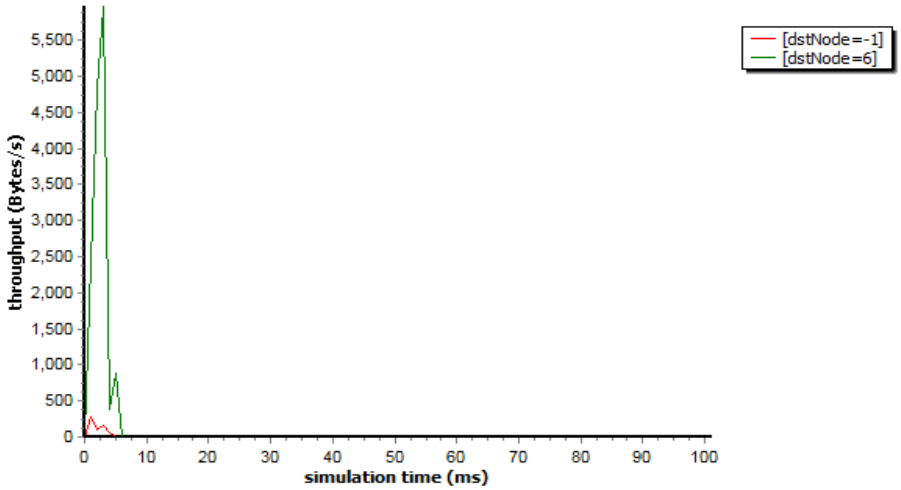


Figure 4-31: throughput over time at node 6 when packet size = 100 byte

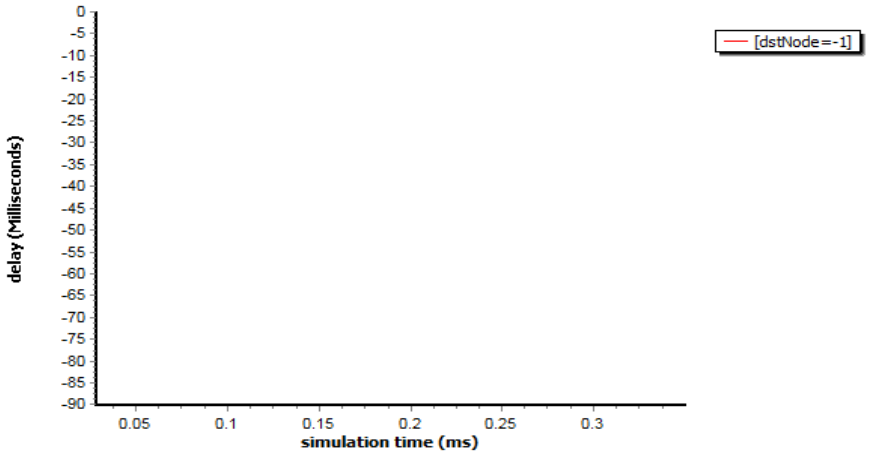


Figure 4-32: delay over time at node 6 when pack size = 120 byte

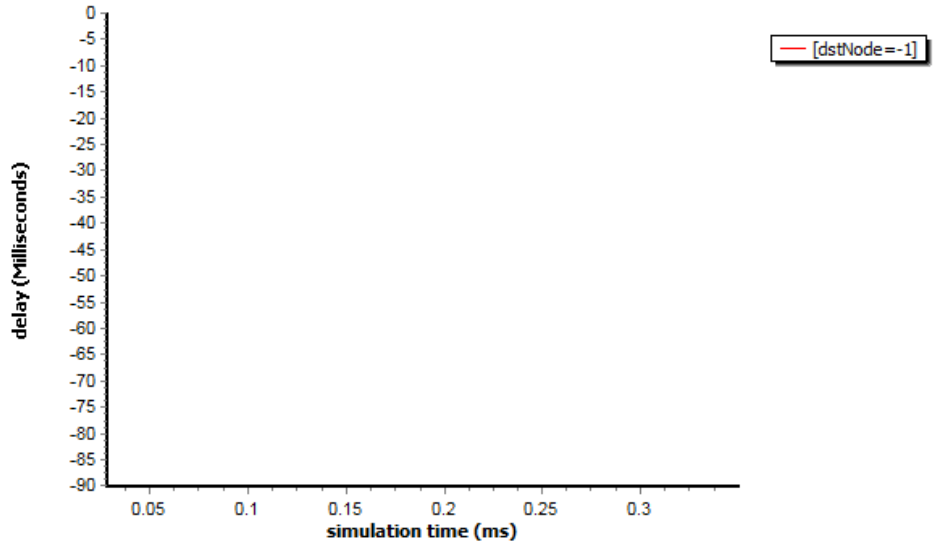


Figure 4-33: jitter over time at node 6 when pack size = 120 byte

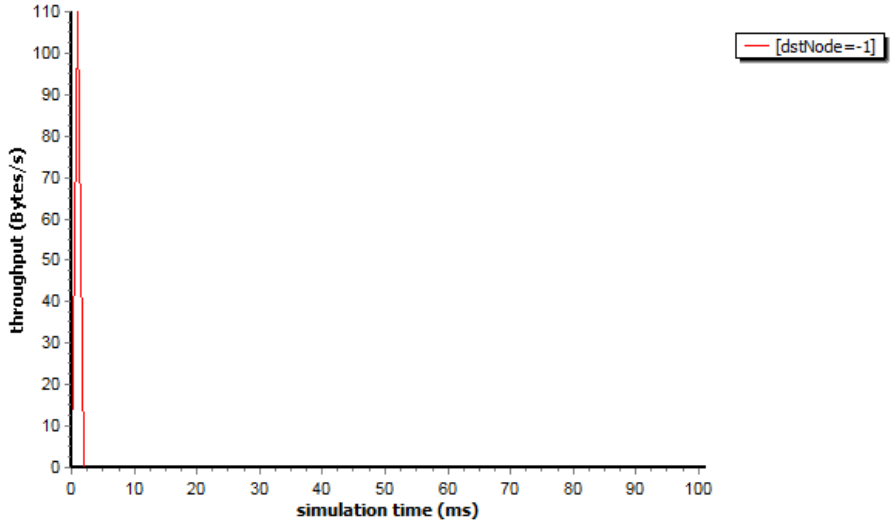


Figure 4-34: throughput over time at node 6 when packet size = 120 byte.

Table 4-15 shows the effect of packet size on the delay, jitter and throughput, 50 byte has been chosen as an optimal value of packet size depend on the results in figure 4-20 and figure 4-21, in this value the delay has a less value and throughput has a higher value.

Table 4-15: Performance data of AODV protocol with respect to packet

Packet size /byte	Delay /ms	Jitter /ms	Throughput b/s
50	0.015	0.0	3900
70	0.059	0.0	1250
100	0.029	0.03	0.0
120	0.0	0.0	0.0

4.4 Queue Size Test

In this set of simulations, a group of Queue size is ranging from 50 to 1000 packet is applied. The data rate value is 20k and the packet size is depend on the result of case 1 and case2. The TCL script for this simulation is in appendix A.

Table 4-16: Simulation environment 3

Parameter	Value
Simulator	Ns 2.34
MAC Type	802.15.4
Simulation Time	100 seconds
Channel Type	Wireless Channel
Routing protocol	AODV
Antenna Model	Omni
Simulation Area	50 m * 50 m
Traffic Type	CBR
Interface queue length	50
Interface queue type	Drop Tail
Number of nodes	26
Queue Size	50 ,100 , 500,1000

4.4.1 50 packet Queue Size Test

Queue size =50

PDF = 2520/3749 *100 = 67.2%

Packet loss = 3749-520= 1229 packet.

4.4.2 100 packet Queue Size Test

Queue size =100

Total packet sent to node = 3749.

PDF = 2520/3749 *100 = 67.2%

Packet loss = 3749-520= 1229 packet.

4.4.3 500 packet Queue Size Test

Queue size =500.

PDF = 4998/5377 *100 = 92.9 %

Packet loss = 5377-4998= 379 packet.

4.4.4 1000 packet Queue Size Test

Queue size =1000

PDF = 4998/5377 *100 = 92.9 %

Packet loss = 5377-4998= 379 packet.

When the queue size is small, the PDF is low and the packet loss is high and vice versa. As is show in table 4-17.

Table 4-17: Performance data of AODV protocol with respect to Queue

Queue size	PDF	Packet Loss
50	67.2%	1229
100	67.2%	1229
500	92.9 %	379
1000	92.9 %	379

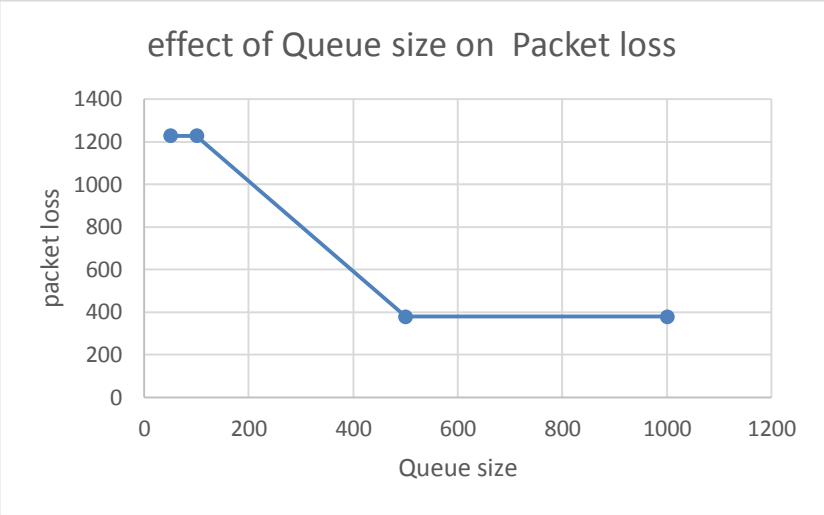


Figure 4-35: effect of Queue size on packet loss

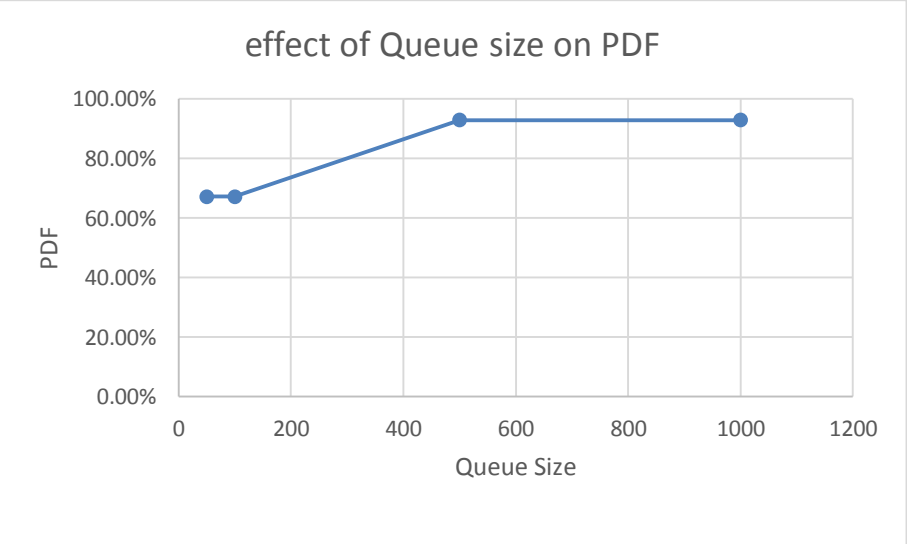


Figure 4-36: Effect of Queue size on PDF

From Figure 4-35 and 4-36 it is clear that when the Queue size is 50 or 100 the PDF is 67.2% and the packet loss is 1229, and when the queue size is 500 or 1000 the PDF is 92.9% and the packet loss is 379, so the optimal value of the Queue size is 500 or 1000.

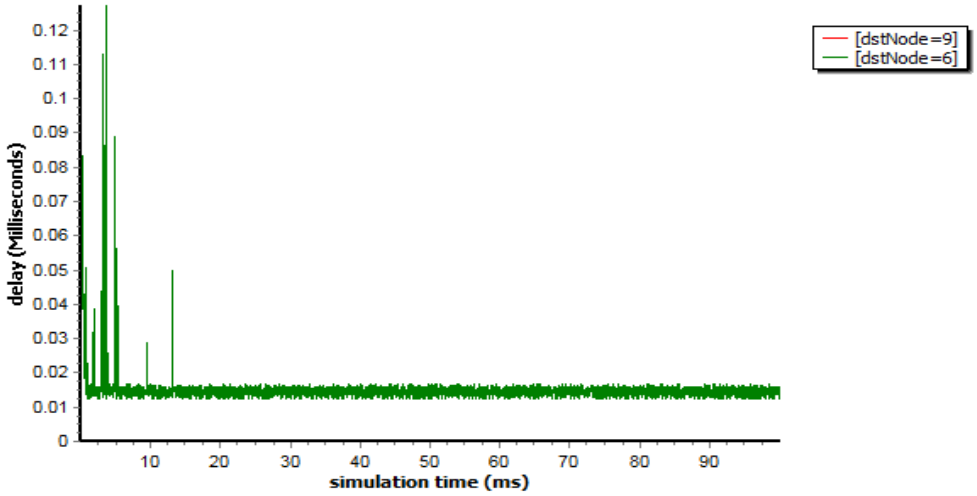


Figure 4-38: delay over time at node 6 when queue size =,500 and 1000 packet

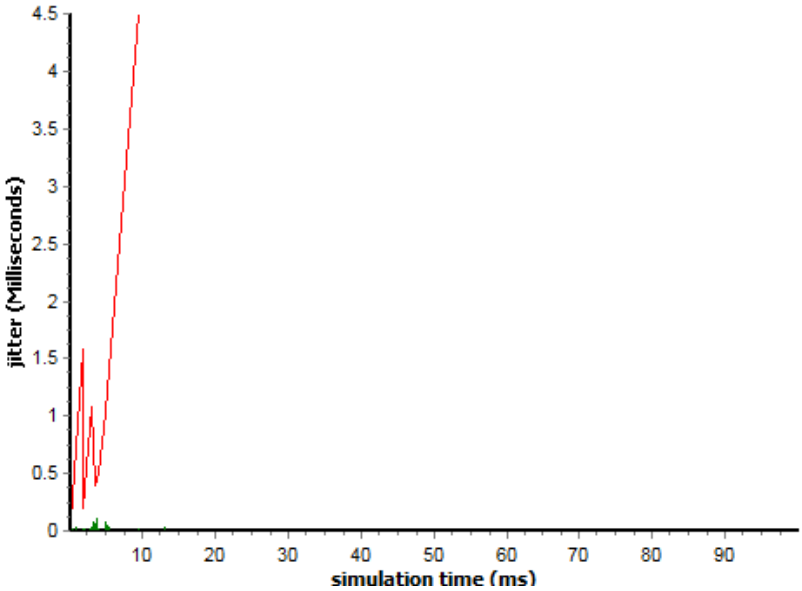


Figure 4-39: jitter over time at node 6 when queue size = 500 and 1000 packet.

Table shows the delay, jitter and throughput when the queue size has different values.

Table 4-18 Performance data of AODV protocol with respect Queue size

Queue size	Delay /ms	Jitter /ms	Throughput b/s
50	0.015	0.0	3900
100	0.12	0.0	3900
500	0.015	0.0	3900
1000	0.065	0.0	3900

In this case, 22 nodes try to access node 6 at the same time using optimal values of performance metrics.

Where

Packet size = 50 byte.

Queue size = 1000 packet.

Data rate for all nodes = 20k .

Data rate for the main node = 200k.

Area = 50*50

Simulation time = 100 sec.

- **Simulation results:**

Number of nodes received by node 6 = 3318.

CBR packet sent from node 1 to node 6 = 60.

CBR packet sent from node 5 to node 6 = 9731.

CBR packet sent from node 9 to node 6 = 378.

CBR packet sent from node 20 to node 6 = 1334.

CBR packet sent from node 23 to node 6 = 206.

CBR packet sent from node 12 to node 6 = 3098.

CBR packet sent from node 13 to node 6 = 380.

CBR packet sent from node 15 to node 6 = 349.

CBR packet sent from node 17 to node 6 = 60.

CBR packet sent from node 18 to node 6 =2.

Total number pf packet sent to node 6= 15598.

PDF = 3318/ 15598 * 100 = 21.3%.

Packet loss = 15598 – 3318 = 12280 Packet.

In this simulation when we use the optimal values of performance metrics the number of nodes, access the main node is increase to 10 nodes.to increase the number of nodes to be more than 10 node the data rate of the main node should be increase to be more than 200k.

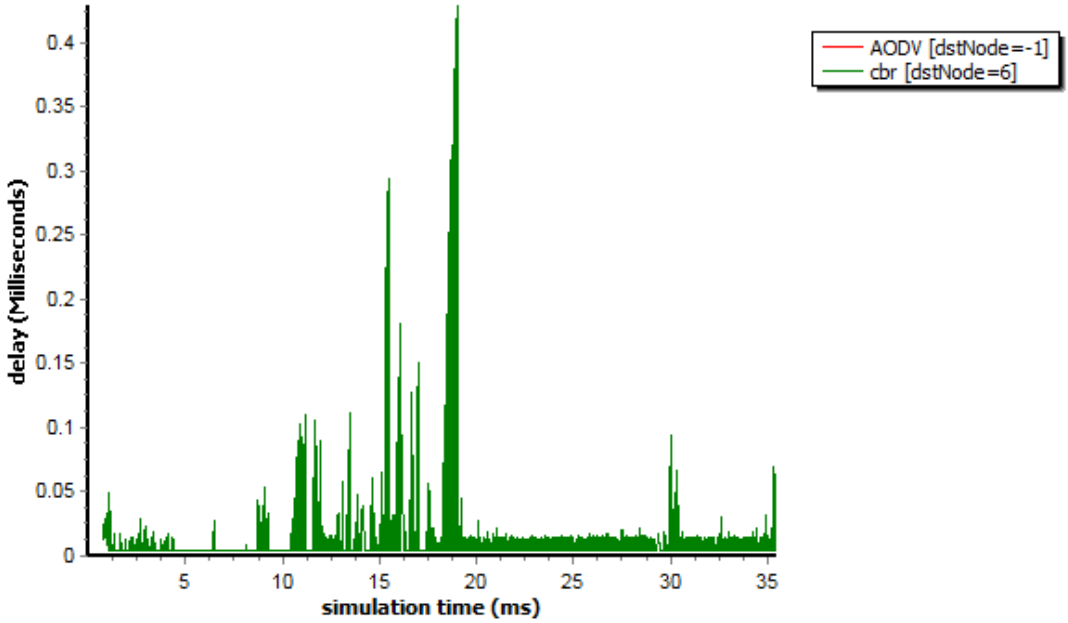


Figure 4-40: Delay over time when 10-node try to access the main node

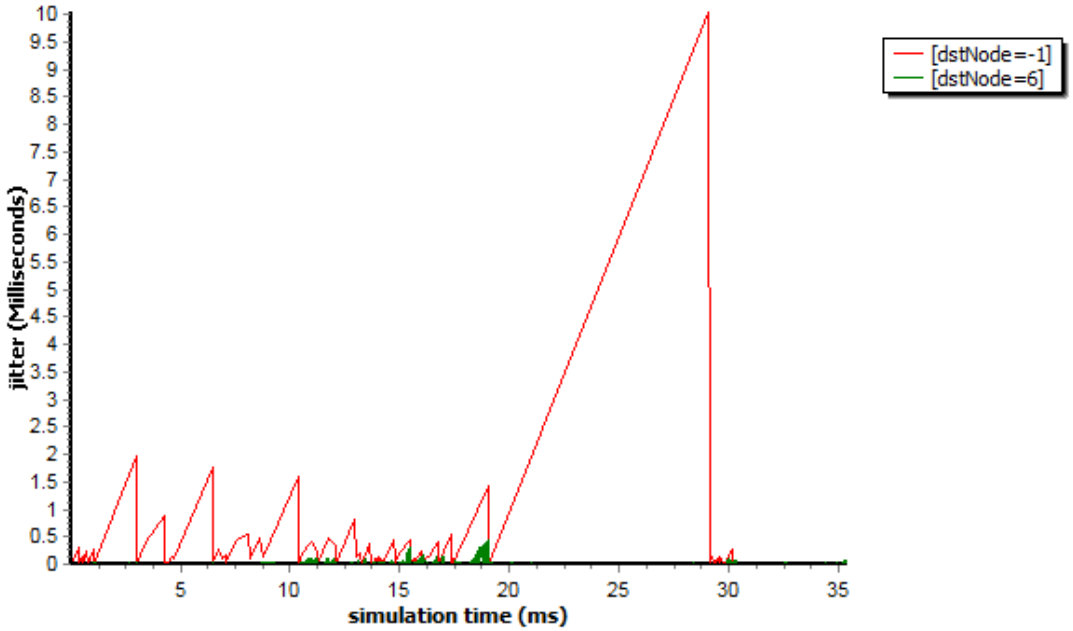


Figure 4-41: jitter over time when 10-node try to access the main node concurrently

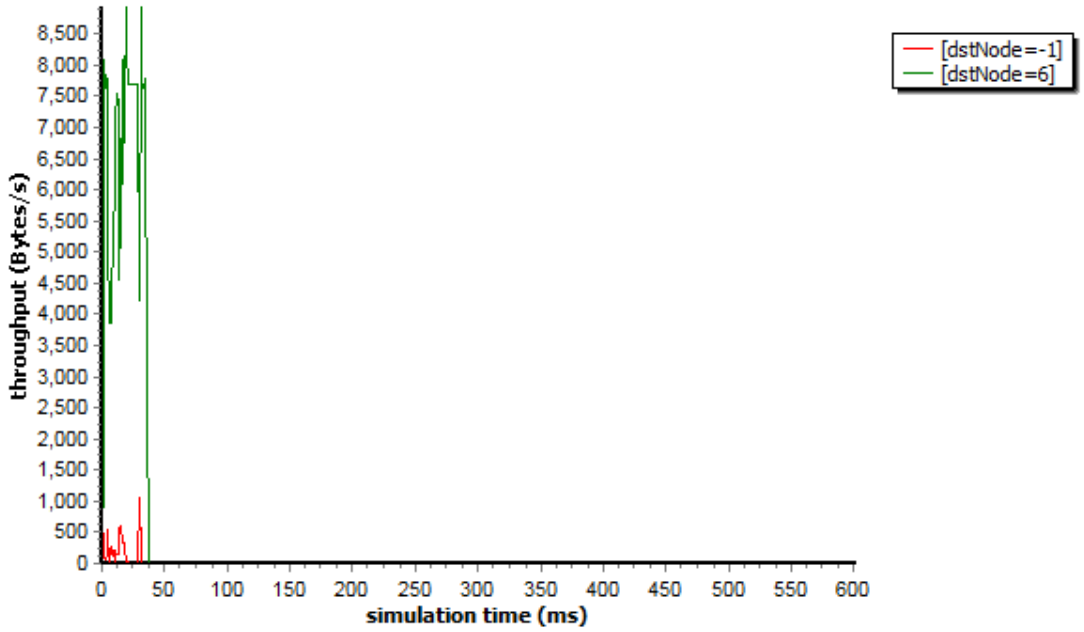


Figure 4-42: throughput over time when 10-node try to access the main node

The result show that the acceptable QoS metrics can be achieved by using packet size of 50 byte , queue size of 1000 packet and data rate of 200kpbs to the main node while maintain other node at 20kbps . It is clear from our research that whenever the rate of data increases it is better to increase the size of the packet to obtain a higher throughput of packets, as shown in table 4-10 but with the increase of the size of the packet, there is decrease in the number of user who try to reach the main equipment concurrently because the size of the queue is not suitable.

Table 4-20: literature Review Results

4 Agent , 4 Sink	*Time T (70 sec)*	
Number of node	*20*	*30*
Throughput (kbps)	*55.200*	*147.199*
Packetloss(No.of packets)	*70*	*145*
Delay(sec)	*0.01645*	*0.00839*
Packet Size(byte)	*512*	
Queue length (packet)	*50*	

Table 4-21: Case Study Results

22 agent , 1 Sink	Time T (70 sec)
Number of node	26
Throughput (kbps)	Show figure 4-3
Packet loss(No.of packets)	595
Packet delivery fraction	85%
Total byte received by destination	235410
Delay(sec)	Show figure 4-1
Packet Size(byte)	70
Queue length (packet)	50
Number of node access main node Concurrently	7

Table 4-22: Our Study Results

22 agent , 1 Sink	Time T (70 sec)
Number of node	26
Throughput (kbps)	Show figure 4-40
Packetloss(No.of packets)	12280
Packet delivery fraction	21.3%
Total byte received by destination	519000
Delay(sec)	Show figure 4-40
Packet Size(byte)	50
Queue length (packet)	1000
Number of node access main node Concurrently .	10

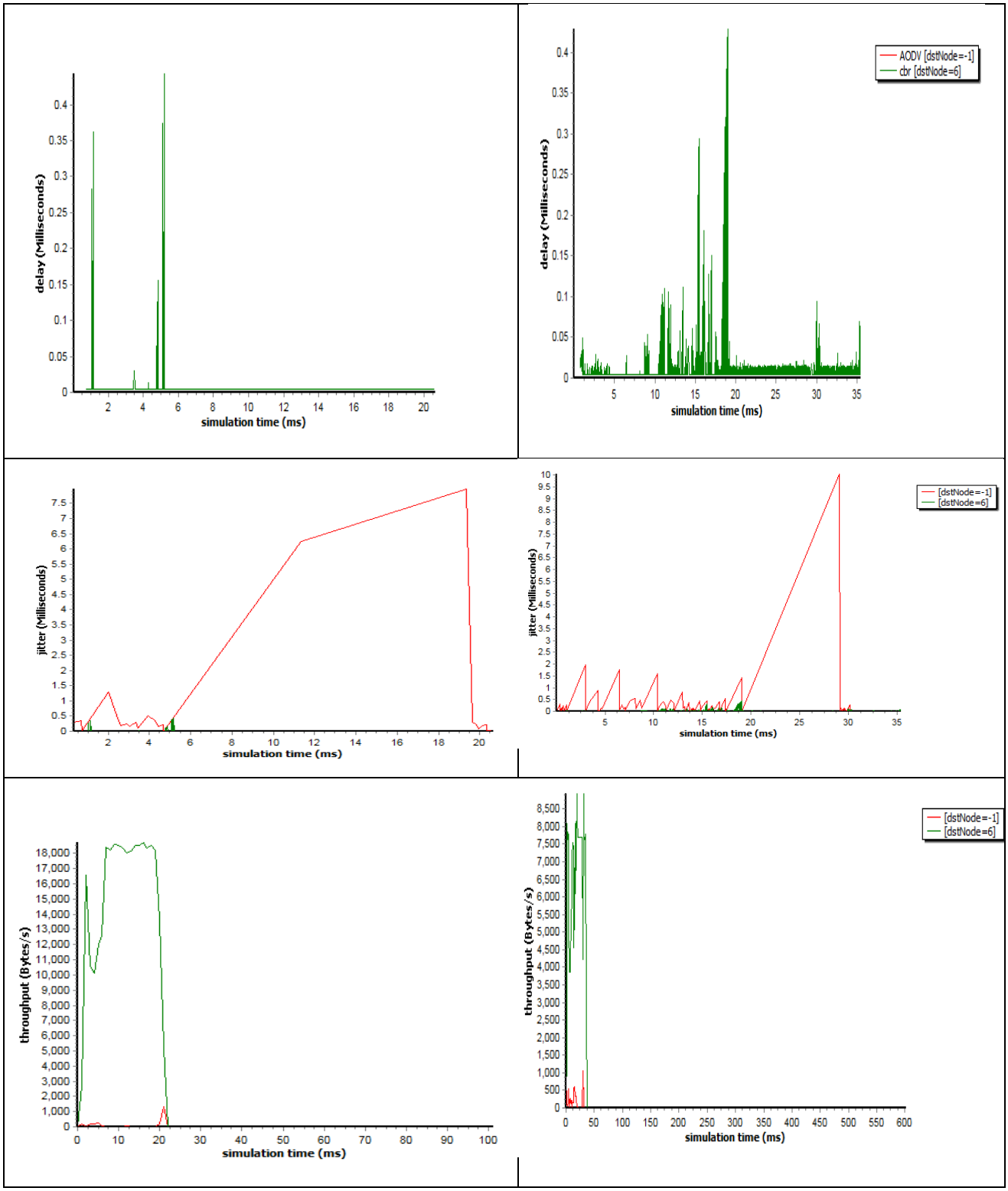


Figure 4-43: value of delay, jitter and throughput before and after simulation.

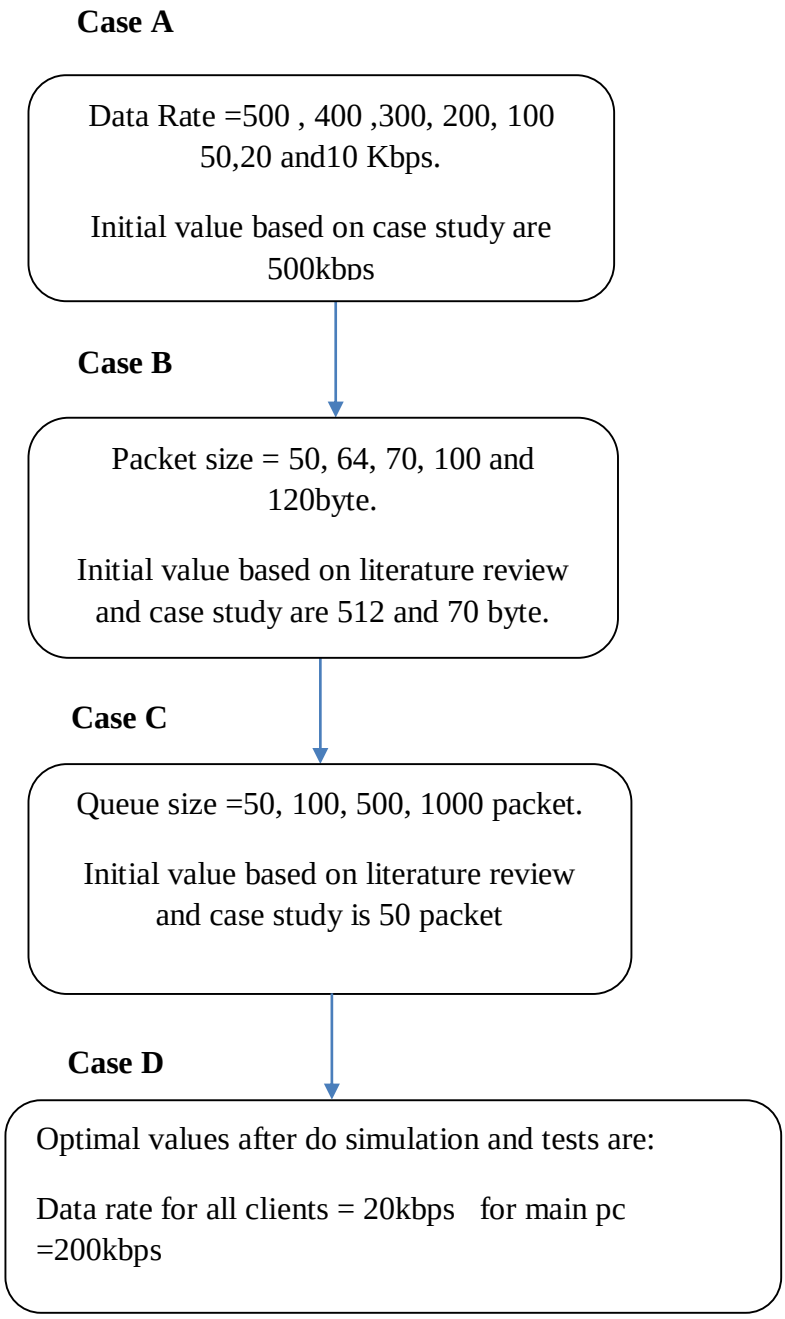


Figure 4-44 Simulation scenario

Figure 4-44 shows a group of different values related to performance metrics are tested in the previous simulation using ns2 software.

Chapter Five

Conclusions and recommendations

5.1 Introduction

5.2 Conclusion

This thesis introduce how to enhance the virtual classroom environment by evaluate and optimize Quality of Service metrics in Mobile ad-hoc network IEEE 802.15.4 using AODV protocol, Because of the necessity of QoS in ad hoc networks, a few QoS relevant works are described. Finally, a simulation tool, NS2, is introduced and some simulations are done to test the performance of the AODV routing protocol in different scenarios.

Different group of performance metric have been tested to determine an optimal value, to enhance the virtual classroom environment by increasing number of nodes that can access the main node concurrently with acceptable values of Qos metrics. Furthermore is also aims minimize the packet loss, delay and jitter and maximize throughput and PDF.

That data rate of the main node should be 10 times the data rate of the client node, in this case 10 clients at most access the main node concurrent.

Recommendation:

There are many issues related to ad-hoc networks that could be subject to further studies:

- It will be better to enable the master node to generate adaptive optimum values according to the number of node i.e. if the number of node is 10 data rate should be 100 kbps, packet size is 50 byte

and queue size is 1000 packet this will enhance the AODV to work in adaptive manner.

- In this research, the effect of security is neglected. Further research are advised to consider the security issue in AODV.
- Pause time and speed moving could be additional metrics but they are not mentioned in this study.
- The simulation environment (NS-2) could be improved to enable future using to check high values of the parameters.
- As mentioned in the result it is Cleary show that as the number of nodes (that try to access the main node concurrently) increasing with the constant of parameters (packet size – queue size and data rate) the throughput will be high, so an adaptive set of recommendation to the end user to adjust this parameter is urgently need to maintain the connectivity while having high throughput.

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Appendix A TCL Script

```
#
# ======================================================================
# Define options
#
# ======================================================================
set val(chan)           Channel/WirelessChannel    ;# Channel
Type
set val(prop)           Propagation/TwoRayGround   ;# radio-
propagation model
set val(netif)          Phy/WirelessPhy/802_15_4
set val(mac)            Mac/802_15_4
set val(ifq)            Queue/DropTail/PriQueue    ;# interface
queue type
set val(ll)             LL                         ;# link layer
type
set val(ant)            Antenna/OmniAntenna        ;# antenna
model
set val(ifqlen)         50                         ;# max packet
in ifq
set val(nn)             26                         ;# number of
mobilenodes
set val(rp)             AODV                       ;# routing
protocol
set val(x)       50
set val(y)       50

set val(nam)           wpan_demo1.nam
set val(traffic) cbr                       ;# cbr/poisson/ftp

#read command line arguments
proc getCmdArgu {argc argv} {
        global val
        for {set i 0} {$i < $argc} {incr i} {
                set arg [lindex $argv $i]
                if {[string range $arg 0 0] != "-"} continue
                set name [string range $arg 1 end]
                set val($name) [lindex $argv [expr $i+1]]
        }
}
getCmdArgu $argc $argv

set appTime1            0.0  ;# in seconds
set appTime2            0.3  ;# in seconds
set appTime3            0.5  ;# in seconds
set appTime4            0.7     ;# in seconds
set appTime5            0.7     ;# in seconds
set appTime6            0.7     ;# in seconds

set stopTime            100  ;# in seconds

# Initialize Global Variables
```

```
set ns_          [new Simulator]
set tracefd     [open ./wpan_demo1.tr w]
$ns_ trace-all $tracefd
if { "$val(nam)" == "wpan_demo1.nam" } {
        set namtrace     [open ./$val(nam) w]
        $ns_ namtrace-all-wireless $namtrace $val(x) $val(y)
}

$ns_ puts-nam-traceall {# nam4wpan #}         ;# inform nam that
this is a trace file for wpan (special handling needed)

Mac/802_15_4 wpanNam namStatus on       ;# default = off (should
be turned on before other 'wpanNam' commands can work)
#Mac/802_15_4 wpanNam ColFlashClr gold        ;# default = gold
#Mac/802_15_4 wpanNam NodeFailClr grey        ;# default = grey


# For model 'TwoRayGround'
set dist(5m)  7.69113e-06
set dist(9m)  2.37381e-06
set dist(10m) 1.92278e-06
set dist(11m) 1.58908e-06
set dist(12m) 1.33527e-06
set dist(13m) 1.13774e-06
set dist(14m) 9.81011e-07
set dist(15m) 8.54570e-07
set dist(16m) 7.51087e-07
set dist(20m) 4.80696e-07
set dist(25m) 3.07645e-07
set dist(30m) 2.13643e-07
set dist(35m) 1.56962e-07
set dist(40m) 1.20174e-07
Phy/WirelessPhy set CSThresh_ $dist(15m)
Phy/WirelessPhy set RXThresh_ $dist(15m)

# set up topography object
set topo       [new Topography]
$topo load_flatgrid $val(x) $val(y)

# Create God
set god_ [create-god $val(nn)]

set chan_1_ [new $val(chan)]

# configure node

$ns_ node-config -adhocRouting $val(rp) \
            -llType $val(ll) \
            -macType $val(mac) \
            -ifqType $val(ifq) \
            -ifqLen $val(ifqlen) \
            -antType $val(ant) \
            -propType $val(prop) \
            -phyType $val(netif) \
            -topoInstance $topo \
            -agentTrace OFF \
            -routerTrace OFF \
            -macTrace ON \
            -movementTrace OFF \
```

```
                #-energyModel "EnergyModel" \
                #-initialEnergy 1 \
                #-rxPower 0.3 \
                #-txPower 0.3 \
            -channel $chan_1_

for {set i 0} {$i < $val(nn) } {incr i} {
      set node_($i) [$ns_ node]
      $node_($i) random-motion 0        ;# disable random motion
}

source ./wpan_demo1.scn

# Setup traffic flow between nodes

proc cbrtraffic { src dst interval starttime } {
   global ns_ node_
   set udp($src) [new Agent/UDP]
   eval $ns_ attach-agent \$node_($src) \$udp($src)
   set null($dst) [new Agent/Null]
   eval $ns_ attach-agent \$node_($dst) \$null($dst)
   set cbr($src) [new Application/Traffic/CBR]
   eval \$cbr($src) set packetSize_ 50
   eval \$cbr($src) set interval_ $interval
   eval \$cbr($src) set random_ 0
   eval \$cbr($src) set rate_ 50Kb
   #eval \$cbr($src) set maxpkts_ 10000
   eval \$cbr($src) attach-agent \$udp($src)
   eval $ns_ connect \$udp($src) \$null($dst)
   $ns_ at $starttime "$cbr($src) start"
}

proc poissontraffic { src dst interval starttime } {
   global ns_ node_
   set udp($src) [new Agent/UDP]
   eval $ns_ attach-agent \$node_($src) \$udp($src)
   set null($dst) [new Agent/Null]
   eval $ns_ attach-agent \$node_($dst) \$null($dst)
   set expl($src) [new Application/Traffic/Exponential]
   eval \$expl($src) set packetSize_ 70
   eval \$expl($src) set burst_time_ 0
   eval \$expl($src) set idle_time_ [expr $interval*1000.0-
70.0*8/250]ms    ;# idle_time + pkt_tx_time = interval
   eval \$expl($src) set rate_ 250k
   eval \$expl($src) attach-agent \$udp($src)
   eval $ns_ connect \$udp($src) \$null($dst)
   $ns_ at $starttime "$expl($src) start"
}

if { ("$val(traffic)" == "cbr") || ("$val(traffic)" == "poisson")
} {
   puts "\nTraffic: $val(traffic)"
   #Mac/802_15_4 wpanCmd ack4data on
   puts [format "Acknowledgement for data: %s" [Mac/802_15_4
wpanCmd ack4data]]
   set lowSpeed 0.5ms
   set highSpeed 1.5ms
   Mac/802_15_4 wpanNam PlaybackRate $lowSpeed
```

```
   $ns_ at [expr $appTime1+0.1] "Mac/802_15_4 wpanNam
PlaybackRate $highSpeed"
   $ns_ at $appTime2 "Mac/802_15_4 wpanNam PlaybackRate
$lowSpeed"
   $ns_ at [expr $appTime2+0.1] "Mac/802_15_4 wpanNam
PlaybackRate $highSpeed"
   $ns_ at $appTime3 "Mac/802_15_4 wpanNam PlaybackRate
$lowSpeed"
   $ns_ at [expr $appTime3+0.1] "Mac/802_15_4 wpanNam
PlaybackRate $highSpeed"
   eval $val(traffic)traffic 19 6 0.2 $appTime1
   eval $val(traffic)traffic 10 4 0.2 $appTime2
   eval $val(traffic)traffic 3 2 0.2 $appTime3
   eval $val(traffic)traffic 1 6 0.2 $appTime4
   eval $val(traffic)traffic 20 6 0.2 $appTime5
   eval $val(traffic)traffic 9 6 0.2 $appTime6


   Mac/802_15_4 wpanNam FlowClr -p AODV -c tomato
   Mac/802_15_4 wpanNam FlowClr -p ARP -c green
   if { "$val(traffic)" == "cbr" } {
      set pktType cbr
   } else {
      set pktType exp
   }
   Mac/802_15_4 wpanNam FlowClr -p $pktType -s 19 -d 6 -c blue
   Mac/802_15_4 wpanNam FlowClr -p $pktType -s 10 -d 4 -c green4
   Mac/802_15_4 wpanNam FlowClr -p $pktType -s 3 -d 2 -c cyan4
   Mac/802_15_4 wpanNam FlowClr -p $pktType -s 1 -d 6 -c red
   Mac/802_15_4 wpanNam FlowClr -p $pktType -s 20 -d 6 -c blue
   Mac/802_15_4 wpanNam FlowClr -p $pktType -s 9 -d 6 -c green4

   $ns_ at $appTime1 "$node_(19) NodeClr blue"
   $ns_ at $appTime1 "$node_(6) NodeClr blue"
   $ns_ at $appTime1 "$ns_ trace-annotate \"(at $appTime1)
$val(traffic) traffic from node 19 to node 6\""
   $ns_ at $appTime2 "$node_(10) NodeClr green4"
   $ns_ at $appTime2 "$node_(4) NodeClr green4"
   $ns_ at $appTime2 "$ns_ trace-annotate \"(at $appTime2)
$val(traffic) traffic from node 10 to node 4\""
   $ns_ at $appTime3 "$node_(3) NodeClr cyan3"
   $ns_ at $appTime3 "$node_(2) NodeClr cyan3"
   $ns_ at $appTime3 "$ns_ trace-annotate \"(at $appTime3)
$val(traffic) traffic from node 3 to node 2\""
   $ns_ at $appTime4 "$node_(1) NodeClr red"
   $ns_ at $appTime4 "$node_(6) NodeClr red"
   $ns_ at $appTime4 "$ns_ trace-annotate \"(at $appTime4)
$val(traffic) traffic from node 1 to node 6\""

  $ns_ at $appTime5 "$node_(20) NodeClr blue"
   $ns_ at $appTime5 "$node_(6) NodeClr blue"
   $ns_ at $appTime5 "$ns_ trace-annotate \"(at $appTime5)
$val(traffic) traffic from node 20 to node 6\""

   $ns_ at $appTime6 "$node_(9) NodeClr green4"
   $ns_ at $appTime6 "$node_(6) NodeClr green4"
   $ns_ at $appTime6 "$ns_ trace-annotate \"(at $appTime6)
$val(traffic) traffic from node 9 to node 6\""
}
```

```
proc ftptraffic { src dst starttime } {
   global ns_ node_
   set tcp($src) [new Agent/TCP]
   eval \$tcp($src) set packetSize_ 60
   set sink($dst) [new Agent/TCPSink]
   eval $ns_ attach-agent \$node_($src) \$tcp($src)
   eval $ns_ attach-agent \$node_($dst) \$sink($dst)
   eval $ns_ connect \$tcp($src) \$sink($dst)
   set ftp($src) [new Application/FTP]
   eval \$ftp($src) attach-agent \$tcp($src)
   $ns_ at $starttime "$ftp($src) start"
}

if { "$val(traffic)" == "ftp" } {
   puts "\nTraffic: ftp"
   #Mac/802_15_4 wpanCmd ack4data off
   puts [format "Acknowledgement for data: %s" [Mac/802_15_4
wpanCmd ack4data]]
   set lowSpeed 0.20ms
   set highSpeed 1.5ms
   Mac/802_15_4 wpanNam PlaybackRate $lowSpeed
   $ns_ at [expr $appTime1+0.2] "Mac/802_15_4 wpanNam
PlaybackRate $highSpeed"
   $ns_ at $appTime2 "Mac/802_15_4 wpanNam PlaybackRate
$lowSpeed"
   $ns_ at [expr $appTime2+0.2] "Mac/802_15_4 wpanNam
PlaybackRate $highSpeed"
   $ns_ at $appTime3 "Mac/802_15_4 wpanNam PlaybackRate
$lowSpeed"
   $ns_ at [expr $appTime3+0.2] "Mac/802_15_4 wpanNam
PlaybackRate 1ms"
   $ns_ at $appTime4 "Mac/802_15_4 wpanNam PlaybackRate
$lowSpeed"
   $ns_ at [expr $appTime4+0.2] "Mac/802_15_4 wpanNam
PlaybackRate 1ms"
   ftptraffic 19 6 $appTime1
   ftptraffic 10 4 $appTime2
   ftptraffic 3 2 $appTime3
   ftptraffic 15 25 $appTime4
   Mac/802_15_4 wpanNam FlowClr -p AODV -c tomato
   Mac/802_15_4 wpanNam FlowClr -p ARP -c green
   Mac/802_15_4 wpanNam FlowClr -p tcp -s 19 -d 6 -c blue
   Mac/802_15_4 wpanNam FlowClr -p ack -s 6 -d 19 -c blue
   Mac/802_15_4 wpanNam FlowClr -p tcp -s 10 -d 4 -c green4
   Mac/802_15_4 wpanNam FlowClr -p ack -s 4 -d 10 -c green4
   Mac/802_15_4 wpanNam FlowClr -p tcp -s 3 -d 2 -c cyan4
   Mac/802_15_4 wpanNam FlowClr -p ack -s 2 -d 3 -c cyan4
   Mac/802_15_4 wpanNam FlowClr -p tcp -s 1 -d 6 -c red
   Mac/802_15_4 wpanNam FlowClr -p ack -s 6 -d 1 -c red
   Mac/802_15_4 wpanNam FlowClr -p tcp -s 20 -d 6 -c blue
   Mac/802_15_4 wpanNam FlowClr -p ack -s 6 -d 20 -c blue
Mac/802_15_4 wpanNam FlowClr -p tcp -s 9 -d 6 -c green4
   Mac/802_15_4 wpanNam FlowClr -p ack -s 6 -d 9 -c green4
   $ns_ at $appTime1 "$node_(19) NodeClr blue"
   $ns_ at $appTime1 "$node_(6) NodeClr blue"
   $ns_ at $appTime1 "$ns_ trace-annotate \"(at $appTime1) ftp
traffic from node 19 to node 6\""
   $ns_ at $appTime2 "$node_(10) NodeClr green4"
```

```
   $ns_ at $appTime2 "$node_(4) NodeClr green4"
   $ns_ at $appTime2 "$ns_ trace-annotate \"(at $appTime2) ftp
traffic from node 10 to node 4\""
   $ns_ at $appTime3 "$node_(3) NodeClr cyan3"
   $ns_ at $appTime3 "$node_(2) NodeClr cyan3"
   $ns_ at $appTime3 "$ns_ trace-annotate \"(at $appTime3) ftp
traffic from node 3 to node 2\""
   $ns_ at $appTime4 "$node_(1) NodeClr red"
   $ns_ at $appTime4 "$node_(6) NodeClr red"
   $ns_ at $appTime4 "$ns_ trace-annotate \"(at $appTime4)
$val(traffic) traffic from node 1 to node 6\""

  $ns_ at $appTime5 "$node_(20) NodeClr blue"
   $ns_ at $appTime5 "$node_(6) NodeClr blue"
   $ns_ at $appTime5 "$ns_ trace-annotate \"(at $appTime5)
$val(traffic) traffic from node 20 to node 6\""

   $ns_ at $appTime6 "$node_(9) NodeClr green4"
   $ns_ at $appTime6 "$node_(6) NodeClr green4"
   $ns_ at $appTime6 "$ns_ trace-annotate \"(at $appTime6)
$val(traffic) traffic from node 9 to node 6\""

}

# defines the node size in nam
for {set i 0} {$i < $val(nn)} {incr i} {
      $ns_ initial_node_pos $node_($i) 2
}

# Tell nodes when the simulation ends
for {set i 0} {$i < $val(nn) } {incr i} {
    $ns_ at $stopTime "$node_($i) reset";
}

$ns_ at $stopTime "stop"
$ns_ at $stopTime "puts \"\nNS EXITING...\""
$ns_ at $stopTime "$ns_ halt"

proc stop {} {
    global ns_ tracefd val env
    $ns_ flush-trace
    close $tracefd
    set hasDISPLAY 0
    foreach index [array names env] {
        #puts "$index: $env($index)"
        if { ("$index" == "DISPLAY") && ("$env($index)" != "") }
{
                set hasDISPLAY 1
        }
    }
    if { ("$val(nam)" == "wpan_demo1.nam") && ("$hasDISPLAY" ==
"1") } {
          exec nam wpan_demo1.nam &
    }
}

puts "\nStarting Simulation..."
$ns_ run
```

APPENDEX B Trace File

```
s 0.290775880 _24_ MAC  --- 107 cbr 77 [0 6 18 800] ------- [19:0
6:0 27 6] [107] 3 0
D 0.291225000 _19_ IFQ  --- 364 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [364] 0 0
D 0.292025000 _19_ IFQ  --- 365 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [365] 0 0
D 0.292825000 _19_ IFQ  --- 366 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [366] 0 0
D 0.292983830 _21_ MAC  LQI 108 cbr 77 [0 15 14 800] -------
[19:0 6:0 29 21] [108] 1 0
s 0.293623909 _6_ MAC  --- 107 ACK 5 [0 18 6 0]
D 0.293625000 _19_ IFQ  --- 367 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [367] 0 0
r 0.293975939 _24_ MAC  --- 107 ACK 5 [0 18 6 0]
D 0.294425000 _19_ IFQ  --- 368 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [368] 0 0
r 0.294615909 _6_ MAC  --- 107 cbr 70 [0 6 18 800] ------- [19:0
6:0 27 6] [107] 4 0
s 0.295127783 _20_ MAC  --- 108 cbr 77 [0 15 14 800] -------
[19:0 6:0 29 21] [108] 1 0
D 0.295225000 _19_ IFQ  --- 369 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [369] 0 0
D 0.296025000 _19_ IFQ  --- 370 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [370] 0 0
D 0.296825000 _19_ IFQ  --- 371 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [371] 0 0
D 0.297462370 _19_ IFQ  --- 55 cbr 70 [0 14 13 800] ------- [19:0
6:0 30 20] [55] 0 0
D 0.297625000 _19_ IFQ  --- 372 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [372] 0 0
s 0.297975830 _21_ MAC  --- 108 ACK 5 [0 14 15 0]
r 0.298327877 _20_ MAC  --- 108 ACK 5 [0 14 15 0]
D 0.298425000 _19_ IFQ  --- 373 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [373] 0 0
r 0.298967830 _21_ MAC  --- 108 cbr 70 [0 15 14 800] -------
[19:0 6:0 29 21] [108] 2 0
D 0.299225000 _19_ IFQ  --- 374 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [374] 0 0
v 0.29999999999999999 eval {set sim_annotation {(at 0.3) cbr
traffic from node 10 to node 4}}
D 0.300025000 _19_ IFQ  --- 376 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [375] 0 0
D 0.300825000 _19_ IFQ  --- 378 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [376] 0 0
s 0.301577830 _21_ MAC  --- 108 cbr 77 [0 18 15 800] -------
[19:0 6:0 28 24] [108] 2 0
D 0.301625000 _19_ IFQ  --- 380 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [377] 0 0
D 0.302425000 _19_ IFQ  --- 382 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [378] 0 0
s 0.302585000 _10_ MAC  --- 0 AODV 55 [0 ffffffff a 800] -------
[10:255 -1:255 30 0] [0x2 1 1 [4 0] [10 4]] (REQUEST)
s 0.302615644 _19_ MAC  --- 109 cbr 77 [0 14 13 800] -------
[19:0 6:0 30 20] [109] 0 0
D 0.303225000 _19_ IFQ  --- 384 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [379] 0 0
```

```
D 0.304025000 _19_ IFQ  --- 386 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [380] 0 0
s 0.304425858 _24_ MAC  --- 108 ACK 5 [0 15 18 0]
r 0.304777886 _21_ MAC  --- 108 ACK 5 [0 15 18 0]
D 0.304825000 _19_ IFQ  --- 388 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [381] 0 0
r 0.305177028 _9_ MAC  --- 0 AODV 48 [0 ffffffff a 800] -------
[10:255 -1:255 30 0] [0x2 1 1 [4 0] [10 4]] (REQUEST)
r 0.305177045 _13_ MAC  --- 0 AODV 48 [0 ffffffff a 800] -------
[10:255 -1:255 30 0] [0x2 1 1 [4 0] [10 4]] (REQUEST)
D 0.305271693 _20_ MAC  LQI 109 cbr 77 [0 14 13 800] -------
[19:0 6:0 30 20] [109] 0 0
r 0.305417858 _24_ MAC  --- 108 cbr 70 [0 18 15 800] -------
[19:0 6:0 28 24] [108] 3 0
D 0.305625000 _19_ IFQ  --- 390 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [382] 0 0
D 0.306135644 _19_ RTR  CBK 109 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [109] 0 0
D 0.306135644 _19_ RTR  CBK 34 cbr 70 [0 14 13 800] ------- [19:0
6:0 30 20] [34] 0 0
D 0.306135644 _19_ RTR  CBK 110 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [110] 0 0
D 0.306135644 _19_ RTR  CBK 111 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [111] 0 0
D 0.306135644 _19_ RTR  CBK 112 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [112] 0 0
D 0.306135644 _19_ RTR  CBK 113 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [113] 0 0
D 0.306135644 _19_ RTR  CBK 114 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [114] 0 0
D 0.306135644 _19_ RTR  CBK 115 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [115] 0 0
D 0.306135644 _19_ RTR  CBK 116 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [116] 0 0
D 0.306135644 _19_ RTR  CBK 117 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [117] 0 0
D 0.306135644 _19_ RTR  CBK 118 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [118] 0 0
D 0.306135644 _19_ RTR  CBK 119 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [119] 0 0
D 0.306135644 _19_ RTR  CBK 120 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [120] 0 0
D 0.306135644 _19_ RTR  CBK 121 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [121] 0 0
D 0.306135644 _19_ RTR  CBK 35 cbr 70 [0 14 13 800] ------- [19:0
6:0 30 20] [35] 0 0
D 0.306135644 _19_ RTR  CBK 122 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [122] 0 0
D 0.306135644 _19_ RTR  CBK 123 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [123] 0 0
D 0.306135644 _19_ RTR  CBK 124 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [124] 0 0
D 0.306135644 _19_ RTR  CBK 125 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [125] 0 0
D 0.306135644 _19_ RTR  CBK 126 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [126] 0 0
D 0.306135644 _19_ RTR  CBK 127 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [127] 0 0
```

```
D 0.306135644 _19_ RTR  CBK 128 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [128] 0 0
D 0.306135644 _19_ RTR  CBK 129 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [129] 0 0
D 0.306135644 _19_ RTR  CBK 130 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [130] 0 0
D 0.306135644 _19_ RTR  CBK 131 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [131] 0 0
D 0.306135644 _19_ RTR  CBK 132 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [132] 0 0
D 0.306135644 _19_ RTR  CBK 133 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [133] 0 0
D 0.306135644 _19_ RTR  CBK 134 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [134] 0 0
D 0.306135644 _19_ RTR  CBK 36 cbr 70 [0 14 13 800] ------- [19:0
6:0 30 20] [36] 0 0
D 0.306135644 _19_ RTR  CBK 135 cbr 70 [0 14 13 800] -------
[19:0 6:0 30 20] [135] 0 0
```

APPINDEX C Simulation Results

CBR packet received by node 6 = 3363 packet.

CBR packet sent from node 0 to node 6 = 17 packet.

CBR packet sent from node 1 to node 6 = 0 packet.

CBR packet sent from node 2 to node 6 = 0 packet.

CBR packet sent from node 4 to node 6 = 0 packet

CBR packet sent from node 5 to node 6 = 0 packet.

CBR packet sent from node 7 to node 6 = 0 packet.

CBR packet sent from node 8 to node 6 = 0 packet.

CBR packet sent from node 9 to node 6 = 0 packet.

CBR packet sent from node 12 to node 6 = 0 packet.

CBR packet sent from node 13 to node 6 = 24 packet.

CBR packet sent from node 14 to node 6 = 0 packet.

CBR packet sent from node 15 to node 6 = 17 packet.

CBR packet sent from node 16 to node 6 = 0 packet.

CBR packet sent from node 17 to node 6 = 0 packet.

CBR packet sent from node 18 to node 6 = 0 packet.

CBR packet sent from node 19 to node 6 = 0 packet.

CBR packet sent from node 20 to node 6 = 57 packet.

CBR packet sent from node 21 to node 6 = 493 packet.

CBR packet sent from node 22 to node 6 = 51 packet.

CBR packet sent from node 23 to node 6 = 0 packet.

CBR packet sent from node 24 to node 6 = 3367 packet.

CBR packet sent from node 25 to node 6 = 0 packet.

PDF = 3363/3958*100 = 85%

Packet loss = 595 packet.

500 kbps data rate test

CBR packet received by node 6 =1801 packet.

CBR packet sent from node 1 to node 6 = 0 packet.

CBR packet sent from node 9 to node 6 = 71 packet.

CBR packet sent from node 20 to node 6 = 4237 packet.

Total packet sent to node 6 =71+ 4237 + 0 = 4308 packet.

400 kbps Data Rate Test

CBR packet received by node 6 =1631.

CBR packet sent from node 1 to node 6 = 0

CBR packet sent from node 9 to node 6 = 63.

CBR packet sent from node 20 to node 6 = 3809.

300 kbps Data Rate Test

CBR packet received by node 6 =24.

CBR packet sent from node 1 to node 6 = 0.

CBR packet sent from node 9 to node 6 = 0.

CBR packet sent from node 20 to node 6 = 86.

200 kbps Data Rate Test

CBR packet received by node 6 =130.

CBR packet sent from node 1 to node 6 = 0.

CBR packet sent from node 9 to node 6 = 6.

CBR packet sent from node 20 to node 6 = 298.

100 kbps Data Rate Test

CBR packet received by node 6 =257.

CBR packet sent from node 1 to node 6 = 0.

CBR packet sent from node 9 to node 6 = 6.

CBR packet sent from node 20 to node 6 = 571.

50 kbps Data Rate Test

CBR packet received by node 6 =691.

CBR packet sent from node 1 to node 6 = 0.

CBR packet sent from node 9 to node 6 = 0.

CBR packet sent from node 20 to node 6 = 1459.

20 kbps Data Rate Test

CBR packet received by node 6 =4976

CBR packet sent from node 1 to node 6 = 0

CBR packet sent from node 9 to node 6 = 158

CBR packet sent from node 20 to node 6 = 5077

10 kbps Data Rate Test

CBR packet received by node 6 = 1900.

CBR packet sent from node 1 to node 6 = 0.

CBR packet sent from node 9 to node 6 = 127.

CBR packet sent from node 20 to node 6 = 1974.

120 byte packet size test :

CBR packet received by node 6 =0

CBR packet sent from node 9 to node 6 = 0

CBR packet sent from node 20 to node 6 = 0

CBR packet sent from node 19 to node 6 = 0

100 byte packet size test :

CBR packet received by node 6 =2485 packet.

CBR packet sent from node 9 to node 6 = 174 packet.

CBR packet sent from node 20 to node 6 = 2542 packet.

CBR packet sent from node 1 to node 6 = 0 packet.

70 byte packet size test :

CBR packet received by node 6 =3528.

CBR packet sent from node 9 to node 6 = 45

CBR packet sent from node 20 to node 6 = 3582.

CBR packet sent from node 1 to node 6 = 0.

50 byte packet size test :

CBR packet received by node 6 =13134.

CBR packet sent from node 9 to node 6 = 158.

CBR packet sent from node 20 to node 6 = 13277.

CBR packet sent from node 1 to node 6 = 0.

50 packet Queue Size Test

CBR packet received by node 6 = 2520.

CBR packet sent from node 9 to node 6 = 21.

CBR packet sent from node 20 to node 6 = 2888.

CBR packet sent from node 19 to node 6 = 840.

Total packet sent to node = 3749.

100 packet Queue Size Test

CBR packet received by node 6 = 2520.

CBR packet sent from node 9 to node 6 = 21.

CBR packet sent from node 20 to node 6 = 2888.

CBR packet sent from node 19 to node 6 = 840.

500 packet Queue Size Test

CBR packet received by node 6 = 4998.

CBR packet sent from node 9 to node 6 = 237.

CBR packet sent from node 20 to node 6 =43.

CBR packet sent from node 19 to node 6 = 5097.

1000 packet Queue Size Test

CBR packet received by node 6 = 4998.

CBR packet sent from node 9 to node 6 = 237.

CBR packet sent from node 20 to node 6 =43.

CBR packet sent from node 19 to node 6 = 5097.