CHAPTER 5

IN AODV ROUTING: DETERMINING FACTORS ALONG WITH THE ROUTE MAINTENANCE PARAMETERS

5.1 Introduction

The ad-hoc network is never exclusively highly dynamic or static. Hence, it is expected that routing protocol must be adaptive and flexible for all kinds of ad-hoc network situations. Most of the time, a prime concern of all routing protocols is route discovery and route maintenance process by exchanging routing information among the nodes. Moreover, the key thought of the routing protocols is also focused on searching an efficient technique to collect and to distribute the route state information between mobile nodes whenever the changes in topology are found. Nevertheless, there also exist various determining factors (which have been discussed in depth in section 2.7) along with the route maintenance parameters which may significantly affect the network performance more than the topology. Therefore, the presented work in this chapter attempts to analyze an optimal relation between the route maintenance parameters and the different determining factors in which network gives stable routing (i.e. offers the best performance) while focusing on the AODV routing especially. In this chapter, the performance of the AODV network is again subjected to IEEE 802.11 MAC protocol under random waypoint topology. Although, here it is for the different NLD and for a fixed number of SD pair. This chapter uses the QualNet simulation tool to carry out the results, and the graphs have been prepared from obtained simulation results by using D-plot. Moreover, the CBR traffic generator has been provided to generate the traffic between the mobile nodes. Here, the performance observation of the AODV routing protocol is based on different QoS metrics like throughput, delay, jitter etc.

This chapter conducts extensive simulations to get an optimal relation between the route maintenance parameters and various determining factors where network performance is best. For that, two different scenarios are created and in each scenario has two separate cases, which have been discussed in detail in the further section. The first scenario of this chapter concludes that the curve ART=1 performs better, especially at higher node's mobility than other values of ART. Further, it also concludes that the overall network performance increases as NLD increases in the network until a certain value. After that, the performance starts to degrade because of a large number of mobile nodes in a given area. Moreover, as per the second scenario, the default QualNet transmission power is not adequate for higher transmission ranges. Furthermore, it can be noticed that the network acquires the highest throughput at ART=1 second, whereas for other ART values, it is almost constant for all transmission ranges. In addition, the second scenario also concludes that the throughput is high at lower node's mobility for all transmission ranges and it is constant for higher node's mobility, especially at the high values of transmission range. The simulation objective, scenario overview, simulation outline, and simulation results have been talked about in further sections. One paper is published and another one is communicated based on this part of thesis work;

- **Book Chapter:** Smart Innovation, Systems and Technologies (SIST), Book Series, **Publisher:** Springer International Publishing Switzerland.
  - ✓ **Sachin Kumar Gupta** and R.K. Saket, "Observation of AODV Routing Protocol's Performance at Variation in ART Value for Various Node's Mobility," Nov 2015, 51(2), 1-8. (In press)
- **Sachin Kumar Gupta** and R. K. Saket, "In AODV routing; Impact of ART, NLD, Mobility & Transmission Range," *EURASIP Journal on Wireless*

Communications and Networking, Springer, **(SCI, IF=0.72)** (Under Review).

5.2 Simulation Objective

Although, the route discovery process and route maintenance process are the key concept in the ad-hoc network environment that deal with the topology changes. However, various factors are there which influence the network performance more than the topology changes. This study considers only a few factors, namely; NLD, mobility, and transmission range of the node along with the route maintenance parameters (here, ART is considered only). These few factors are termed as the determining factors in this chapter. The main concern of this chapter is to find out the proper combination between ART, and determining factors; NLD, mobility & transmission range so that network performance can be enhanced.

From the SOTA section (1.4.6), it is clear that several researchers have attempted to observe the performance of the AODV routing protocol by considering various factors like size of network, number of nodes in the given area, transmission range, mobility etc. However, they were restricted to only these factors and few of them separately considered the route maintenance parameters only, but combine study between the route maintenance parameters and determining factors has not been studied so far. Therefore, this chapter presents the combined study between the route maintenance parameters and determining factors in AODV network to observe the performance.

5.3 Scenario Overview

In this chapter, QualNet simulation software version '7.1' is used for creating and analyzing the simulation scenarios in order to study and observe the AODV routing performance under the influence of ART, NLD, mobility, and transmission range. Further, after creating the scenario, the CBR traffic generator has been introduced between the mobile nodes to generate the traffic with the rate of 2KBps. Moreover, here each mobile node moves according to the random waypoint mobility model, where the value of pause time is 5 seconds. Here, the scenario simulation is run for the number of times for 300 seconds in order to get the best results, and their average value is chosen for plotting the graphs with the help of D-plot.

In this chapter, two different scenarios have been created, and two separate cases are introduced under each scenario in order to determine the proper combination of above discussed factors (i.e. ART, NLD, mobility, and transmission range). These scenarios are as follows:

Scenario-1

Case-1: QoS metrics (Throughput, Delay, & Jitter) Vs ART for different Node's Mobility.

Case-2: Throughput Vs Node's Mobility for different values of NLD; at ART= 1 & 3 seconds.

Scenario-2

Case-1: Throughput Vs ART for different Transmission Range; at default QualNet transmission power and calculated transmission powers.

Case-2: Throughput Vs Node's Mobility for different Transmission Range; at default QualNet transmission power and calculated transmission powers, where ART=3 seconds.

Basically, the first scenario deals with an impact of ART on the throughput for various values of node's mobility as well as the impact of node's mobility on the throughput for different values of NLD. Moreover, the second scenario is mainly concerned with various transmission range at the default QualNet power and calculated transmission powers (calculated from equation 1). According to this chapter, an optimal value of ART is the dynamic function of the node's mobility and the transmission range. In addition, the node's mobility has a significant effect on the network performance and also, it is the function of the NLD and transmission range.

5.4 Simulation Outline

In this chapter, as the main objective is to identify an optimal relation between the route maintenance parameters; ART and various determining factors; NLD, mobility and transmission range. Hence, doing so various ART value is considered as 0.5, 1, 3, 5, 7, 9, and 11 (in sec). In other words, ART value is varied from its default value and it is initiated from the narrow range (0.5, 1, and 3) and later on, it has been extended to the broader range (5, 7, 9, and 11). The main reason of this ART variation is to analyze the impact on QoS metrics, when its value is keeping too short (like 0.5, 1, and 3) or keeping too long (like 5, 7, 9, and 11) while taking the different values of NLD, mobility, and transmission range. The impact of variation in default ART value while taking the various values of determining factors is discussed in depth in the section *'5.5'* (it will be more apparent from there).

This chapter uses QoS metrics for identifying an optimal relation between various considered factors. The QoS metrics are the common parameters that are used to demonstrate the performance of ad-hoc network routing protocols. The obtained results from these simulation studies are significant to propose solutions to the QoS metrics degradation problem in the AODV ad-hoc network environment.

5.4.1 Simulation Parameters

Table (5.1), (5.2), and (5.3) tabulate the various simulation parameters that have been considered to create the simulation scenarios at wireless subnet properties, node configuration, and scenario properties, respectively on the QualNet simulation tool. These parameters are common for all the scenarios.

Table 5.1: Wireless subnet properties

Physical Layer	
Packet Reception Model	PHY802.11b
Channel Bandwidth	11 Mbps
Antenna Model	Omni directional
Antenna Height	1.5 m
Antenna Efficiency	0.8
Temperature	290 K
Noise Factor	10
MAC Layer	
Mac Protocol	802.11
Short Packet Transmit Limit	7
Long Packet Transmit Limit	4
MAC Propagation Delay	1 µs
Network Layer	
Network Protocol	IPv4
Routing Protocol	
Routing Protocol IPv4	AODV
Network Diameter	35
Node Traversal Time	40 ms
Maximum_Route_Request_Retries	2
Maximum_Number_of_Buffer_Packets	100
Route Deletion Constant	5
Enable Hello Message	Yes
Hello Interval	1 s
Maximum Allowed Hello Loss	2
TTL Start	1
TTL Increment	2
TTL Threshold	7
Router Property	
Type Router	Generic

Table 5.2: Node (device) configuration

Network Layer	IPv4
Routing Protocol	AODV
Router Property	Generic
Mobility and Placement	
Mobility Model	Random waypoint
Pause Time	5 s
Application Layer	
Applications	CBR
Packet Size	512 Bytes/packet
Packet Inter-Arrival Time	0.25 s or 4 Packets/s
Data Rate	2KBps

Table 5.3: Scenario Properties

General Parameters	
Simulation Time	300 s
Terrain Size (Area)	1500 m X 1500 m
Number of Channels	1
Channel Frequency	2.4 GHz in Ad hoc mode
Pathloss Model	Two ray
Node Placement Strategy	Randomly

5.5 Analysis of Simulation Scenarios and Results

This section explains each scenario along with its results which are obtained from the simulation scenario.

5.5.1 Simulation Scenario-1

"Case-1: *QoS metrics (Throughput, Delay, & Jitter) Vs ART for different Node's Mobility"*

In the first case of scenario-1, 80 nodes are spread randomly over a constant area size of 1500m X 1500m and they are moving according to the random waypoint mobility model with various speed as 0.5, 5, 10, 15 (in mps). Moreover, the offer loads in the network are 10% of total nodes (i.e. 8 SD pairs are considered to generate the traffic). Along with the above, the analysis of the optimal relation has been done based on three different QoS metrics that are throughput, delay and jitter. And here, the graphical method is used to analyze the results on QoS metrics for various node's mobility.

Along with the parameters of table (5.1), (5.2), and (5.3), the parameters of table (5.4) have also been taken into account while creating a simulation scenario in the QualNet for case-1 simulation study.

Table 5.4: Simulation parameters: case-1 of scenario-1

Active Route Timeout (ART)	0.5, 1, 3, 5, 7, 9, 11 (in sec)
Transmission Range	200 m
Transmission power for 11 Mbps	15 dbm
Network Load Density (NLD)	80
Unicast connection between node or offer loads in the network (SD pair)	8 (10 % of 80)
Node's Mobility	0.5, 5, 10, 15 (in mps)

5.5.1.1 Results Discussion: Case-1 of Scenario-1

This sub-section shows and discusses the various QoS metrics (i.e. throughput, delay and jitter) graphs that have been plotted for different node's mobility with ART on the X-axis and QoS metrics on Y-axis.

Figure (5.1) illustrates the throughput as a function of ART for different node's mobility like 0.5, 5.0, 10.0 and 15.0 mps. From the figure, one can observe as expected, the throughput decreases as the average node's mobility increases. When there is zero mobility or very less mobility, like less than 0.5 mps, routes never expire. Hence, for lower node's mobility, throughput is higher than the other node's mobility and nearly unchanged for higher values of ART. This result is expected since the node's mobility is stationary and the changes in ART value do not influence the throughput. At higher values of node's mobility such as 5.0, 10.0, and 20 mps, the value of throughput decreases with an increase in ART. The main reason of this consequence is the continuous change in node positions, which make it difficult to establish a connection between them. From the figure, it can also be observed that at a very low value of ART (i.e. at ART<1), the throughput is not good. It may be due to the node that holds the route state information for very less time after it has been used which causes a node to repeat the route discovery process most of the time after each use of the route while a valid route is still there. From the above discussion, it is concluded that the higher throughput value is achieved at a low value of ART than the default QualNet value (i.e. 3 second). It is also noticed that the curve ART=1 acquires the highest throughput.

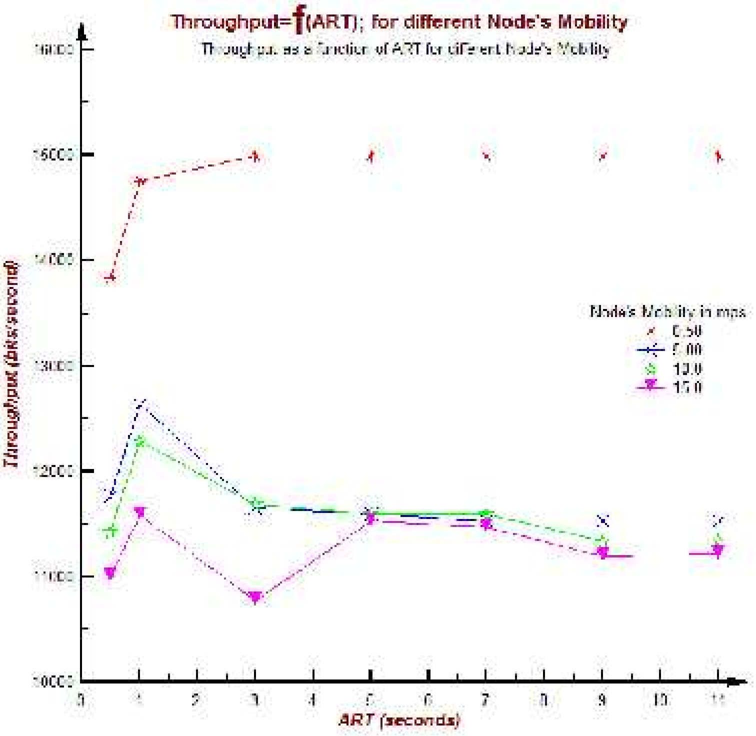

Figure 5.1: Throughput Vs ART

Figure (5.2) and (5.3) reflects the delay and jitter as a function of ART for different values of node's mobility like 0.5, 5.0, 10.0 and 15.0 mps, respectively. In both cases, one can easily understand that the value of delay as well as jitter increases as the node’s mobility increases in the network. It happens because the changes in network topology become more common with an increase in node's mobility. Hence, the route discovery process becomes very difficult. Moreover, at higher node's mobility, the route breakage between the established connections is quite frequent or it can be said that the several small sessions accomplish one end-to-end communication session. Furthermore, at very higher node’s mobility (like 10 or 15 mps), drastic changes can be seen in both cases (delay as well as jitter) with an increase in ART value. It may be due to the fast changes in network topology, and hence, the route becomes invalid very quickly. Therefore, the network at very higher node’s mobility reflects the awkward behavior. So, holding the route state information for a longer time is not suggested, particularly for a very high value of node mobility because it creates memory overheads. From the above discussion and figures (5.2) & (5.3), it is concluded that the network gives its best at lower ART value (i.e. 0.5 sec), which is less than its default value.

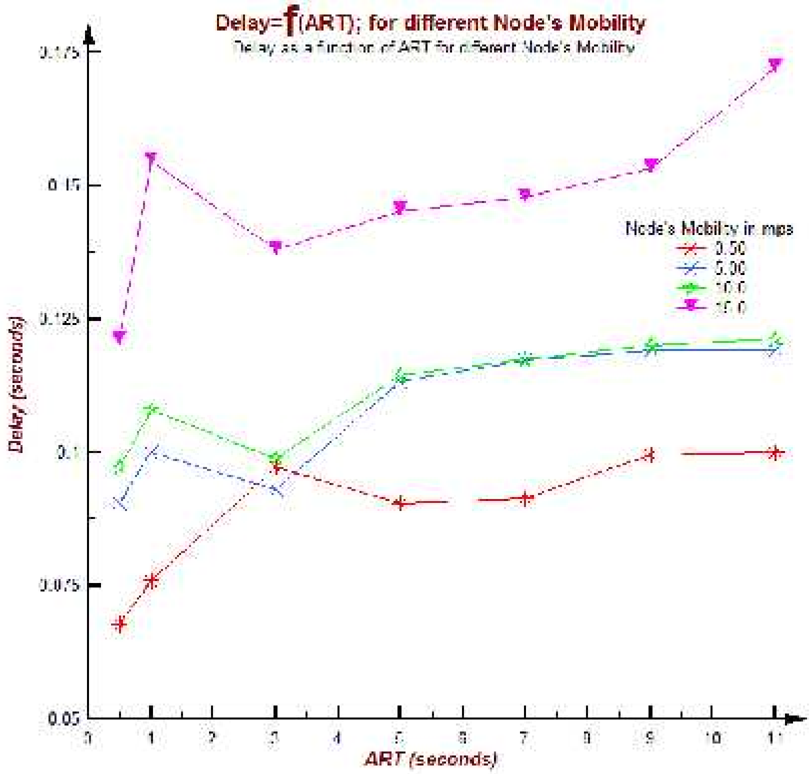

Figure 5.2: Delay Vs ART

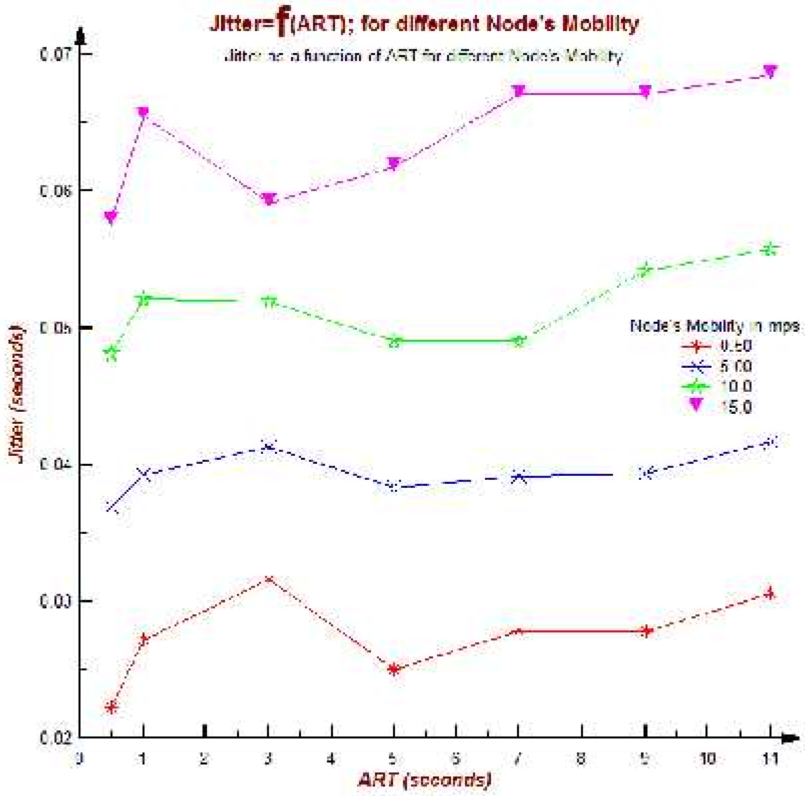

Figure 5.3: Jitter Vs ART

Additionally, it can also be concluded from all the above discussions (throughput, delay and jitter graphs) that the optimal value of ART is the dynamic function of the node's mobility.

***"Case-2:** Throughput Vs Node's Mobility for different values of NLD; at ART=1 & 3 seconds"*

In this case, the throughput is getting compared with the node's mobility for different value of NLD at the default value of ART (i.e. ART=3) as well as less than the default value of ART (i.e. ART=1). Here, NLD value is increased from 70 to 90 in a regular interval of 10 at (i.e. three different NLD) constant network size. Again, in this case, the nodes distribution is random over an area, and nodes are moving according to the random waypoint mobility model. For all NLD values, traffic flows for 8 simultaneous unicast connections between 8 random chosen node pairs. This scenario is taken to identify the effect of node's mobility variation on throughput for different values of NLD in an AODV network. In addition to the common parameters of this chapter (section 5.4.1), the simulation parameters of the table (5.5) have also been considered during the creation of case-2 simulation scenario.

Table 5.5: Simulation parameters: case-2 of scenario-1

Node's Mobility	0.5, 5, 10, 15 (in mps)
Network Load Density (NLD)	70, 80, 90
Unicast connection between node or offer loads in the network (SD pair)	8
Transmission Range	200 m
Transmission power for 11 Mbps	15 dBm
Active Route Timeout (ART)	1 & 3 (in sec)

5.5.1.2 Results Discussion: Case-2 of Scenario-1

Figure (5.4) demonstrates the result obtained from this simulation scenario that is plotted for various value of NLD with node’s mobility on the X-axis and throughput on Y-axis. Of course, there is a difference in the throughput value for different NLD. However, at zero node’s mobility or low node’s mobility such as <0.5 mps, the value of throughput is high as compared to higher node's mobility. At a default value of ART, the performance of the network is degraded because of slow reaction to the rapid changes in the network topology which is seen at higher node's mobility (such as 5, 10 and 15 mps). Further, the network experiences good throughput as NLD increases over a same size (as considered in this case) of the network on same unicast connection pairs. It is expected because as NLD increases in the network, the availability of intermediate nodes towards any particular destination is also increased. Therefore, the traffic congestion decreases with an increase in NLD and hence the route discovery process becomes easier. It does not mean that if NLD increases very high, the throughput will also be improved. As in this case, the area is constant and hence after a particular value, the performance starts to degrade. The main reason behind this consequence may be the heavy congestion in the network.

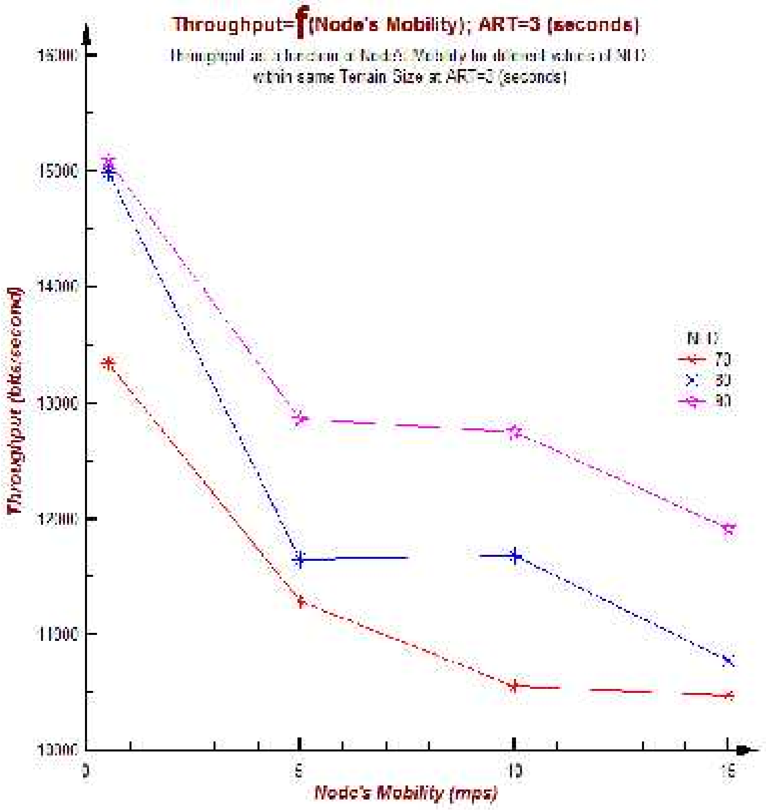

Figure 5.4: Throughput Vs Node's Mobility at ART=3

Moreover, the same situation has been analyzed with ART=1 as shown in figure (5.5). From the figure, it may be observed that the variation in ART value (especially, ART<3, as in this case it is 1) has a significant effect on throughput at the higher node's mobility such as 5, 10 and 15 mps. This result is obvious because the network is easily able to adopt the rapid changes of topology at the lower value of ART, which is generally represented at higher node's mobility. Again, in this case, the network performance increases with an increase in NLD. In both cases of the first scenario, 11 Mbps channel bandwidth, and 15dbm default QualNet transmission power are used. From the above discussion (i.e. both graphs of case-2), it is concluded that the ART=1 performs well at higher node's mobility whereas, in the case of low node's mobility better one is observed at ART=3 with an increase in NLD.

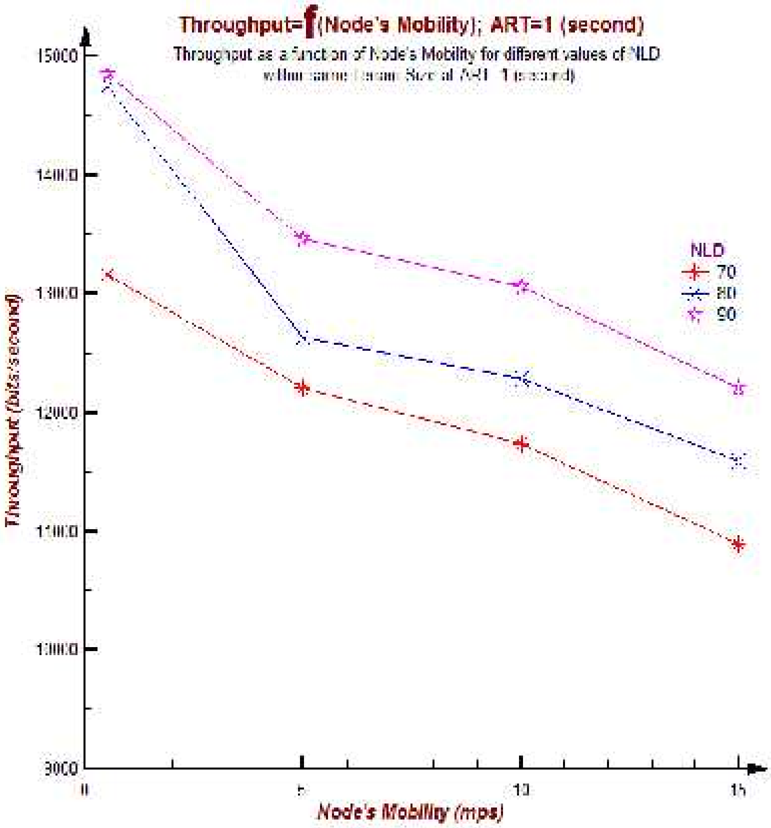

Figure 5.5: Throughput Vs Node's Mobility at ART=1

5.5.2 Simulation Scenario-2

This simulation scenario is mainly taken to analyze the performance of the AODV network for different transmission range.

***"Case-1:** Throughput Vs ART for different Transmission Range; at default QualNet transmission power and calculated transmission powers"*

In this section, throughput is shown as a function of ART for different values of transmission range at 15dbm default transmission power and various transmission powers of its respective transmission range that are calculated by equation (1). Here, 40 nodes are spread randomly over an area of 1500m X 1500m and they are moving according to the random waypoint mobility model. Among 40 nodes, 8 node pairs have randomly been chosen as traffic generators. The main motive of this section is to analyze and to compare the impact of various transmission ranges on the throughput. The simulation set-up of this scenario also uses the parameters of table (5.6).

Table 5.6: Simulation parameters: case-1 of scenario-2

Active Route Timeout (ART)	0.5, 1, 3, 5, 7, 9, 11 (in sec)
Transmission Range	100, 150, 200, 250, 300, 350, 400, 450, 500 (in meter)
Transmission power for 11 Mbps	15 dBm & Calculated Powers
Network Load Density (NLD)	40
Unicast connection between node or offer loads in the network (SD pair)	8
Node's Mobility	5 (in mps)

5.5.2.1 Results Discussion: Case-1 of Scenario-2

Figure (5.6) represents the result that has been obtained from this simulation scenario. Case-1 of second scenario tries to find out the impact of variation of transmission range on the throughput at fixed transmission power. From the figure (5.6), it can clearly be observed that initially the throughput increases as the node's transmission range increases. Further, as the transmission range is increased beyond 300 meters, the value of throughput starts to decline. Obviously, the default QualNet transmission power of 11 Mbps channel bandwidth is not sufficient for higher transmission ranges such as 350, 400, 450 and 500 meters. At the outset until 300 meters of transmission range, throughput increases because the number of intermediate nodes or hops decreases with an increase in transmission range. It may be due to the degradation of the number of intermediate nodes or hops. Therefore, the possibility of route failure issues is also reduced and hence, throughput is increased. During 300 seconds of simulation, maximum unicast offered load is 16384 bps. However, at default transmission power, the maximum received throughput is only 13857.17 bps which is offered by a 300m curve at ART=1. One can also notice from the figure that at ART=1, maximum throughput is acquired in the all cases of transmission range, whereas throughput values are almost constant for higher values of ART. It may be due to the constant node's mobility throughout the whole simulation. Hence, the changes in ART value will not affect the throughput.

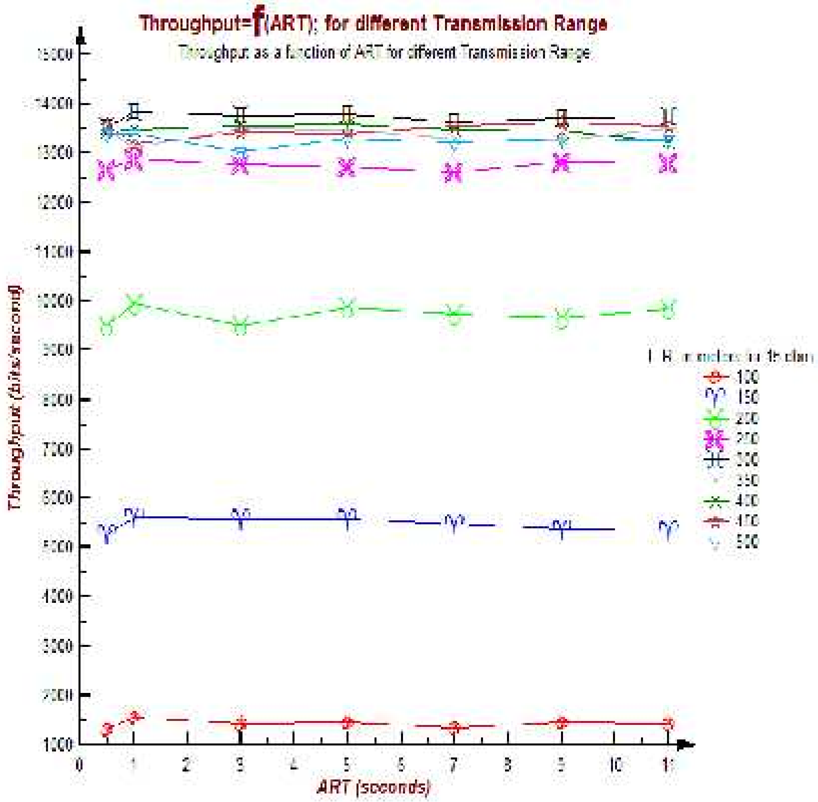

Figure 5.6: Throughput Vs ART at default QualNet transmission power

Furthermore, the same situation is simulated at the different transmission powers (such as 15.00, 18.57, 21.07, 23.00, 24.59, 25.93, 27.00, 28.10, and 29.03 dbm) for its respective transmission range (like 100, 150, 200, 250, 300, 350, 400, 450, and 500 meters respectively) instead of 15 dbm. Here, each node requires the different transmission power to obtain its respective transmission range that has been calculated from an equation-1 (adopted from 'W. Al-Mandhari, *et al.*, 2008').

$$P(watt) = \left[\frac{4\text{®}\, X\, (T.R.)}{0.1248575} \right]^2 X 10^{-9.5} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$P(dbm) = 10 X \log_{10}\left(P(watt) X 10^3 \right)$$

Where ‘P’ is the transmission power in watt and ‘T. R.’ is the transmission range in meter.

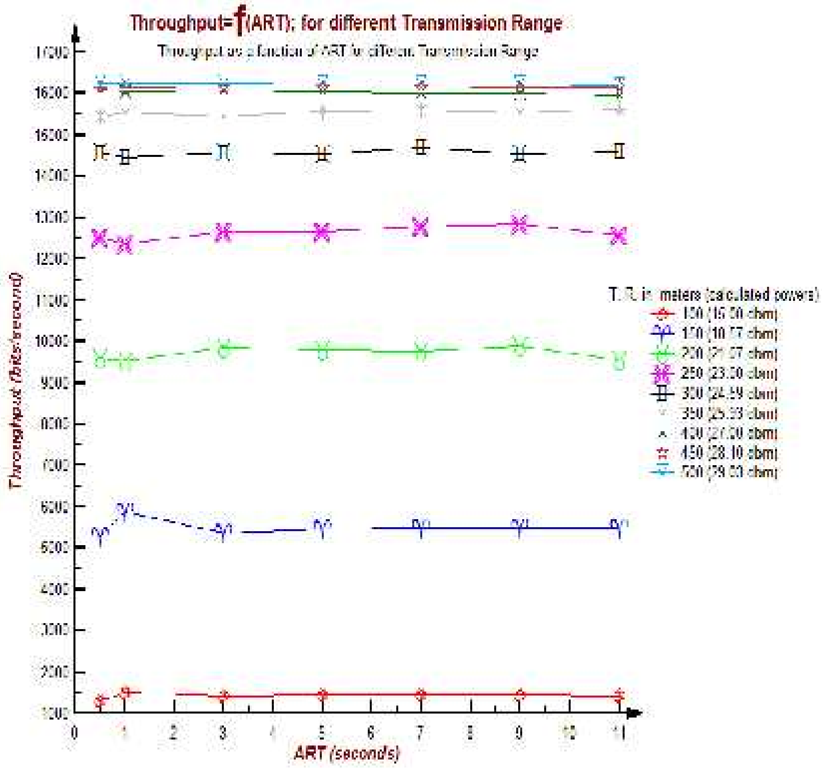

Figure 5.7: Throughput Vs ART at calculated transmission powers

In this case, the value of throughput increases with an increase in transmission range from 100 to 350 meters. Later on, for the higher values of transmission range, it becomes almost constant as shown in figure (5.7). It is also noticeable that initially in lower ranges of transmission, the increasing ratio of throughput is high, and gradually this ratio decreases. Here, reason is same like figure (5.6). And finally, network acquires almost the same throughput for higher ranges of transmission that is seen at 400, 450 and 500 meters. It may be because, for these values of transmission range, the network has achieved its maximum throughput value. From the figure (5.7), one can also see that at higher values of transmission range throughput is nearly unchanged for all values of ART. This result is expected because there is no variation in node's mobility and hence changes in ART value, especially in higher transmission ranges, do not affect the throughput. In this case, during the whole simulation maximum received throughput is 16263.69 bps out of 16384.00 bps. Table (5.7) represents the comparison of average throughput/PDR for all taken transmission range at the default QualNet transmission power and calculated transmission powers.

Table 5.7: Comparison of average throughput/PDR for all taken transmission range at default QualNet transmission power and calculated transmission powers

Transmission Range (meter)	Average Throughput & PDR at default QualNet transmission power (bps)		Average Throughput & PDR at calculated transmission powers (bps)	
	Throughput	PDR	Throughput	PDR
100	1423.11	0.087	1428.83	0.087
150	5455.04	0.332	5490.76	0.335
200	9703.35	0.592	9751.75	0.595
250	12759.02	0.779	12814.10	0.782
300	**13724.84 (Max.)**	**0.838**	14574.36	0.889
350	13583.89	0.829	15534.94	0.948
400	13479.70	0.823	16031.18	0.978
450	13473.09	0.822	16142.75	0.985
500	13272.85	0.810	**16235.12 (Max.)**	**0.990**

From the above comparison table (5.7), it is clear that the default QualNet transmission power of 11 Mbps channel bandwidth is not sufficient for the higher values of transmission range like more than 300. Hence, if higher values of transmission range are required, then it is suggested to use equation-1 to calculate the power for a respective transmission range.

*“**Case-2**: Throughput Vs Node's Mobility for different Transmission Range; at default QualNet transmission power and calculated transmission powers, where ART=3 sec”*

A Case-2 of the second scenario has been considered to examine the throughput against the node’s mobility for different values of transmission range at default ART value (i.e. ART=3). Moreover, this section observes the difference of throughput at default transmission power and calculated transmission powers. Again, the node placement and movement strategy are same here as in case-1 of scenario-2. The parameters of the table (5.8) have also been considered while creating this simulation scenario.

Table 5.8: Simulation parameters: case-2 of scenario-2

Node's Mobility	0.5, 5, 10, 15, 20 (in mps)
Transmission Range	200, 250, 300, 350, 400 (in meter)
Transmission power for 11 Mbps	15 dBm & Calculated Powers
Network Load Density (NLD)	40
Unicast connection between node or offer loads in the network (SD pair)	8
Active Route Timeout (ART)	3 (in sec)

5.5.2.2 Results Discussion: Case-2 of Scenario-2

This sub-section shows and discusses the throughput graphs that have been plotted for different values of transmission range with node’s mobility on the X-axis and throughput on Y-axis.

Figure (5.8) indicates the outcome that has been received from this simulation scenario at default transmission power (i.e. 15 dbm). From the figure, it can be noticed that for lower ranges of transmission (i.e. 200 & 250 meters), the decreasing ratio of throughput with an increase in node's mobility is more than the higher ranges of transmission. Moreover, it can also be observed that for higher transmission ranges such as 300, 350 and 400 meters, the throughput is almost constant especially at higher values of node's mobility. This result is expected because, at the higher ranges of transmission, the number of hops towards a particular destination is reduced. And hence, the possibilities of route breakage due to higher node's mobility are also minimized. Therefore, it may be concluded that the higher node's mobility, especially at higher values of transmission range does not affect the throughput as much. From the figure (5.8), it can also be noticed that the curve 300 acquires the maximum throughput. After that, performance starts to degrade because default transmission power is not sufficient for higher values of transmission range at this channel bandwidth.

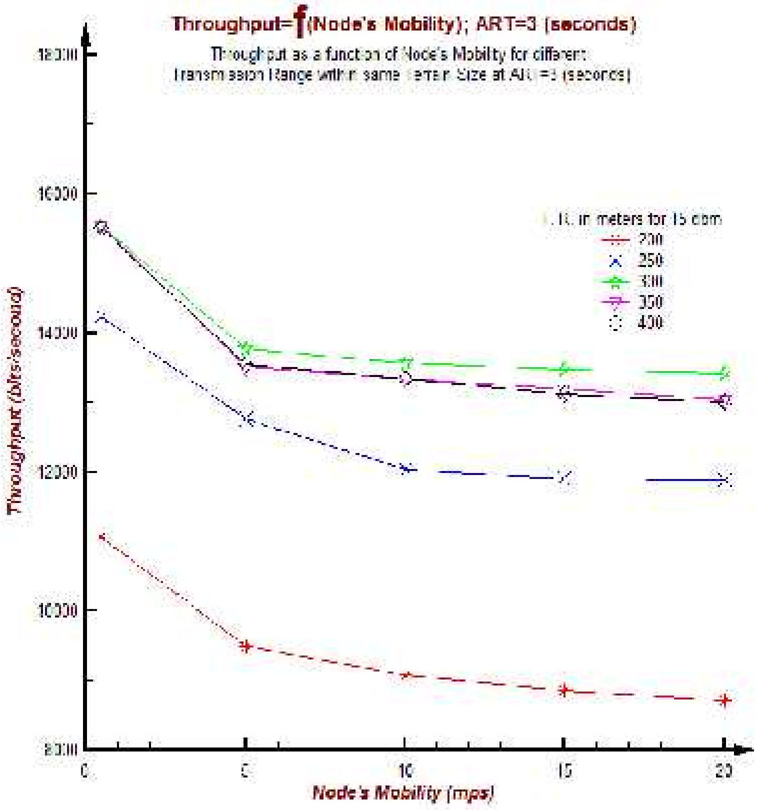

Figure 5.8: Throughput Vs Node's Mobility at default transmission power

Moreover, the same scenario has been taken for analysis, but for various calculated transmission powers instead of its default power. Again, the equation-1 has been used for calculating the various transmission powers to achieve respective transmission range by each node. From the figure (5.9), it can be observed that the 400m curve delivers the highest throughput. Now, in this case, nodes can achieve the 400 meters of coverage distance because of 27.00 dbm transmission power. Again, the network performance decreases here with an increase in node's mobility. Moreover, at the higher range of transmission like 400 meters, the network performance is nearly unchanged for all node’s mobility. The reason is same as in the previous case.

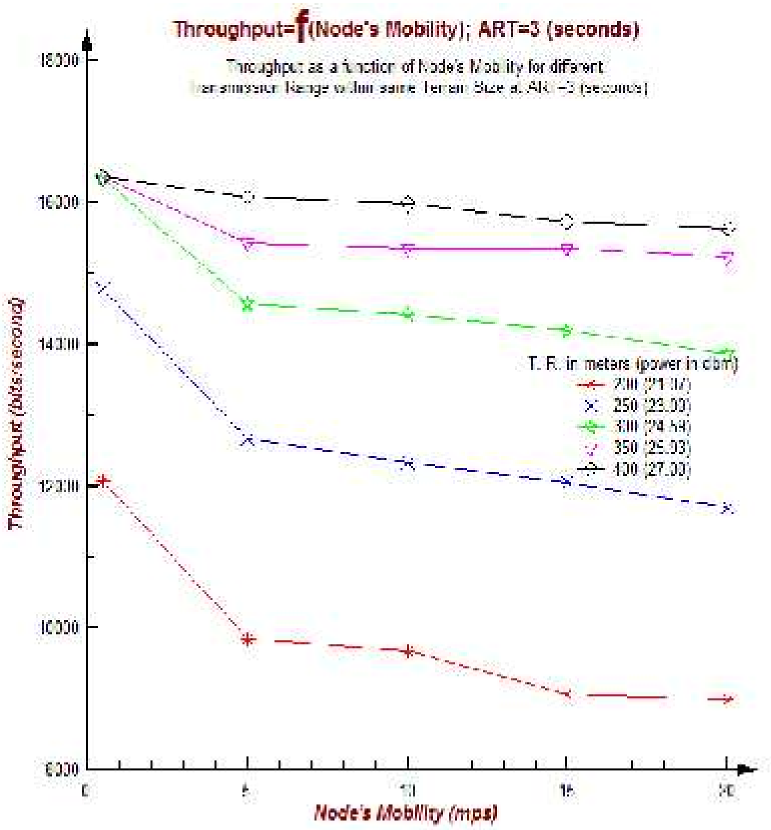

Figure 5.9: Throughput Vs Node’s Mobility at calculated transmission powers

5.6 Conclusion

In this chapter, various determining factors along with route maintenance parameters are taken to study the impact on the AODV routing performance. Mainly, this chapter tries to analyze the optimal relation between these considered factors in which QoS metrics are better. For that two different scenarios have been considered and each scenario presents two separate cases.

The first case of scenario-1 analyzes the impact of ART variation on QoS metrics for different value of node's mobility. As per this case, at higher node's mobility (like 5, 10, & 15 mps), the network performance in terms of throughput, delay and jitter is not good with an increase in ART value. It may be due to the frequent topology changes that are more common at higher node's mobility. Hence, routes become invalid very quick. Therefore, it is suggested that the route state information should not be held for a longer period of time in a highly mobile environment. In other words, the lower ART value (ART<1) gives the best result, especially at higher node's mobility. If there is zero mobility or very less mobility (<0.5 mps), the network performance becomes good and it is nearly constant for other higher values of ART. This result is obvious because the node's mobility is almost stationary and hence, changes in ART value do not affect the network performance. Here, better QoS metrics are achieved at ART<3 for all taken node's mobility (i.e. best throughput is observed at ART=1 whereas for delay & jitter, the best one is at ART=0.5). A 2nd case of 1st scenario concludes that the overall throughput increases as the NLD increase. This happens because of the increase in connectivity between nodes due to the number of intermediate nodes. However, after a certain increase in NLD, throughput starts decreasing because the area is constant and there could be congestion in the network. For all values of NLD at lower node's mobility, the throughput values are high as compared to higher node's mobility. At the default value of ART for all NLD, the value of throughput is decreased because of the slow reaction to the rapid changes in the network topology, which is seen at higher node's mobility. Moreover, for ART=1 instead of its default value has a significant outcome on the throughput, especially, at the higher node's mobility. It may be due to easy adaptation by the network to rapid changes in topology at a lower value of ART.

The main motive to consider the 2nd scenario is to analyze the effect of various transmission range on the throughput at default QualNet transmission power and calculated transmission powers which has been calculated by using equation-1. The 1st case of 2nd scenario concludes that the throughput value increases up to 300 meters of the transmission range. After 300 meters, the value of throughput is decreased, as the channel bandwidth has been fixed at 11 Mbps. Therefore, the 15dbm transmission power is not adequate on this channel bandwidth to transmit the packets beyond 300 meters. Till 300 meters, the number of hops reduces as the transmission range increases, which in turn reduces the possibility of route breakage. Here, it can also be noticed that at ART=1, maximum throughput is acquired almost for all transmission ranges, and it is almost constant for other higher ART values. It may be due to the constant node’s mobility throughout the simulation (here, it is fixed at 5 mps). Hence, changes in ART value do not affect the throughput. Moreover, the same condition has been analyzed for the calculated transmission powers. In this case, the value of throughput increases up to 350 meters of transmission range. Later on, the throughput becomes almost constant for higher values of transmission range. In 2nd case of this scenario, for all transmission ranges, the value of throughput is higher at lower node's mobility. And, it is almost constant at higher values of node’s mobility which is seen especially in higher transmission ranges. The main reason for this outcome is the reduction in the number of hops towards a particular destination as transmission range increases. And hence, higher values of node’s mobility do not have much impact on the throughput.

Chapter 6 conducts a simulation study for the comparative performance analysis between the various routing protocols (like AODV, DSR, DYMO, IARP, and IERP) under the varying pause time environment.