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Scalability Analysis of MANET in 5G Environment

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Abstract
Technology is moving towards 5G. While moving towards 5G, network goes on connecting things and people from connecting people. Things can be stable or mobile. MANET will work in mobile object or things. So the test network will be MANET. While technology moves towards 5G, environmental factors like Density, Mobility, Data rate, etc will get changed. In this paper, several testing have been done by changing density, mobility and datarate to their corresponding values in 5G and provide conclusion in corresponding routing protocol. Among the mostly used routing protocols of MANET, this paper check AODV from Reactive Routing protocol while DSDV from Proactive routing protocol. To check the performance of the network, Throughput has been taken as performance Metric. Going to the results, it is seen that AODV performs better than that of DSDV in 5G environment in all scenarios. So AODV is scalable towards 5G. But if the number of nodes increases in large amount, it is better to make small MANET networks independently working and in back end connected to infrastructure based network. Also, mmWave frequencies are expected to have an important role in 5G. So, this paper also check the throughput of mmWave and mmwave gives stable throughput than that of other communication media. So, these routing protocols will still better serve with mmwave.

Keywords
MANET, AODV, DSDV, 5G

1. Introduction

Network connectivity is being increasing day by day. While we are moving towards 5G from 4G, it's about connecting people and things. Almost all the things will be connected in 5G. In wireless network, we have two types of network. One with Infrastructure Based whereas another with infrastructure less. Mobile Adhoc Networks (MANET) are infrastructure less wireless network used for wireless communication. Scalability is the term that is related to the ability of any system or protocol. Here, Scalability is the ability of any routing protocol to perform efficiently as one or more the inherent parameters of network grow to large in value.

Mobile Adhoc Network (MANET) is a network in which there are a group of interconnected set of mobile wireless devices which can act as both transmitter and receiver. MANET can be set up anywhere at any time. The main purpose of MANET is easy setup of wireless network at anytime in case of need when there is no any fixed infrastructure or the infrastructure is not working. In MANET, the same node sometimes works as transmit node or receive node or Router or relay node based on the necessity. The range of the wireless signal may not be same in all the nodes, as the nodes are made up of different equipment or components. The Electrical Backup Power of all the nodes may also not be same. In communication, there are different generations during the evolution. Up to the fourth generation, all is about connecting people. Whereas in 5th generation, it is about connecting people and things.

5th Generation = connecting People + Things

So in 5G, nodes density, nodes mobility, datarate, etc will be increased. For the connection between things, MANET will be the best solution. As MANET are driven by their routing protocols scalability of the routing protocols will be studied by changing different parameters like density, mobility, datarate, etc up to the standard of 5G.

2. Related Work

From past up to now, many researchers have done research on MANET. With the evolution in the wireless network, several researches have been done

in the field of MANET as well due to its easy and fast deployment that can be used in different scenarios. In the Requirements issued by ITU for 5G [1] , there are different requirement.

- Connection density should be 1000000 per sq km.
- Mobility should be 0km/hr - 500Km/hr
- Mobility Interruption Time should be 0ms
- Bandwidth should be 100MHZ
- Peak Datarate should be DL 20Gbps and UL 10Gbps
- User Experienced Datarate should be DL 100Mbpss and UL 50Mbps

So these are the requirements for 5G. For any protocol to work in 5G should meet the requirement mentioned in the paper [1]. Similarly, the research paper [2], A survey in QOS aware routing protocols has been done for MANET-WSN coverage scenarios in IOT networks. Connecting IoT modules (smart phone, home devices, smart car, etc.), people, data and things to internet and each other will become a prevalent system. QOS guarantee for applications in WSN MANET network is a real challenge. Routing cost function for single Matric is given by:

$$f(p) = \frac{\sum_{i=1}^{p} D_i}{B_i} \tag{1}$$

Routing cost function combined from metrics like B (Bandwidth) and D (Delay time). p is a candidate route, p = $(i_1, i_2, i_3, \ldots, i_{n-1}, i_n)$. Where i_j are nodes in p, $(1 \leq j \leq n)$. Let D_i ,i_{j+1} be the metric of the link (i_j, i_{j+1}) . Then, the metric of the route p, denoted by D_P. [3] Shows different security attacks that can be in MANET and protocols for protection against them. Most of the security protocols can handle only one attack at a time. Handling only 1 type of attack at a time is not sufficient to achieve better QOS performance.

In paper [4] Investigation done on single path routing protocol and multipath routing protocol for development of high throughput routing protocol. Performance comparison in routing protocols like AODV, AOMDV and OLSR in terms of throughput, packet delivery, routing overhead and end to end delay has been carried out via NS2. Regarding MANET Network, there need to consider several areas which we get from papers. Throughput means frames, packets or bytes efficiently transmitted per unit time

$$\text{Throughput} = \frac{\sum \text{received packets size}}{\text{time}}$$

End to End Delay (E2E Delay): It is the time taken by a by a packet to travel

$$D_{avg} = Tr_{avg} - Ts_{avg}$$

Normalized Routing Load (NRL) is the ratio of Network control Packets or routing packets to all the delivered packets.

$$NRL = \frac{\sum \text{Routing Packets}}{\sum \text{Packets Received}}$$

Packet Delivery Ratio(PDR) is ratio of packets successfully delivered to the total number of packets sent

$$PDR = \frac{\sum \text{Number of Packets received at destination}}{\sum \text{Number of Packets send by Nodes}}$$

In the environment where there is not fixed infrastructure, [5] MANET can be used in congested areas like stadiums and campuses, disastrous areas. 5G is intended to provide much higher data rates and lower end to end over the air latency. QoS classified into 3 primaries based on mathematical properties, delay, bandwidth and loss probability. Delay metric follows the additive composition rule, bandwidth metric follow Concave composition rule and Loss probability follow multiplicative composition rule. In 5G,[6] mm wave frequencies are expected to have major role to meet the 5G standards.Research Paper Shows the use of mm wave in MANET networks. Path Loss in WIFI signals is given by

$$PL(dB) = 20\log(f) + 20\log(d) - 147.56dB \tag{2}$$

Whereas the pathloss in mm wave is given by

$$PL(dB) = 20\log(f) + 2\log(d) - 147.56dB - 17dB - 17dB \tag{3}$$

Whereas d is the distance between the transmitter and receiver and f is the used frequency.

In this research paper [7], a network is made in NS2 simulator. 3 metrics are discussed to know the performance evaluation of the network. Metrics used are Packet Delivery Ratio, Average residual energy of node and Network lifetime. Comparison of the Simulator Tools is shown in [8]. As per this paper, NS3 supports mobility of Nodes, is extensible and scalable upto 20000. So this paper uses NS3 for simulation. Similarly comparative study of routing protocols is carried out in [9]. In paper [10],

comparison study Is carried out between the simulators and routing protocols and seen that AODV protocols is giving best output in reactive while DSDV is giving best in proactive routing protocols. So we have used these protocols for the research work in this paper. [11] describes the process for end to end simulation of mmWave module in NS3. In [12] explains about one dimension that is increase in information rate and to adjust this has worked for adjusting antenna parameters in sub-6 GHz.Similarly in [13] energy consumption is minimized by purposing cloud assisted MANET by the perform of fast recovery of local route.

So in earlier research papers, study of MANET has been carried out in certain specific scenarios. But, regarding the scalability of the MANET, very little research are carried which is not sufficient. As technology is changing from connection people to connecting everything in upcoming 5G, research should be done in the scalability of current MANET towards 5G environment. As MANET is guided by it's routing protocols, in this research work will analyse the scalability of MANET towards 5G environment using those protocols. For making 5G environment, we will make vary the value of density, mobility and datarate to that of 5G. Also, will check the throughput of MANET with mmWave.

3. Methodology

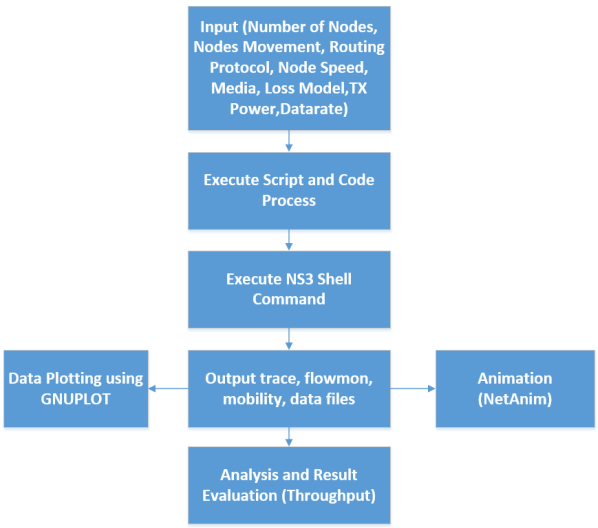

Figure 1: System Block Diagram

Methodology involves different steps to execute the research work.

1. Environment setup and Network Creation First the simulation environment readiness is done. After the environment is ready, will make the wireless network in the simulator and define the parameters. In Ubuntu 22.04 LTS operating system, NS3 3.36.1 simulator is used for the work. While moving towards 5G environment, there will be the change in the environmental conditions. During analysis, we will change the values of Density, mobility and Datarate to check the scalability of MANET. Also, mmWave will plays a vital role in 5G, we will compose a mmWave module in NS3 check the performance metric on it as well.

2. Defining the Parameters in the network Parameters need to be set to make the network as per our plan. Below are the parameters that we will define for making the nodes Channel Type, Radio Propagation Model, Network Interface Type, MAC Type, Interface Queue type, Link Layer Type, Antenna Model, Number of Mobile Nodes, Routing Protocols, Dimension of Topography, Time of simulation end, etc. Regarding the Routing Protocols, this paper will check the AODV and DSDV routing protocols. Simulation is carried in NS3. Simulation will run for 200 seconds and we will vary total number of nodes and mobility of the nodes as per the research requirement. Node movement will be randomwaypoint mobility model and loss model will be Friis loss model. The area of the simulation throughout the work is 300m*500m

3. Nodes movement from the initial position and packet transfer between the nodes The Transmitting and receiving nodes will move from their initial position. Packets will be transferred from the transmitting and receiving nodes. The process will continue upto the period of the simulation time interval.

4. Event generation and record in different Routing Protocols Different Routing protocols will be implemented and events will be noted. After implementing the different Routing Protocols, the performance of the network in all the Routing protocols will be calculated. Based on the performance, we can purpose the best Routing protocol for the MANET. For the calculation of the Performance, throughput will be the performance Metrics. Throughput: Throughput means frames, packets or bytes efficiently transmitted per unit time

$$\text{Throughput} = \frac{\sum \text{received packets size}}{\text{time}} \quad (4)$$

5. Event generation for same Routing Protocols in 5G

environment and Analysis Events for the corresponding 5G environment will be generated to check the scalability of those protocols in 5G environment.From the events of the performance, we will make a report and analyse the data. Based on the analysis, we will conclude the scalability of the routing protocols towards 5G. For making the corresponding environment to 5G, we will change the density, mobility, datarate and frequency. For density, mobility and datarate, we will increase the values towards its corresponding value at 5G environment. For frequency, we will check in mmWave.

4. Implementation, Results and Analysis

Ubuntu 22.04 LTS is the used OS while NS3 3.36.1 is the used simulator. NetAnim, GNU plot, trace metrics, etc. will be the tools for analysing the data.

For making the environment to the corresponding 5G, we will increase the density, mobility and datarate of the nodes. As per the research paper [1], the requirement for 5G are

Connection Density : 1,000,000 devices per km^2

Mobility: 0km/hr to 500km/hr (0m/s to 139m/s)

User Experienced Data Rate: Downlink : 100Mb/s & Uplink:50Mb/s

Peak Data Rate: Downlink:20Gb/s & Uplink:10Gb/s

For initial network setup, we will use the below parameters for MANET network in NS3 simulator.

Table 1: Simulator Parameters for Network setup

SN	Parameter	Value
1	Simulation Time	200s
2	Simulation Area	300m*1500m
3	MAC Layer	802.11
4	Traffic Type	CBR
5	Mobility Model	RandomWay Point
6	Nodes Speed	20mps
7	DataRate	2Mbps
8	Loss Model	Friis Loss Model
9	TX Power	7.5 dBm
10	Nodes Density	50 Nodes

For checking the scalability of the MANET network towards 5G environment, we will change the values of Nodes density, Nodes mobility and Nodes datarate towards it's corresponding value in 5G environment as mentioned in [1]

4.1 Testing in Different Density

This research paper test the results for different node density in the same geographical area.As we go towards 5G environment, there will be the change in the Nodes density. First performance metrics is checked for 50 nodes using the protocols AODV and DSDV.After that the number of nodes is increased to 1000 and the performance metrics is checked.

4.1.1 Testing for 50 Nodes

First test will be done for 50 nodes. These 50 nodes will be communicating with each other using MANET. There will be a set of 50 nodes and will be communicating with each other. Nodes will be moving in 20m/s speed. Performance is tested in both AODV and DSDV protocols.

AODV Protocol Simulation is run for 50 notes with AODV routing protocol.

Figure 2 shows the set of mobile nodes which communicate each other. In total there are 50 nodes and communicate with AODV protocol. Details of Node 35 is seen in the figure.

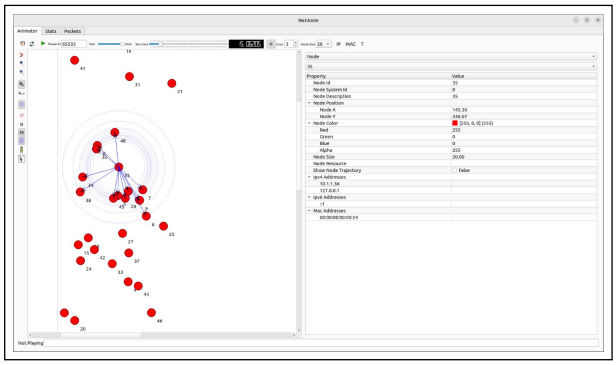

Figure 2: Simulation in AODV with 50 Nodes

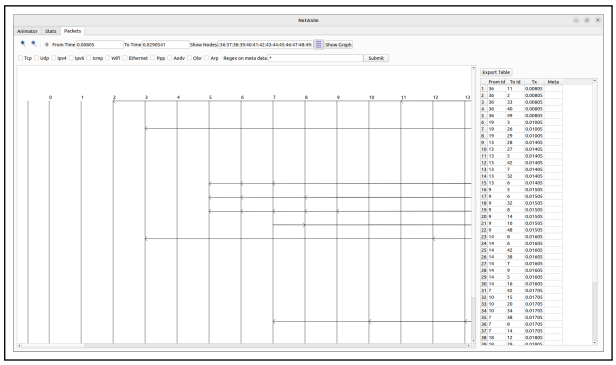

Figure 3: Simulation in AODV with 50 Nodes Packets seen in application

In figure 3 Simulation in AODV with 50 Nodes Packets seen in application. Packets seen from the application. We can see the packet transmitted from which Node ID to which Node ID.

DSDV Protocol In DSDV protocol als0 study is carried out.

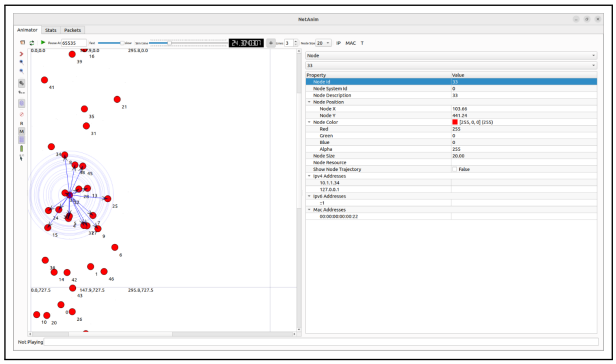

Figure 4: Simulation in DSDV with 50 Nodes

Figure 4 shows the set of mobile nodes which communicate each other. In total there are 50 nodes and communicate with DSDV protocol. Above figure just shows the nodes while below figure show the property of specific node that we select. In figure has selected Node 33

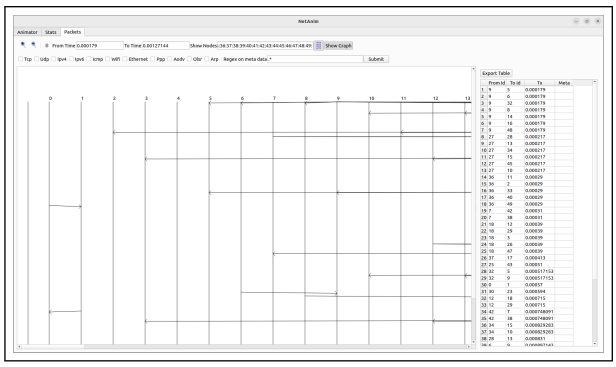

Figure 5: Simulation in DSDV with 50 Nodes Packets seen in application

Figure 5 shows the Packets seen from the application. We can see the packet transmitted from which Node ID to which Node ID. Packets seen from the application. We can see the packet transmitted from which Node ID to which Node ID.

4.1.2 Testing for 1000 Nodes

While we move towards 5G, the number of nodes will be increased drastically. One of the major requirements for 5G is increase in density of the nodes. Currently for simulation we are using 300m*500m that is 0.45 sq km area. As per the requirement of 5G, the density of the connection will be high. Although increase of the nodes up to the requirement may not support by simulator, we are increasing the nodes number to 1000 and doing the analysis.

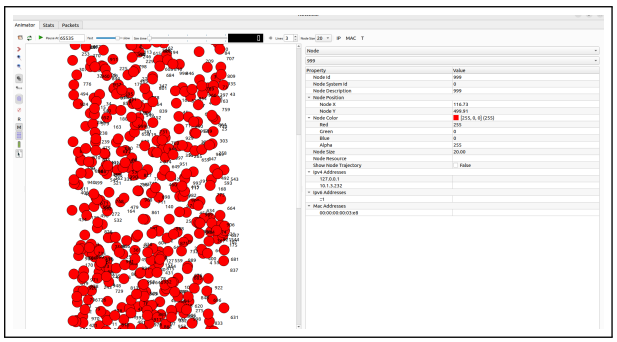

Figure 6: Simulation in AODV with 1000 Nodes. Some part of Network is seen

Figure 6 shows 1000 nodes in area of 0.45 sq. km area that we had considered before. In right side, details of Node 999 is shown. All Nodes are mobile nodes and we have taken screenshot of a moment.

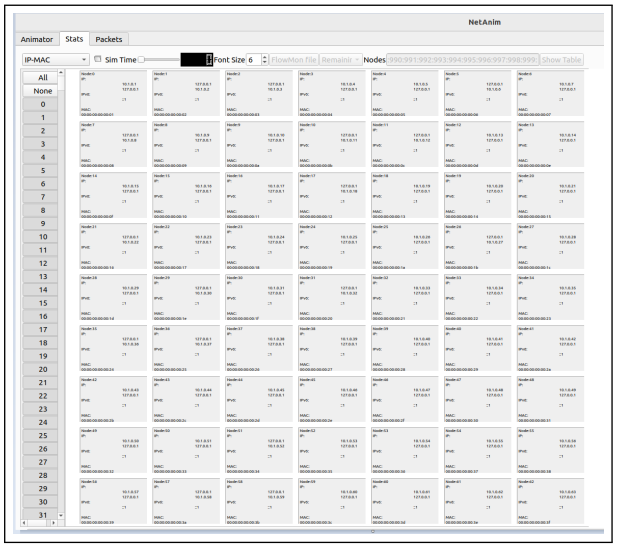

Figure 7: Simulation in AODV with 1000 Nodes IP and MAC status

Figure 7 shows the IP and MAC status of the Nodes. Just a section of the network is taken in this figure. Clearly we can see the MAC address of each nodes along with corresponding IP Address that is assigned to the nodes.

4.1.3 Result for Node Density Increment

Throughput is taken as the performance metrics. In 5G environment, nodes density is the major factor that will be changed. As mentioned in literature review earlier, there will be 1 node in 1 sq meter area. The impulse graph is kust to check the pattern. Calculating the throughput for each cases and merging it, comes the chart as below. In the pulse diagram, it is seen that while increasing the number of nodes, the throughput goes on decreasing.

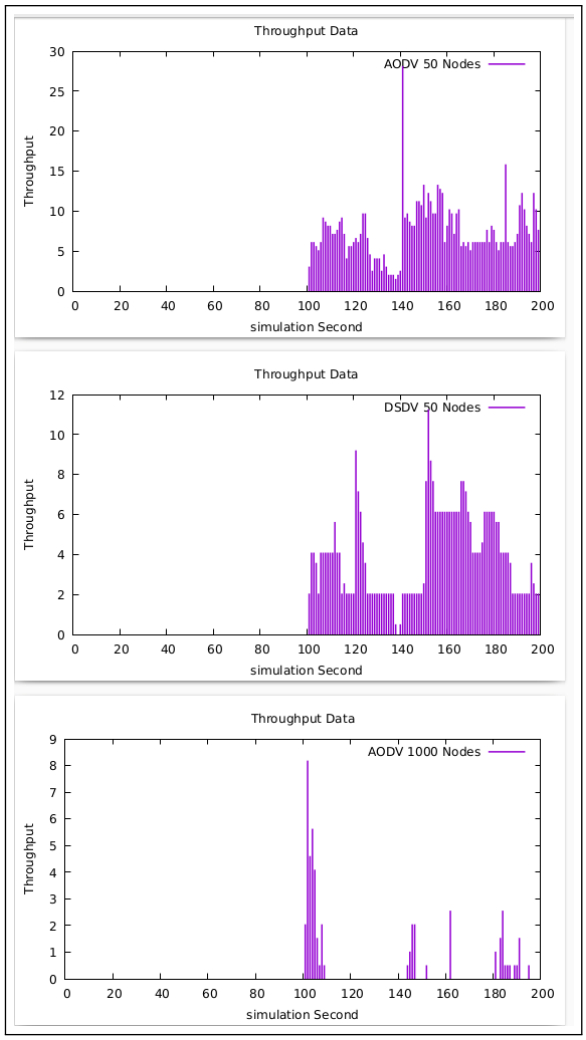

Figure 8: Throughput Impulse & Graph plot for 3 scenarios for routing protocols

Figure 8 shows the Throughput Impulse for AODV with 50 Nodes, AODV with 1000 Nodes and DSDV with 50 Nodes.

In 5G, there will be very high density of the Nodes. Analysing from the above graphs, we can see that in AODV is better in 50 nodes. But while increasing the number of Nodes from 50 to 1000, throughput seems to be decreased. So if the area is large, the MANET can be break down into small network connected with infrastructure based network in back end. Later, further check in density vairiation will also be done.

4.2 Testing in Different Mobility

For the 50 Nodes, paper carry out the simulation for different speeds 20m/s, 50m/s and 130m/s. First, simulation for AODV and then for DSDV is carried. As per the requirement of 5G as mentioned in [1], mobility can be 0 to 500km/hr (138.889 m/s). So, similar experiment will be carried out for different density. Finally checked the throughput for both AODV routing protocol and DSDV routing protocol for all the speeds that is 20m/s, 50m/s and 130m/s.

4.2.1 Result for Node Mobility Increment

Below data and graphs shows the result of the Node in different mobility.

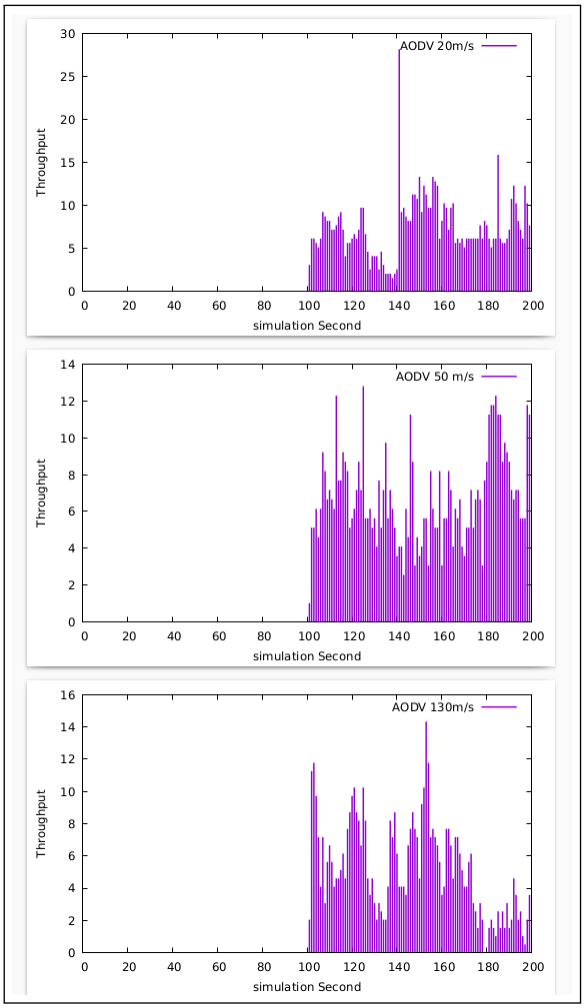

Figure 9: Throughput Impulse & Graph plot for different mobility speeds for AODV

Figure 9 shows the Impulse and graph for different mobility speed of 20m/s, 50m/s and 130m/s for AODV protocol for 50 mobile nodes. From the graph it is seen that AODV protocol will support for mobility increment in 5G.

Similarly for DSDV protocol result like below will be seen.. We have tested the DSDV protocols in different Mobility speeds. As per the requirement of 5G as mentioned in [1], mobility can be 0 to 500km/hr (138.889 m/s). So similar experiment as earlier is carried out.

Figure 10 shows the graph for the speed of 20m/s, 50m/s and 130m/s for DSDV protocol for 50 mobile nodes. In 5G, 130m/s is the maximum speed as defined in [1]. From the graph it is seen that DSDV protocol is not completely scalable for high mobility. As mobility increases, the impulse plots scratches and sometime goes to zero as well.

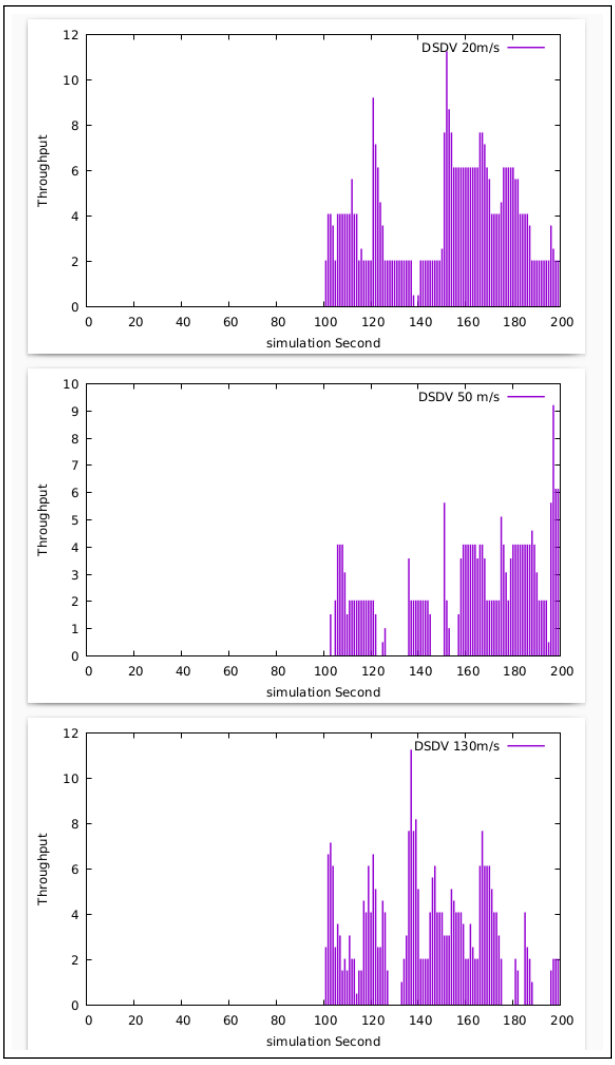

Figure 10: Throughput Impulse and Graph plot for different mobility speeds for DSDV

So from the experiment and simulation of routing protocols with different mobility, it is seen that AODV protocols support increase in mobility while for DSDV protocol, it won't support fully for increase in the nodes speed.

4.3 Testing in Different Datarate

Testing has been done for datarates for AODV and DSDV protocols.Output of throughput has come as follows.

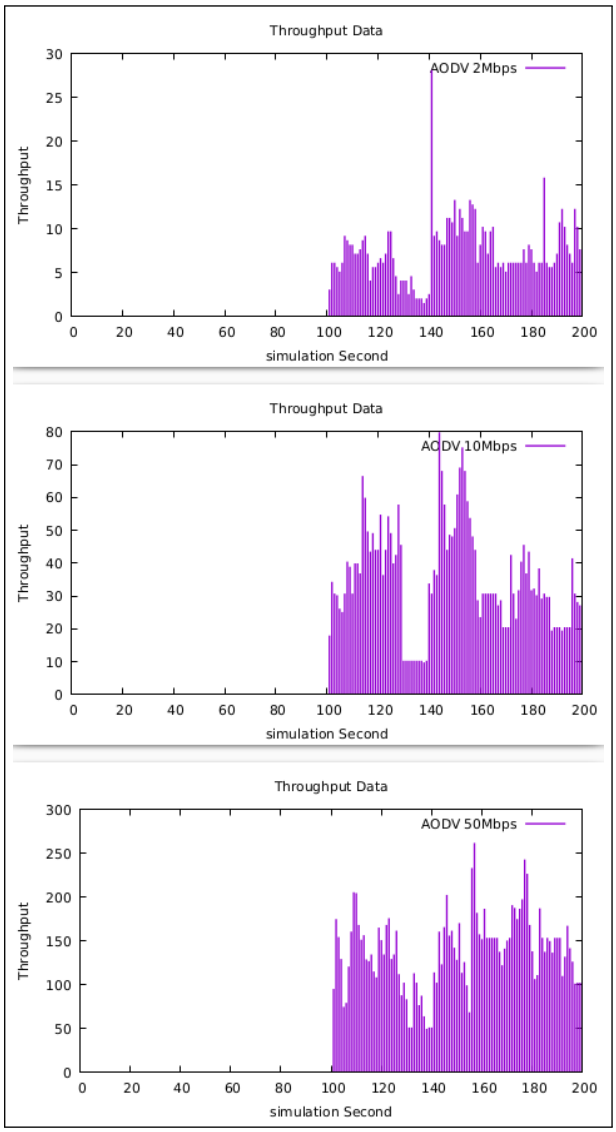

Figure 11: Impulse plot for different Datarates for AODV

Figure 11 shows the Impulse plot for different data rates of 2Mbps, 10Mbps and 50Mbps for AODV protocol for 20 mobile nodes. From the graph it is seen that AODV protocol will support for increment in the datarate. Actually from the graph pattern, it is

clearly seen that while increasing the data rate in AODV, the nodes are working fine. In graph it is shown just 3 cases just to check the pattern. Later will check plot for other datarates as well.

Similarly for DSDV protocols also, test has been carried out.

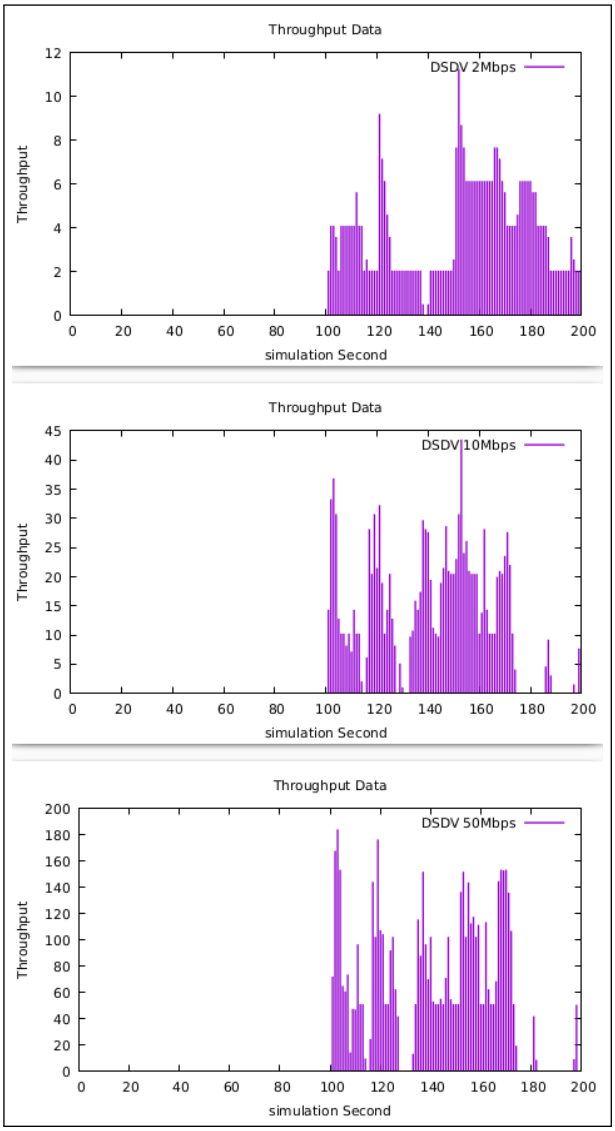

Figure 12: Impulse plot for different Datarates for DSDV

Figure 12 shows the Impulse plot for different data rates of 2Mbps, 10Mbps and 50Mbps for DSDV protocol for 20 mobile nodes. From the graph it is seen that DSDV protocol will not fully support for increment in the datarate. Earlier in AODV, comparatively graph was constant where as in DSDV while increasing the speed, throughput goes to zero in most of the simulation seconds. So, it can be seen that AODV better serves than DSDV.

4.4 Testing with mmwave

As in 5G, mmwave is assumed to have high usage. They may have important role in 5G communication. From the earlier study in paper, AODV seems fine. So, test has been done for AODV in mmwave frequency.

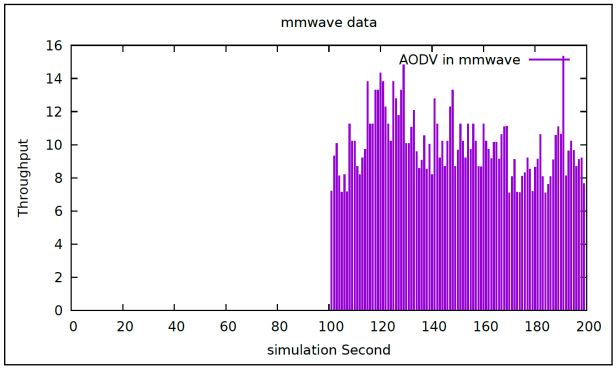

Figure 13: Impulse plot for mmwave for AODV

Figure 13 shows the throughput for the mmwave taken from NS3. For mmwave, it is seen that the throughput is more stable than that of earlier cases. As the throughput is more stable, it will have better delivery ratio. So, mmwave frequency will support AODV protocol with better throughput.

4.5 Overall Comparison

Now, let us have a look in overall comparison of the data that we received from earlier readings in terms of density, mobility and datarate.

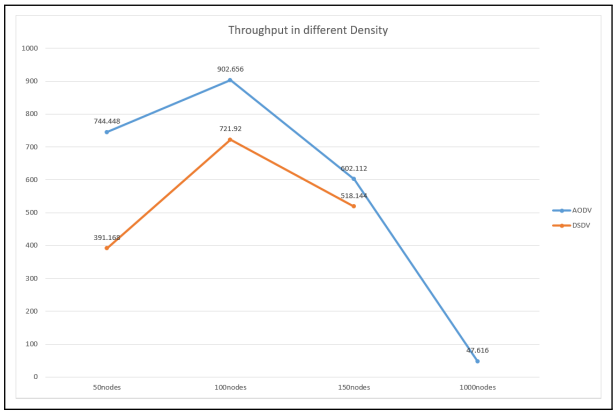

Figure 14: Overall comparison in different Density

Figure 14 shows the comparison in different density for simulation area of 300m*1500m. Overall throughput of AODV for the given simulation period is better. Also, upto 100 nodes, throughput increases with the increase of density but while we go increasing the value of nodes, throughput goes on decreasing trend.

In the figure above, the area of simulation is 300m*1500m. Now lets reduce the simulation area and perform test. Lets take a small area of 100m. sq. for simulation. So, as per the paper [14], in 100m.sq. we need 100 nodes to meet the requirement of 5G. After reducing the simulation area, can be checked for the maximum nodes that 5G requires.

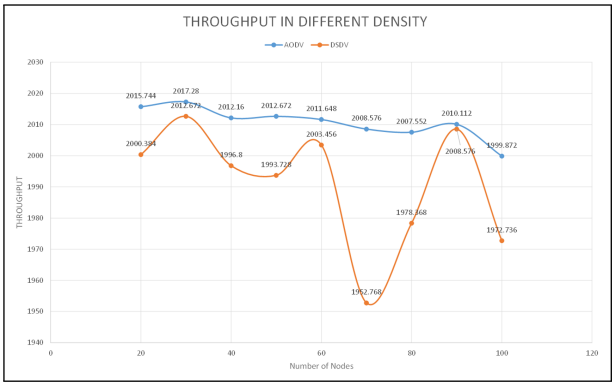

Figure 15: Plot of Throughput in different Nodes Density

From the figure 15, it is seen that AODV and DSDV protocols supports 5G environment while we increase the number of nodes. Throughput of AODV is better than that of DSDV. So, if the area is small, both of the protocols works well although AODV performance is better comparatively.

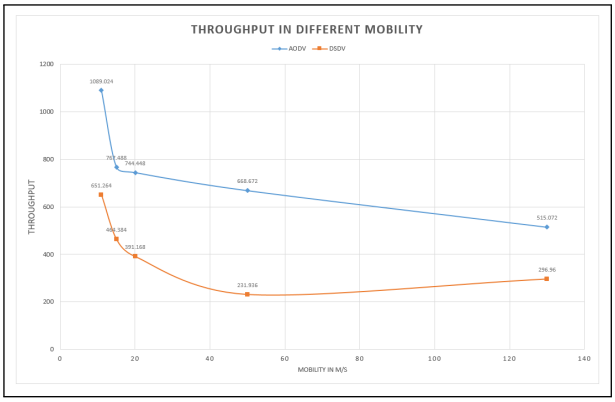

Figure 16: Plot of Throughput in different Mobility

Figure 16 shows the comparison plot in different mobility. From the above figure 16, we can see that the throughput decreases with the increase of the mobility. If we check the results in the graph, the throughput value of AODV at 50mbps is still greater that that of DSDV protocols at 11mbps speed. As the requirement for 5G is the nodes mobility from 0km/hr to 500km/hr which is equal to almost 139m/s. So, from above scatter plot it is seen that the MANET can be scalable towards 5G with those protocols and AODV is serving well than that of DSDV.

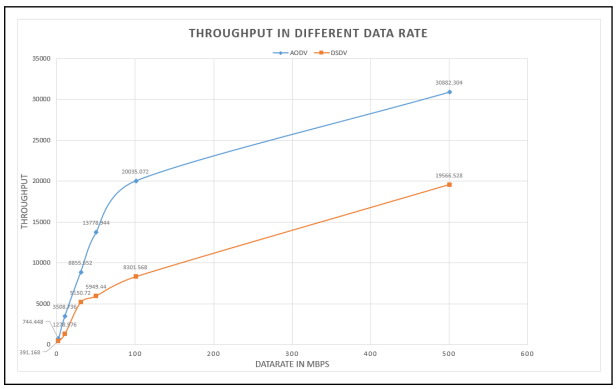

Figure 17: Plot of Throughput in different Datarate

Figure above 17 shows the scatter plot for different datarates. From the graph, it is seen that the overall throughput in both AODV and DSDV protocols are in increasing order with the increase of the data rate. As per the requirement for 5G, user experienced data rate are 50Mbps for uplink and 100Mbps for Downlink, it is seen that MANET is working fine. Also, in 5G Manet, the network will support for realtime video streaming and this bandwidth will be okay for that.

4.6 Scatter Plot of AODV Vs DSDV

Now let us plot AODV vs DSDV for all 3 scenarios of density, mobility and datarate.

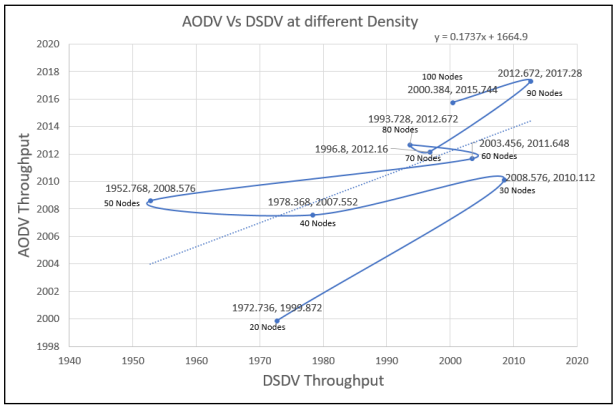

Figure 18: AODV VS DSDV different density

From 18 it is seen that sometime the graph points towards AODV while sometime towards DSDV. This is small area of simulation.So, when the simulation area is small, DSDV can also work well. The overall graph converges towards AODV means AODV works better.

Similarly, let us check for different mobility.

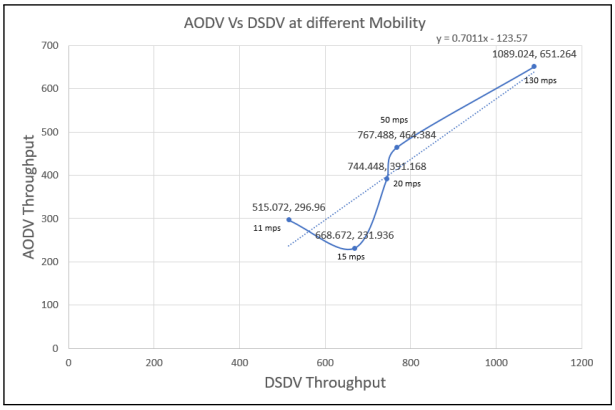

Figure 19: AODV VS DSDV different mobility

From the figure 19, the overall portion of line is towards AODV. Throughput of AODV seems better than that of DSDV.

Now for datarate, scatter plot comes as below.

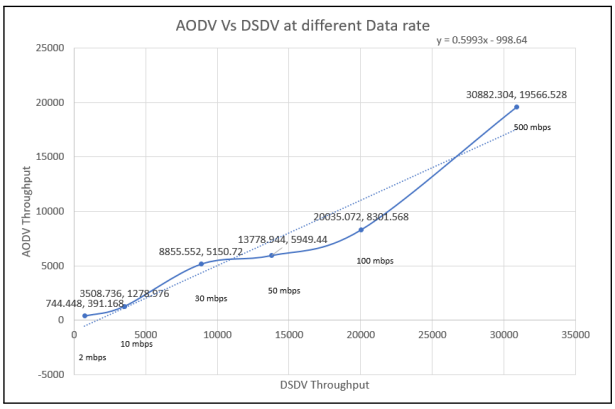

Figure 20: AODV VS DSDV different datarate

From figure 20, seems both AODV and DSDV is working good. But, the throughput of AODV is better comparatively.

5. Conclusion

This paper shows the results of throughput in different density, mobility and datarate fro corresponding 5G values as mentioned in paper [1]. From overall testing, AODV is seen to work fine in 5G. Also in mmwave, AODV has done better performance.

From the figure 15 the protocols of MANET supports with the increase in the number of nodes. AODV can works fine for 5G environment while we increase the number of nodes to corresponding 5G value. Also from the figure 16 overall throughput of AODV and DSDV protocols decreases with the increase in the mobility. Throughput value of AODV is better than that of DSDV. For 5G, mobility requirement is 139m/s which is supported in both protocols. Similarly from figure 17, at low data rates, both performing well whereas while increasing the data rates values in both, performance of AODV is better while increasing the speed. Also from the earlier impulse plots in this paper, AODV is working fine in comparison to DSDV as in DSDV there is high flapping in the throughput and most of the time goes to zero while increasing the parameters related to 5G. Again, if we compare the results with the throughput of AODV in mmwave 13, in mmwave, throughout is still better and stable. From the scatter plots in figure 18, figure 19 and figure 20 it is clear that in all three conditions, AODV is serving well.

Hence in 5G, there will be high numbers mobile nodes with different speeds requiring different data rates, AODV routing protocol can be used. For throughput, threshold can be determined based on the requirement. So, to cover the area in 5G, it is better to compose small MANET networks within the defined threshold. There will be different groups of MANETs and in the backend, those will be connected to the infrastructure-based network with fixed architecture. By doing this, MANET can be designed as per any requirement.

6. Future Enhancements

A lot of effort in this research work, has been put in feature engineering.This research paper works in the field of density, mobility and datarate. In future, research can be done in other dimensions as well. Air Traffic capacity, Latency, Spectral efficiency, Energy efficiency etc should also be noted during the research in future.

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