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A Comprehensive Performance Analysis of WLAN Protocols Using the NS-2 Network Simulator

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ABSTRACT

Objective: *This project focuses on simulating a Wireless Local Area Network (WLAN) using NS-2, specifically targeting a peer-to-peer (Ad-hoc) network.* ***Method:*** *By utilising an Independent Basic Service Set (IBSS), we enabled wireless devices to communicate directly with one another without relying on a central access point or base station. A network bridge was also integrated to connect the WLAN to external networks. Our approach began with a thorough examination of wireless simulation types and the key factors that influence network performance. From there, we mapped out a topology modelled after a university campus, strategically spacing out wireless nodes and adjusting their transmission power to ensure full coverage. To evaluate efficiency, we measured key performance metrics—including packet delivery ratio, delay, jitter, and throughput—and analysed how they scaled with traffic volume. Finally, we deployed and compared three routing protocols (AODV, DSR, and DSDV) to find the most efficient fit.* ***Results:*** *Ultimately, this allowed us to design a highly optimised, resource-efficient network layout that maximises performance without wasting bandwidth.* ***Novelty:*** *This project compares the performance of AODV, DSR, and DSDV routing protocols within an IBSS-based WLAN simulation to identify the most efficient protocol for a university campus network topology.*

INTRODUCTION

The real-world environment consists of numerous things, of which electronics is a major part. Almost all the fields, such as medical, educational, defence, industrial, automobiles, etc., use electronic devices in their functioning. The electronic devices are connected either using a physical connection (wired connection) or without a physical connection (wireless connection). The task of network simulation is accomplished using a network simulator [1], which is a type of software or hardware that predicts the behaviour of a network without an actual network being present.

Out of many popular simulators available in the present world such as NS2, NetSim, OPNET

Modeler, and QualNet, we use NS-2 in our current project for simulating the wireless Local Area Network (WLAN). This is justified because it's an open-source, readily available simulator with rich functionalities and widely used throughout the globe. Further, it's a discrete event simulator [2] targeted at networking research, providing enough support for simulation of TCP, routing, and multicast protocols over wired and wireless (local and satellite) networks. It's written in C++ and an Object-oriented version of Tel called OTcl.

Using ns-2.27, we create a network topology by taking Misan University premises as the simulation area and place static and mobile wireless nodes at specific locations. We then simulate by initiating the data transfer between two mobile nodes and also through multiple nodes.

During simulation, we consider the following parameters:

- The university area for simulation is chosen as 600m x 400 m.
- In the first type of simulation (Adhoc peer 1o peer), we place 25 mobile wireless nodes in
- The entire area at appropriate locations and start peer-to-peer simulation between a certain pair of nodes.
- In the second type of simulation (Bridged), we place 9 static wireless nodes which acts as routers and 16 mobile wireless nodes and then initiate the simulation.
- The nodes are placed at appropriate locations so as to ensure the complete coverage
- The routing protocols such as AODV (Ad-hoc On-demand Distance Vector), DSDV
- (Destination-Sequenced Distance-Vector), and DSR (Dynamic Source Routing) are used in this simulation and are also compared with respect to their network performance.
- The protocol MAC/IEEE 802.11 is used for the simulation.
- Two ray ground radio propagation model and omni Antenna are considered.

By running the above simulation, we calculate the number of packets sent/received/dropped, measure jitter and delay, packet delivery ratio, throughput and other parameters.

Apart from the above calculations, we also plot their variations with respect to packets sent per second for all the three routing protocols AODV, DSR, DSDV.

It has been considered the concepts involved in the simulation of wireless networks in ns2. We shall discuss these concepts taking one at a time and finally lead to the actual implementation.

A. Adhoe Network

A wireless network containing wireless nodes with each connecting to the other wirelessly wi ut the need of a wireless router constitutes an Ad Hoc Wireless Network. The wireless settings f such networks differ slightly from those of a wireless network with or without a wireless router.

B. Radio Propagation Models

The are many different radio propagation model only three of which at currently implemented in ns. These are free space model, two-ray-ground reflection model, and the shadowing model.

There arises the point, questioning the need of these models. We need these so as to predict the received signal power of each packet. It is important in deciding whether a packet needs to b considered or dropped depending on this signal power.

Free space model

This model is based on the assumption of ideal propagation conditions where we consider only one clear line – of – single path between the transmitter and receiver.

we can calculate the received signal power under these conditions using Friis equation for a distance 'd' from the transmitter [3].

$$p_r(d) = (p_t G_t G_r \lambda^2)/(4\pi)^2 d^2 L$$

Where Pt, is the transmitted signal power ,Gt ,transmitter antenna gain, Gr, receiver antenna gain,L(L≥1) is the system loss, and λ is the wavelength.

In the propagation, the communication range/ coverage area of transmitter is represented as a circle around it. A reciver receives all the packets if its within the circle else it loses all the packets.

Two-ray ground reflection model

This model considers both the direct path and a ground reflection path. It's known for its more accurate prediction at a long distance (only over simple, uncluttered ground) than the free space model. Further, the received power at distance d is predicted by

$$P_r(d) = (P_t G_t G_r h_t^2 h_r^2)/\ d^4 L$$

Where ht, is transmitter antenna height and h, is receiver antenna height

Shadowing model

Unlike the other two models described above, this model considers that the power is not deterministic function of distance instead it is a random function (as all the multipath components are not known) due to multipath propagation/ fading effects.

This is mostly used and consists of two parts viz. path loss model (which predicts the mean received power at distance d and the variation of the received power at certain distance.

The overall shadowing model is represented by

$$\frac{[P_r(d)}{P_r(d_0)]_{dB}} = -10\,\beta \log\left(\frac{d}{d_0}\right) + X_{dB}$$

Where'd' is the distance at which the mean received power is predicted and 'do' is a close-in distance which is used as a reference, and 'X dB' is a Gaussian random variable with zero mean and standard deviation, also called shadowing deviation.

C. Routing Protocols

Routing protocols play an important role in any wireless network as it is responsible for delivering the packets to the correct destination from the specified source. Routing [4], is a process wherein a particular path is selected or calculated in a network along which the data or network traffic is sent. It takes place in all the networks (telephone network, internet, and transportation networks). Also, at times, there will be a multi-hop in action wherein the data is routed along many other nodes before reaching the actual destination node. Hence, the need for an efficient routing protocol becomes inevitable. There are three main routing protocols that we use for simulation in ns2, viz. [5]

DSDV (Destination Sequenced Distance Vector)
DSR (Dynamic Source Routing)
AODV (Ad-hoc On-Demand Distance Vector)

DSDV

This routing protocol [6] is based on a table-driven routing scheme, which is mainly meant for solving the routing loop problem. In this, each entry in the routing table contains a sequence number, and these sequence numbers are generally even (if a link is present), else an odd number is used. The number is generated by the destination, and the emitter needs to send out the next update with this number. Routing information is distributed between nodes by sending full dumps infrequently and smaller incremental updates more frequently.

DSR

The DSR agent checks every data packet for source-route information and forwards the packet based on the routing information.

AODV

1ODV routing protocol is a combination of both DSR and DSDV. It implements the basic route discovery and route-maintenance of DSR and the hop-by-hop routing, sequence numbers an beacons of DSDV. Any node wanting to know a route to a particular destination, generates a ROUTE REQUEST which in turn is forwarded by intermediate nodes that also creates a reverse route for itself from the destination.

D. Traffic Agents and Respective Applications

Two types of agents or protocols in ns2 viz used.

TCP/IP (Transport Control Protocol/Internet Protocol) which is a dynamic reliable congestion control protocol that decides the packet reception using acknowledgements and the packet drop using congestion signaling and **UDP** (User Datagram Protocol) which is same as TCP/IP with an additional characteristic of introducing random noise during the transmission based on a flag.

Components of a LAN

The below figure depicts the extended network stack [Z] that makes simulations of local area network possible in ns. A packet when sent down the stack, flows through the link layer (Queue and LL), the MAC layer (Mac), and the physical layer (Channel to Classifier/Mac). The packet then makes its way up the stack through the Mac, and the LL.

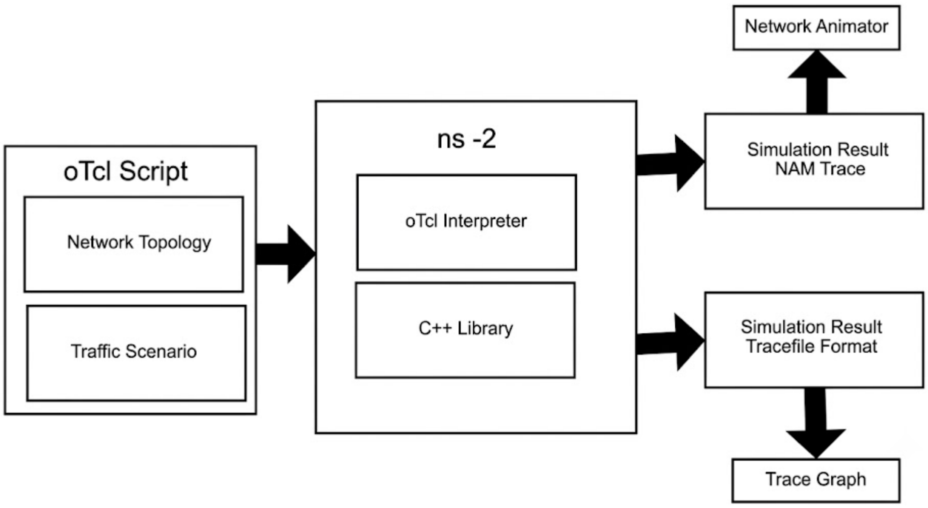


Figure 1. Components of a LAN II3].

E. Packet delivery ratio, jitter and end-to-end delay, throughput

The behavior of wireless nodes [7] is evaluated in terms of Packet delivery ratio, jitter and end-to-end delay which are the three principal considerations that are taken into account when considering QoS applications and network resource management.

The Packet Delivery Ratio (PDR) is the number of packets received by the destination no vided by the number of packets sent by the source node. The higher the ratio, the higher is the efficiency of the network.

PDR (%) = (Number of packets received / Number of packets sent) * 100

Jitter [8] measures the variability of delay of packets in the given stream and is of two types: delay jitter (which bounds the maximum difference in the total delay of different packets), and rate jitter. (which bounds the difference in packet delivery rates at various times).

It is a critical variable for applications that are sensitive to delay as excessive Jitter can cause phase distortion during packet reception. Jitter can be reduced by increasing the node speed and is measured in milli seconds.

F. Omni Antenna

An antenna is a physical device which radiates signals (either electromagnetic or radio) through free space or a communication channel by converting into the form suitable for channel.

Out of the two antenna types available in NS-2, we use omni directional antenna which radiates equally in all the directions. They have a unity gain and is used by mobile nodes in the simulation.

G. NS-2

Network simulator 2 (NS-2) [9] is an open source discrete event simulation tool used for simulating Internet protocol (IP) networks. It was developed by UC Berkeley and widely used worldwide for network simulation purposes. The NS-2 software uses TCL as a front-en interpreter and C++ as the back end network simulation engine. The below figure depicts its architecture

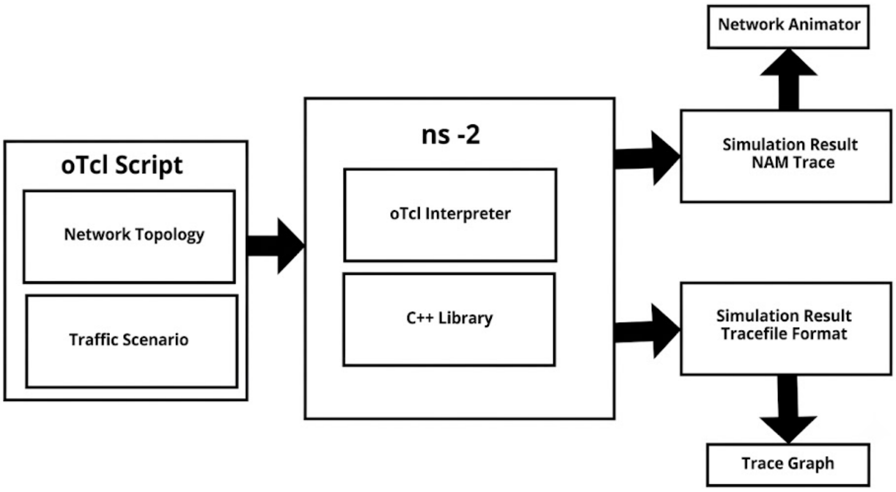


Figure 2. NS-2 Architecture.

H. Research carried out in Wireless Simulation

Wireless simulation is a vast concept which is being undergoing research from many years and still going on. Many people are working on different areas of wireless concepts which include unicast protocols (AODV, DSR, DSDV), multicast routing protocols (Flooding, ODMRP, ToMuRo) [7] where the performance of topological multicast routing algorithms on mobile wireless ad-hoc networks is evaluated, Connectivity of nodes in wireless ad hoc and sensor net [10] where the transmission range of the nodes in ad hoc networks affects the connectivity and routing overhead is studied and analyzed. Apart from the above, there's also been a study on the Multi Hop Communication in Global Wireless Framework [11] where the possibility of allowing all the wireless ad-hoc devices to use the same Network Address in a Global Wireless Framework is presented.

The performance dynamics of Wireless Local Area Networks (WLANs) under varying structural and operational conditions have been a major focus of recent empirical research using the NS-2 simulator. When investigating the fundamentals of the IEEE 802.11 standard across the 2.4 GHz and 5 GHz spectrums, simulations consistently highlight that scaling up node density within restricted enterprise or residential topologies triggers significant channel congestion, driving up collision rates and packet drops [12]. To counteract these physical bottlenecks, researchers frequently model multi-Access Point configurations using orthogonal channel assignment schemes to successfully isolate contention domains. At the same time, the integration of distinct traffic handling mechanisms remains a complex trade-off; while QoS-aware frameworks like Enhanced Distributed Channel Access (EDCA) reliably shield high-priority multimedia traffic from latency spikes, NS-2 data proves that they inherently starve lower-priority application queues during sustained periods of high network saturation [13]. Furthermore, in mixed network topologies where newer protocols like 802.11ax coexist alongside legacy deployments, introducing intelligent reinforcement learning frameworks at the MAC layer has emerged as a crucial approach to balancing channel access fairly and optimizing overall aggregate throughput [14].

When transitioning from fixed infrastructure to mobile and ad-hoc wireless environments, the challenges shift heavily toward topological instability and security vulnerabilities. Simulative benchmarks evaluating routing backbones—such as comparing reactive Ad-hoc On-Demand Distance Vector (AODV) against proactive Destination-Sequenced Distance-Vector (DSDV) protocols—show that increasing node mobility causes frequent link breakages, which sharply inflates packet loss, routing overhead, and end-to-end jitter [15]. This disruption directly impacts the energy profiles of terminal hardware, as automated packet retransmissions accelerate local battery depletion and reduce overall network longevity. Beyond physical movement, these decentralized topologies are highly sensitive to malicious network disruptions. Recent security assessments conducted within NS-2 emphasize that common network-layer exploits, such as blackhole and grayhole routing attacks, severely degrade packet delivery ratios and artificially spike delays [2]. This highlights the pressing need for adaptive, security-aware routing metrics to preserve network stability and efficiency.

RESEARCH METHOD

Any project undergoes a sequence of steps before leading to the final output. It needs to go through a specific cycle to achieve the target result. A similar kind of procedure or cycle is followed in my task of Simulating a WLAN using ns-2 simulation software as depicted in the below figure which seems to be more realistic.

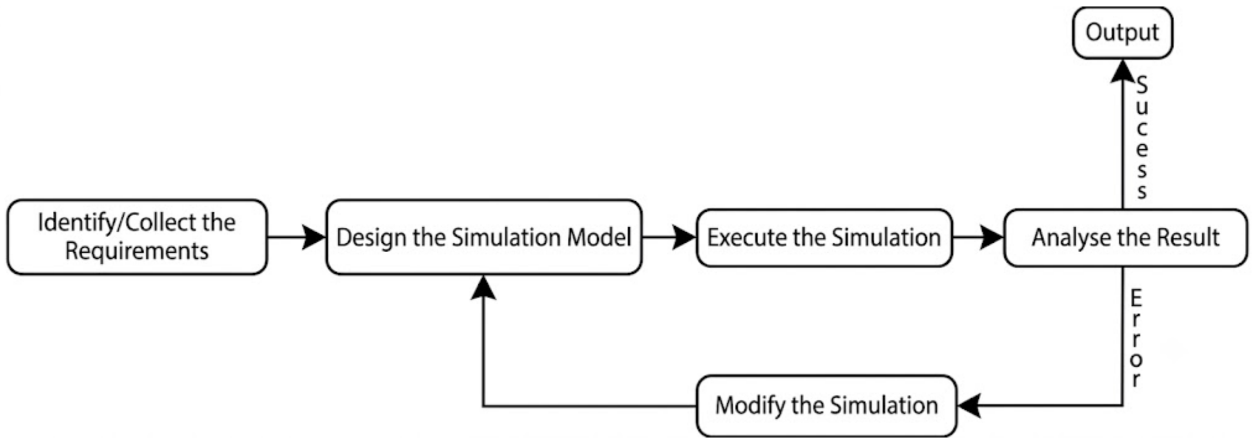


Figure 3. Analyzing the Steps in Simulation.

As shown above, we first understand the task, try analyzing it and find different possible solutions. We then select an appropriate solution and an efficient way of achieving it. We finally start gathering all the requirements needed for achieving the solution.

In a similar fashion, in ns-2 we first identify the simulation area and analyze it properly using its dimensions, possible coverage and non coverage areas, and estimate the required number of nodes and communication range for each node, the power needed and other related parameters. Finally, we start fixing these parameters with the feasible values.

Once we finish collecting all the parameters and its related data, we begin the process of designing the network topology or simulation model. In this, we place all the nodes at random locations calculated in the previous step. We also define the radio propagation model, routing protocol, the agents and corresponding applications, and finally the simulation times.

Then there comes the stage for executing the designed simulation model. We run the simulation model using the available ns commands in Bourne shell using Cygwin which creates a Linux like environment on Windows OS. The results obtained from this execution can be any one of three formats viz NAM, trace file, X-graph.

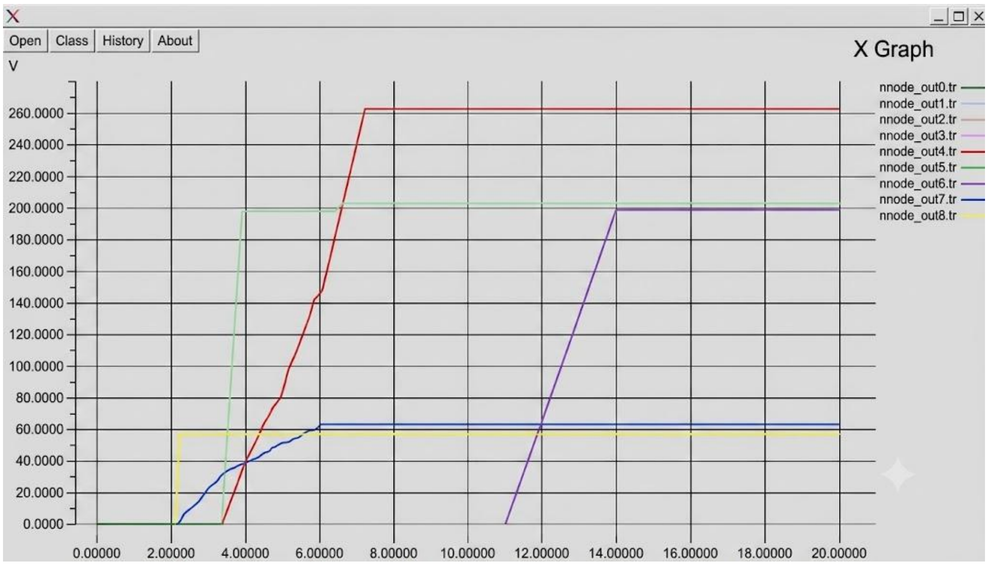
RESULTS AND DISCUSSION

Results

We then analyse the results produced from the above step and compare those with that of the expected simulations as assumed at the beginning of network design. If the simulations prove to br satisfactory, then there completes the simulation process. Else, we modify the simulation model according to the shortcomings and execute the modified design and check the results. If the results now prove to be satisfied we end the process or else repeat the modify, re-execute process until the results are achieved.

A. X- Graph

This is one form of output obtained from NS-2 simulation which displays the number of received packets on Y-axis and its variation with respect to time on X-axis.



Figue 4. X- Graph showing the variation of packets with the time.

B. NAM

When a tcl simulation script is run, it loads a Network animator window where the network simulation gets displayed. The below figure shows the features available in the nam.

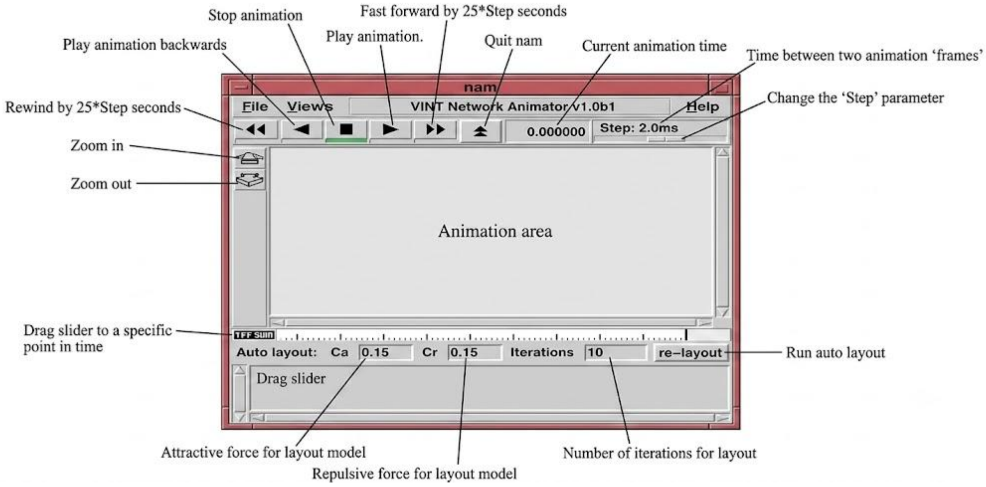


Figure 5. NAM window showing various features [15].

C. Simulation of University Area

We now start the actual simulation of university area by running the tol scripts for both peer-to-peer and bridged simulation using three types of routing protocols viz. AODV, DSR, DSDV

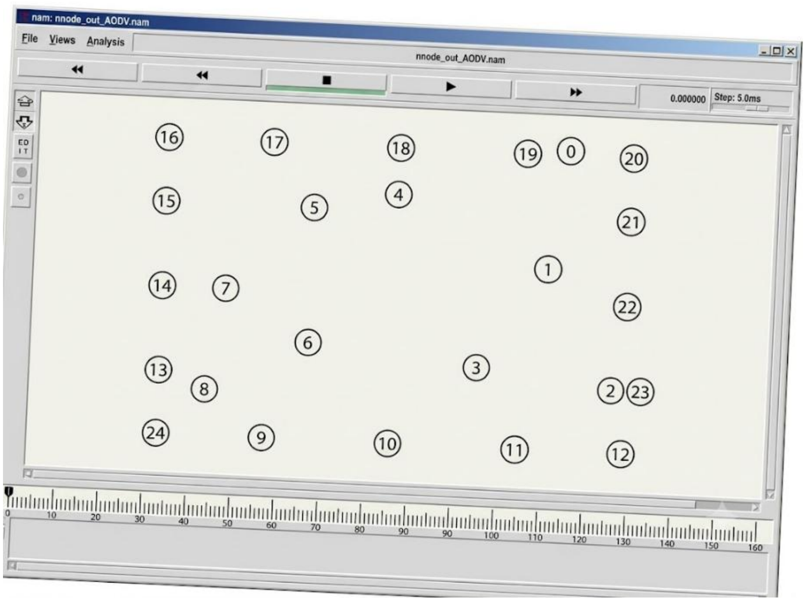


Figure 6. Equivalent Network topology in ns2 showing the nodes layout in the Simulation area of 600 X 400 m.

As seen from the above figure, we distribute 25 nodes in the entire simulation area so as to ensure an efficient data transmission in the select network topology.

Firstly, we consider Adhoc peer to peer network where there is a dedicated transmission randomly between a selected pair of nodes (without the need of the base station) throughout the topology. We then generate the trace files, x-graphs, nam simulation outputs and using those we calculate the parameters like number of packets sent, received, dropped, the delay occurring in between packet transmission and reception, throughput, jitter etc.

Secondly, we take bridged network where we initiate the packet transmission from a static node (which serves the functionality of router) and the packet rcception at a mobile node end.

We divide these 25 nodes into static (9) and mobile (16) nodes. The dynamic routing occurs from the source node through a number of nodes until reaching the target node when the target node moves out of its communication range.

In both the above types of networks, we calculate the parameters for all the 3 different type of routing protocols.

D. Adhoc peer to peer using AODV routing protocol

In the designed Adhoc peer-to-peer network, we select certain pairs of nodes for the simulation.

This can be observed in the below figure where simulation occurs between node 0 and 21, node 1 and 22, node 2 and 11, node 6 and 9, node 8 and 14 which constitute single hop connections wherein a packet undergoes only one transit before reaching the destination from the source. This is a simple type of connection.

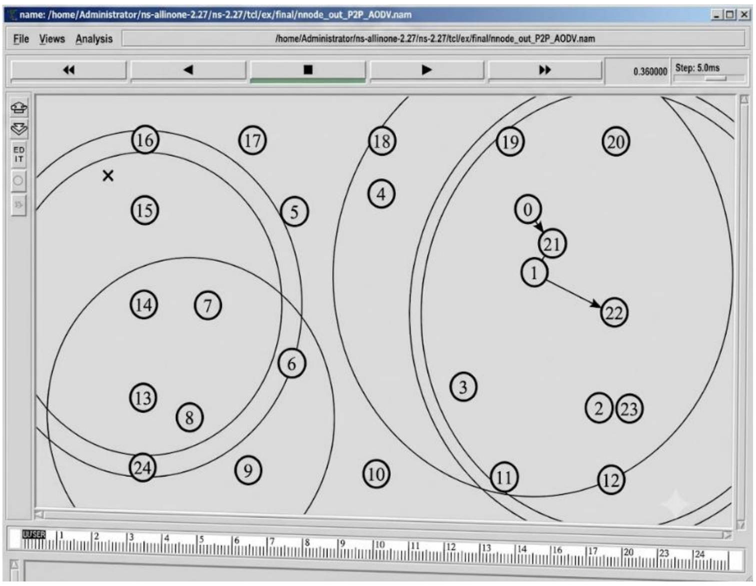


Figure 7. Adhoc peer-to-peer network showing the simulation between pairs of mobile nodes.

Once the above simulation is finished, we get a trace file containing the information regarding the nodes, source and destination addresses, port numbers, simulation times, packet details, network agents etc. We then create an awk script and apply it on this trace file to calculate the total number of packets sent, received, dropped, delay, throughput and other values. We also generate an x-graph showing these results in a graphical format.

E. Bridged Simulation using AODV routing protocol

We now start the bridge simulation, where the static nodes transmit the packets to mobile nodes During this process, we find smooth transmission when the destination mobile node is within the communication range (which can be controlled by the transmitting power) of the source static node. We observe the packet dropping when mobile node moves away from the communication range in the initial stage which will cease when the static nodes find an alternate route to send the data which can be observed in the below figures where static node 0 directly sends the data to mobile node 21 when both are in communication range (Fig 9) and then packets drop (when they move out) and finally retransmission occurs using an alternate route (Fig 10)

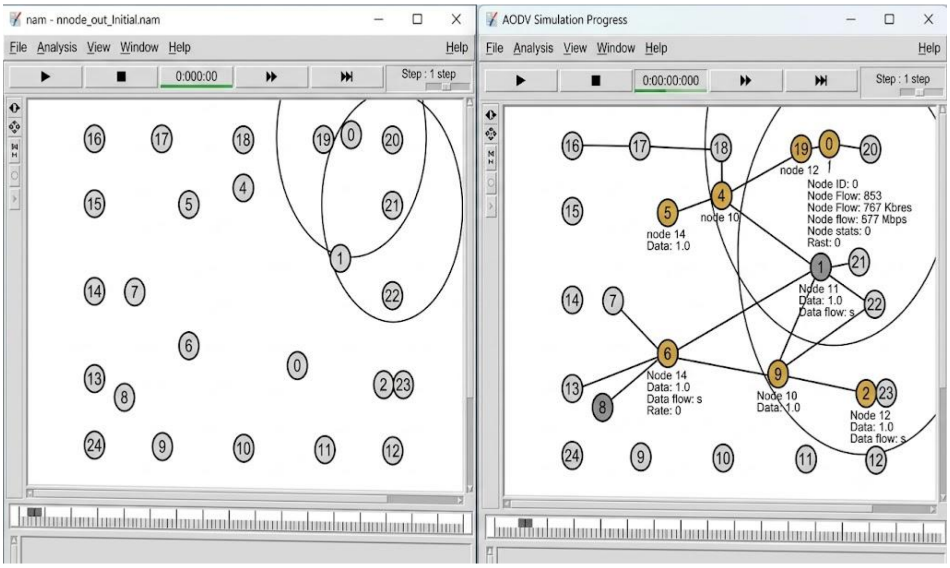


Figure 8. Packet transmission between node 0 (static) and node 21 (mobile).

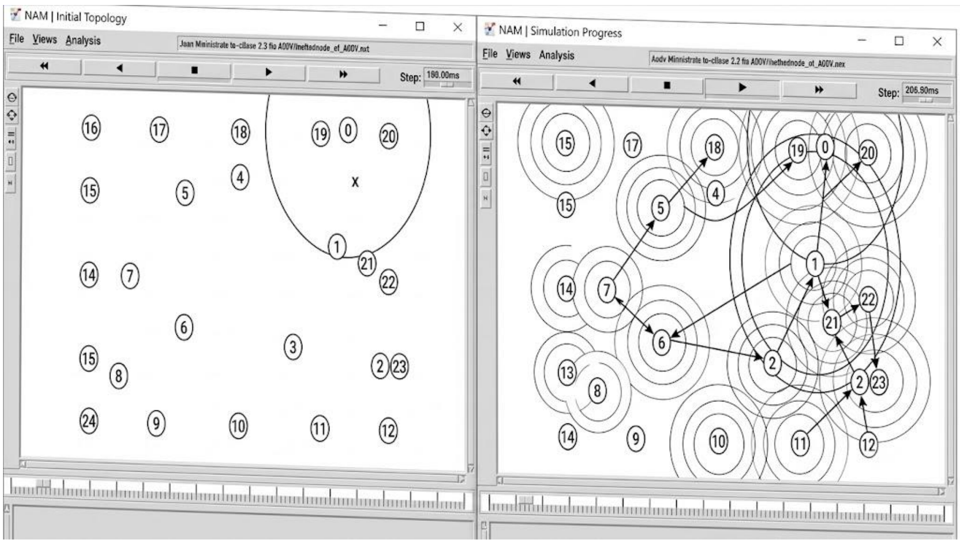


Figure 9. Packet dropping between node 0 (static) and node 21 (mobile) and re-transmission using an alternate routing (node 0 to node 21 via node 1).

F. Special case of Bridged Network

We now consider a special case where there may be a need to send data from one node (node 0) to other node (node 24) located at two extreme corners of the network topology. With the transmitting power presently used (0.03652 Watts) we get a communication range of 150 metres for each node which proves to be a short coming in our current scenario (where the two nodes are much far away than 150 metres). But when we increase the transmitting power (to 0.18489 Watts) we get a communication range of 225 metres using which, node 0 tries to calculate the efficient route (nearest path) to node 24 and starts sending the data as it can be observed in the below figures (Figl1 and Fig 12).

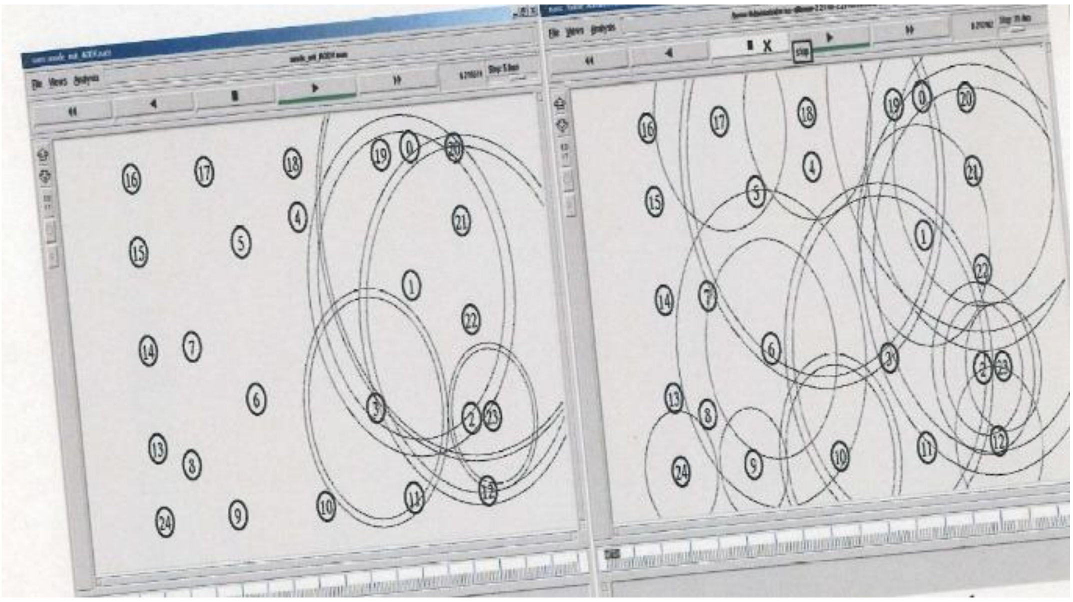


Figure 10. Route request from node 0 to 24 fails due to less transmitting power and proves to be success with increasing transmitting power.

Once the route is calculated using the increased transmitting power, node 0 starts sending the packets to node 24 using the route as shown in the below figure and it solves our problem.

Figure 11. Packet transmission from node 0 to 24 by calculating the more efficient

Routing (via node 1, node 11, node 10, node 9 and finally to destination).

In a similar fashion, we run the simulation using the other two routing protocols (DSR, DSDV) for both peer-to-peer and bridged networks and, in turn, calculate all the parameters as described above.

G. Comparison of the results obtained from the above Simulations

We now reach a stage where we can compare all the values obtained from the above simulations and try using those to improve the efficiency of the simulation and in turn the network design.

Further, we select the best routing protocol for our network using these values.

A comparison of all these values obtained from using different routing protocols for both bridged and peer-to-peer networks is given in Tables 1.1 and 1.2 respectively.

Table 1. Comparison of the results obtained from the bridged network for all the three routing protocols for packet intervals of 0.015 seconds.

Parameter	AODV	DSR	DSDV
Number of packets sent	856	856	856
Number of packets received	785	788	546
Number of packets dropt	71	68	310
Number of bytes dropt	72420	69828	316360
Packet delivery radio (PDR) (%)	91.71	92.06	63.90
Average end to end delay (mili seconds)	184.48	267.99	138.47
Jitter (delay) (mili seconds)	7.11	59.79	27.38
Jitter (Average end to end delay (mili seconds)	13.42	36.74	67.97
Throughput (kilo bits per seconds)	189.84	180.79	131.82

Table 2. Comparison of the results obtained from peer-to-peer network for all the three routing protocols for packet intervals of 0.015 seconds.

Parameter	AODV	DSR	DSDV
Number of packets sent	435	435	435
Number of packets received	435	435	368
Number of packets dropt	0	0	67
Number of bytes dropt	0	0	68420
Packet delivery radio (PDR) (%)	100	100	84.6
Average end-to-end delay (milliseconds)	46.93	47.26	207.55
Jitter (delay) (milliseconds)	55.87	59.91	151.79
Jitter (Average end-to-end delay (milliseconds)	58.93	63.08	158.51
Throughput (kilobits per second)	327.10	314.22	95.07

Discussion

From Table 1, we observe that the number of packets received, dropped, and pdr are almost similar for both AODV and DR, and vary for DSDV to a greater extent for a given number of sent packets. But at the same time, jitter is less, and delay is more for AODV compared to both DSR and DSDV, where these are high. Finally, we also observe that the throughput for AODV is greater than that of DSR, DSDV...

Similarly, from Table 2, we observe that the number of packets received, dropped, por are same for both AODV and DSR and varies for DSDV to a considerable extent for a given number of sent packets. But at the same time, the delay and jitter are almost similar for both AODV and DSR compared to DSDV, where these are high. Finally, we also observe that the throughput for ADV is greater than that of DSR and DSDV.

The above discussions are well supported by the theoretical facts as explained below: The large packet drops in DSDV, as seen in the above tables, support the fact that when a packet to be sent has no routing information, it will be cached, and the routing requests are sent. There is a maximum buffer size for this caching, beyond which the packets are dropped. Hence in the failure of the routing information being calculated, all the packets constituting the extra buffer size are dropped.

Also, the delay in DSDV is the lowest of all due to its low packet delivery ratio in bridged simulation.

We could also observe from the above table that the packet drops in DSR, AODV is minimal, which is due to the fact that there will be an alternate dynamic routing calculation for sending the packets to the destination node. This routing is so fast that it avoids the packet dropping to a greater extent.

CONCLUSION

Fundamental Finding : Your conclusion should be the best part of your paper. A conclusion should: **(**1**)** stress the importance of the thesis statement, (2) give the essay a sense of completeness, and (3) leave a final impression on the reader. **Implication :** Your conclusion should be the best part of your paper. A conclusion should: **(**1**)** stress the importance of the thesis statement, (2) give the essay a sense of completeness, and (3) leave a final impression on the reader. **Limitation :** Your conclusion should be the best part of your paper. **Future Research :** The concept of simulating Adhoc peer-to-peer and bridged networks is a huge field in wireless communication. It's so vast that the research is continuing for years in the past and still going on and is expected to continue in the future as well. In this vast ocean of wireless networking, we could concentrate on developing a network topology for Misan University area based on the available time span. This design is well-suited for the selected area but needs to be enhanced when considered for large geographical areas, which require a more detailed analysis requiring a considerable amount of time. Also, in the current project, we dealt only with the unicast routing protocols, viz. AODV, DSR, and DSDV. Hence, this work can be extended to implement wireless networking for large topographical areas with a detailed analysis of the design and to calculate the more feasible parameter values. Also, there are a wide variety of multicast routing protocols, such as Flooding and On-Demand Multicast Routing Protocol (ODMRP), Topological Multicast Routing Protocol (ToMuRo), which can be considered for the new design to increase the simulation efficiency by reducing the packet dropping in the network.

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