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Design and Simulation of an Optimized Link State Routing Mobile Network

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Abstract

The thrust of this paper is the design and simulation of a Mobile Ad hoc Network (MANET) model. The network was configured using convenient parameters and routing was implemented via Optimized Link State Routing (OLSR) Protocol. The MANET was configured for communication using appropriate setup in Riverbed Modeler 17.5 simulation environment. The performance of the network model was thereafter tested and analysed using appropriate statistics and performance metrics such as Traffic sent, Traffic received, Download Response amongst others. The results demonstrated that OLSR is a convenient protocol for Mobile Ad hoc Network deployments.

1. Introduction

In the last two decades, the digital mobile communication services have grown rapidly. In the 1990s, the digital services started as the second generation of mobile communications with the Global System for Mobile Communications (GSM) improved by the General Packet Radio Service (GPRS) and Enhanced Data Rates for GSM Evolution (EDGE). The third generation used the Universal Mobile Telecommunications System (UMTS) with the High Speed Packet Access (HSPA) improvement. Nowadays, the fourth generation of such services is in use which is called Long Term Evolution (LTE). To provide fast and easy access to the Internet in a lot of different places, the number of Wi-Fi hotspots is increasing rapidly. Wi-Fi stands for a trademark which specifies devices for the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standard and is a subgroup of Wireless Local Area Network (WLAN). In this work both names are used interchangeably. All the previously mentioned communication standards, except Wi-Fi, are based on infrastructure networks only as shown in Figure 1. This means that the base stations are usually static, but the users can be mobile. Furthermore, the users cannot communicate directly with each other, not even if they are in the communication range of one another. Each user can only communicate with its base station which in turn forwards the information. If a node is not inside the transmission range of a base station it is not able to communicate, other devices between this node and the base station cannot act as relays. Therefore, the network coverage has to be considered when designing such networks.

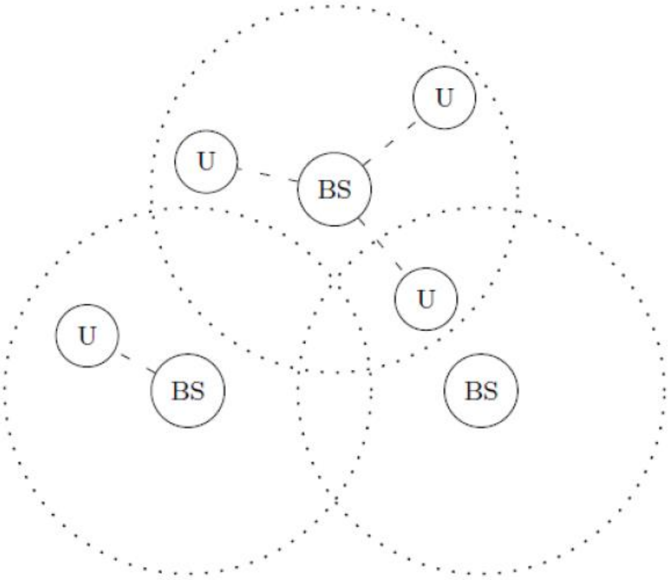


Figure 1: An Infrastructure Network with Three Base Stations (BS) and Four Users (U)

All infrastructure networks require previously installed hardware including radio towers, wired data connections and Backbone, for example. The weaknesses of such infrastructure networks are the high acquisition costs for the installation which leads to the facts that these networks are uneconomic in sparsely populated areas, that it takes relatively long to assemble them and that these networks are administrated by a centralized instance which could represent a single point of failure. Since infrastructure networks usually are not available in isolated areas like in disaster scenarios or military operations or such infrastructure based networks are still too expensive, e.g., satellite connections, the Defense Advanced Research Projects Agency (DARPA) started the development of the Packet Radio Network (PRNET) in 1973 to connect about 50 wireless devices with each other without any given infrastructure [1]. This was the beginning of the ad hoc networks described in Figure 2.

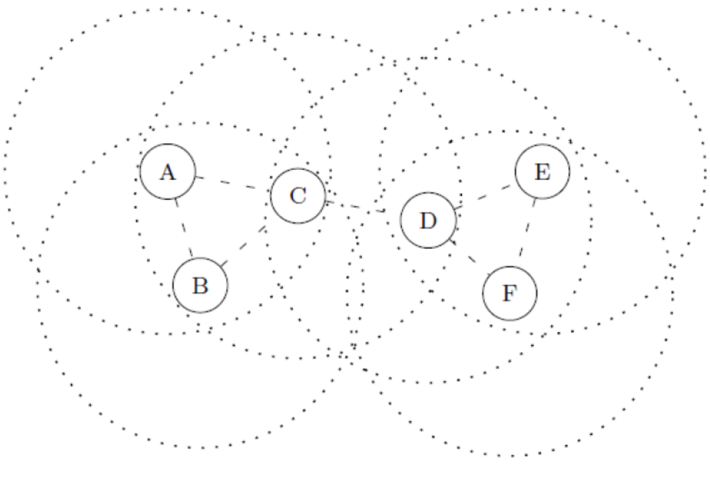


Figure 2: An Ad Hoc Network with Six Nodes and Visualized Transmission Ranges.

Ad hoc networks are usually constructed for a specific task without the need of any previously installed communication infrastructure. Instead, the nodes autonomously create a wireless network and each node communicates directly with its direct neighbor nodes without the need of base stations. The direct neighbors of a node are the devices which are in the direct radio range of the node. If the destination of a transmission is not a direct neighbor of the source node, it is not possible to communicate directly. However, the other nodes in an ad hoc network act as relays and can forward the packets. With this multi-hop feature, ad hoc networks are very scalable and robust against single node failures. These networks are highly adaptive: The participants can enter or leave the network, they can move around and the network can split into multiple parts and merge again. If the devices in such a network are mobile like walking pedestrians, driving cars or flying helicopters, the network is called MANET. MANET stands for Mobile Ad hoc Network. It is a robust infrastructureless wireless network. A MANET can be formed either by mobile nodes or by both fixed and mobile nodes. Nodes randomly associate with each other forming arbitrary topologies. They act as both routers and hosts. The ability of mobile routers to self-configure makes this technology suitable for provisioning communication to, for instance, disaster-hit areas where there is no communication infrastructure, conferences, or in emergency search and rescue operations where a network connection is urgently required. The need for mobility in wireless networks necessitated the formation of the MANET working group within The Internet Engineering Task Force (IETF) for developing consistent IP routing protocols for both static and dynamic topologies [2]. The versatility of MANETs makes them ideal candidates for a wide-range array of applications. Figure 3 shows an example of MANET application. They can be used during natural disasters where there is no communication infrastructure, as an extension of service coverage such as in airport hotspots and in normal enterprise deployment. A common use of MANETs is during group communications in conferences. The key attributes that make MANETs ideal candidates for such applications are their quick self-configuration and low cost of deployment. In case of a natural disaster, a radio link such as a WiMAX radio link may be established to one area and then a MANET access network established to provide coverage extension to the areas that would otherwise be impossible to cover. In this situation, the nodes further away from the base station will rely on intermediate nodes for communication. This provides an important communication network used in such situation.

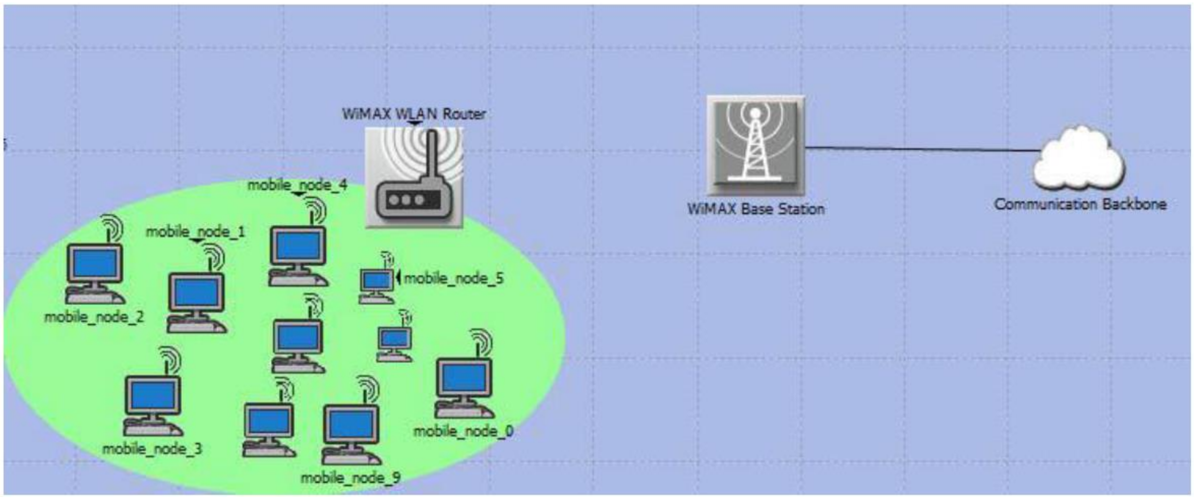


Figure 3. MANET deployment over WiMAX.

In Figure 3, the mobile nodes and the WiMAX WLAN Router form a MANET. The WiMAX WLAN router forms the boundary between the MANET and the WiMAX network. The router is capable of supporting translations between the ad hoc protocols and the appropriate protocols used on the WiMAX network and the communication backbone.

1.2 Statement of Problem

In a MANET, mobile nodes have the ability to accept and route traffic from their neighbours towards the destination, i.e., they act as both routers and hosts. As the network grows, and coupled with node mobility, the challenges associated with self-configuration of the network become more pronounced. More frequent connection tearing and re-associations place an energy constraint on the mobile nodes. The main problem in mobile networking is the limited bandwidth and the high rate of topological changes and link failure caused by node movement [3].

Ad hoc routing protocols are therefore needed to cope with the dynamic nature of MANETs. Examples of ad hoc routing protocols include AODV, OLSR, DSR, TORA, Wireless Routing Protocol (WRP) and the Zone Routing Protocol (ZRP). MANET routing protocols are generally classified in three categories namely Proactive, Reactive and Hybrid. Ad hoc routing protocols exhibiting both reactive and proactive protocols are called hybrid routing protocols. This study is focused only on a particular proactive protocol namely Optimized Link State Routing Protocol (OLSR). The effect of this protocol on MANET performance is analyzed in this study.

1.3 The Optimized Link State Routing (OLSR) Protocol

An OLSR protocol is a proactive or table driven, link-state routing protocol. As the name of the protocol goes, it uses link-state information for route discovery. This means that a node broadcasts information about the connections to its direct neighborhood into the whole network. Any other node in the network accumulates such gathered information and, afterwards, it calculates all possible routes in the network using the Dijkstra algorithm [4]. Routing information is exchanged between the OLSR nodes using a standardized packet format (Figure 4) which is usually transmitted inside User Datagram Protocol (UDP) packets addressed to destination port 698.

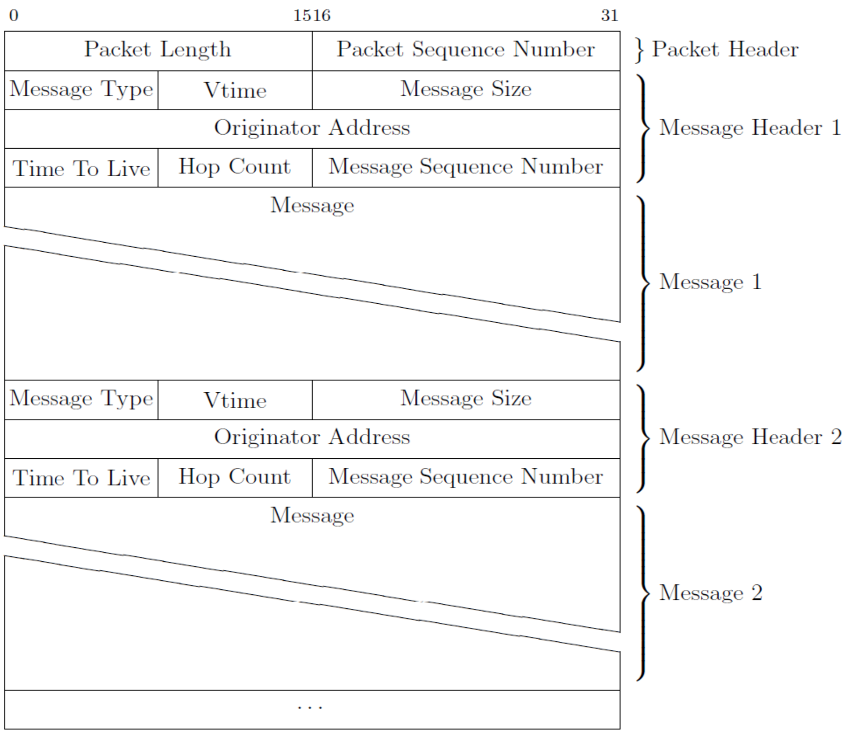


Figure 4: The Structure of an OLSR Packet.

Link-state routing algorithms choose best route by determining various characteristics like link load, delay, bandwidth etc. Link-state routes are more reliable, stable and accurate in calculating best route and more complicated than hop count.

1.4. Related Works

Authors in [5] worked on comparison within mobile ad hoc networks' routing protocols from reactive, proactive and hybrid categories. They comprehensively analyzed the results of simulation for mobile ad hoc routing protocols over the performance metrics of packet delivery ratio, end to end delay, media access delay and throughput for optimized link state routing, temporary ordered routing algorithm and ad hoc on demand distance vector protocol. The author in [6] developed QoS versions of the OLSR (Optimized Link State Routing) protocol. The author introduced heuristics that allow OLSR to find the maximum bandwidth path and proved that these heuristics do improve OLSR in the bandwidth QoS. It was a simulation based work using OPNET. The performance analysis of MANETs routing protocols such as Ad hoc on Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Temporary Ordered Routing Algorithm (TORA), and Optimized Link State Routing (OLSR) using Voice over Internet Protocol (VoIP) traffic was carried out by [7]. The performance metrics used for the analysis of these routing protocols are delay and throughput. The overall results showed that the proactive routing protocol (OLSR) performs better in terms of delay and throughput than the reactive protocols. The work by [7] involved only two performance metrics whereas this paper involves the analysis of OLSR in MANET using multiple performance metrics which present a more pronounced merit as to the performance of OLSR in MANETs and its subsequent adoption as a routing protocol of choice.

2. Methodology

The materials and methods employed in this project are entirely software. The software used in this study is Riverbed (OPNET) modeler 17.5. MANET toolbox in Riverbed was used to simulate the network and the components used for designing the network include MANET_Station (mobile), Application configuration (which decides the type of application running in the network), Profile configuration (for configuring the type of profile on the network) and Server Configuration. The methodology involved three major steps. The first step was creating the network model, followed by Choosing statistics and then Running simulations.

2.1 Creating the Model

The first step when creating a network in Riverbed Modeler is to create a blank scenario. This is done using the start-up wizard. This opens a project editor workspace in which network design is performed. Figure 5 presents the design of the network. Fifteen wireless nodes are deployed in the simulation environment consisting of eight iPhone, six android devices and one svr_wrless_manet chassis. Application Configuration, Profile Configuration and Server_Config models are also deployed into the environment. Each of the nodes acts a router and hence can communicate with any other node in the network using the routing protocol configured. Figures 6 to 11 show the simulation parameters of the various components of the model along with the OLSR configurations.

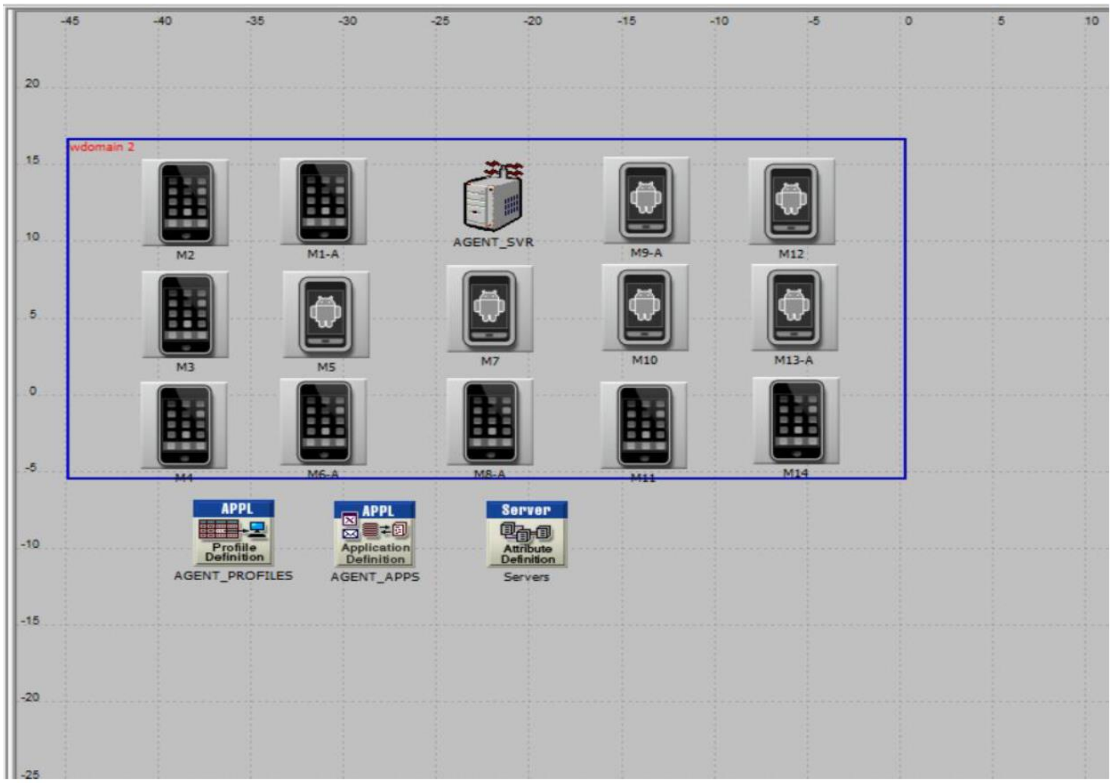


Figure 5. Mobile Ad-Hoc Network Model.

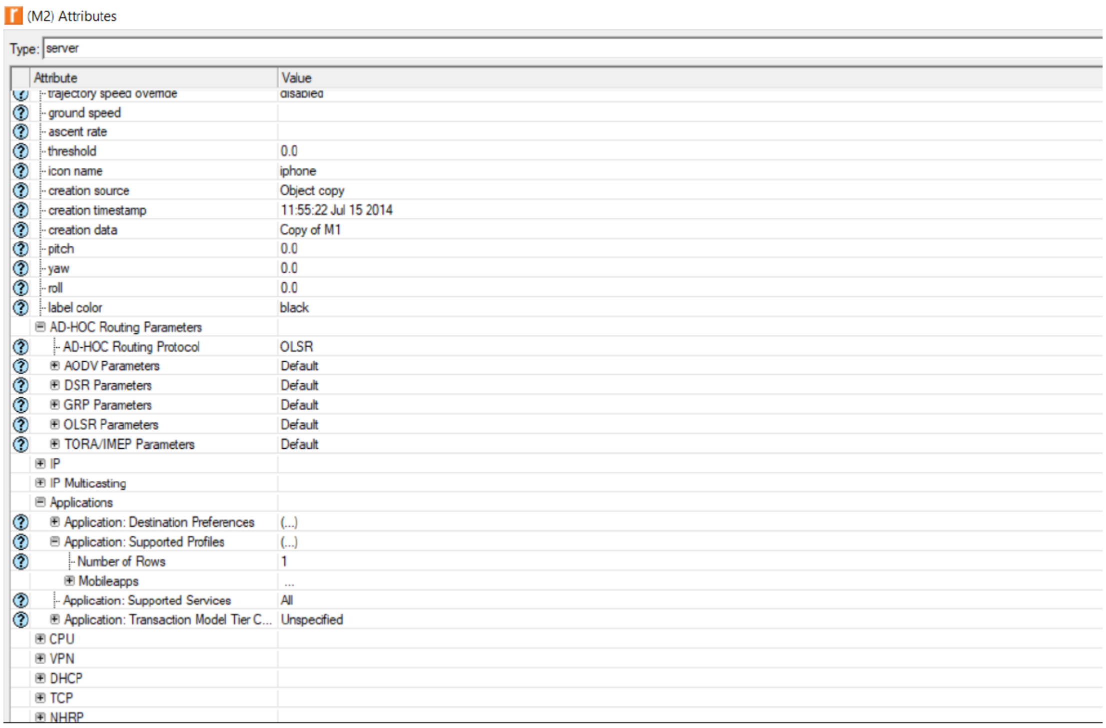
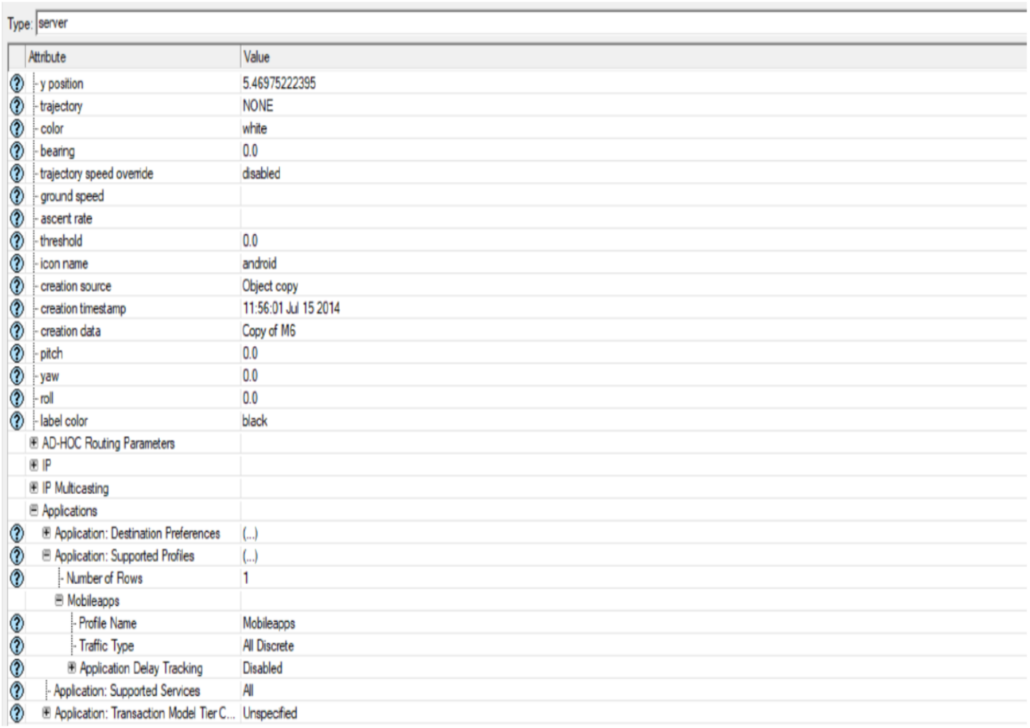


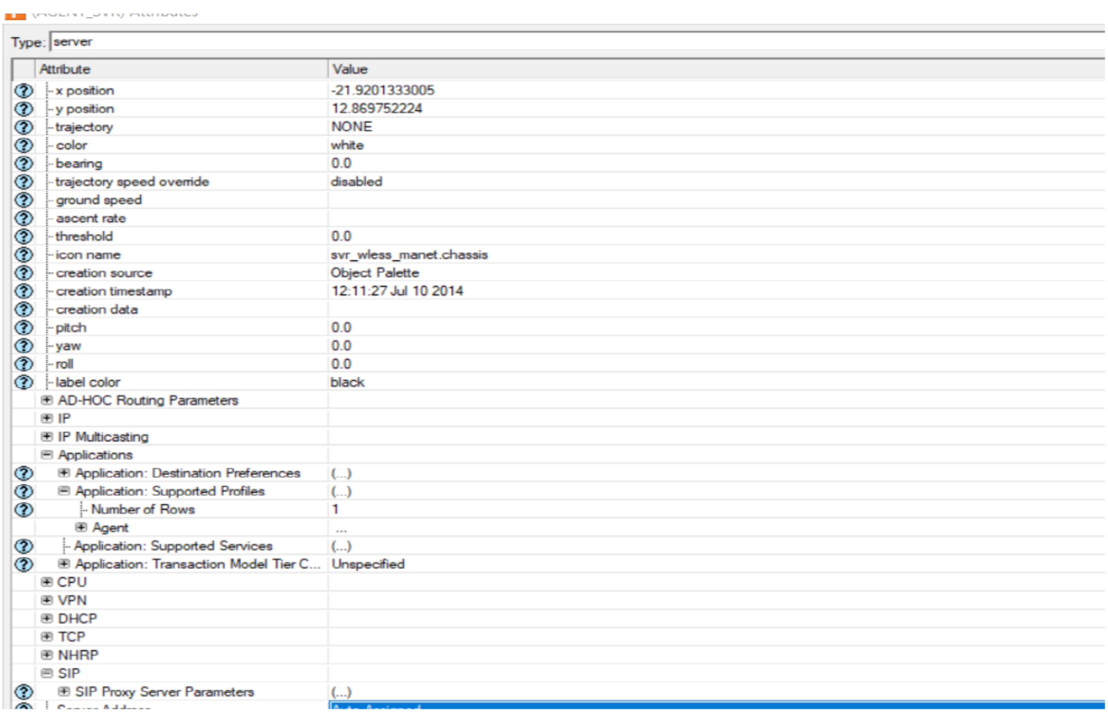
Figure 6. Simulation Parameters for iPhone.



Type: server

Attribute	Value
y position	5.46975222395
trajectory	NONE
color	white
bearing	0.0
trajectory speed override	disabled
ground speed	
ascent rate	
threshold	0.0
icon name	android
creation source	Object copy
creation timestamp	11:56:01 Jul 15 2014
creation data	Copy of M6
pitch	0.0
yaw	0.0
roll	0.0
label color	black
AD-HOC Routing Parameters	
IP	
IP Multicasting	
Applications	
Application: Destination Preferences	(...)
Application: Supported Profiles	(...)
Number of Rows	1
Mobileapps	
Profile Name	Mobileapps
Traffic Type	All Discrete
Application Delay Tracking	Disabled
Application: Supported Services	All
Application: Transaction Model Tier C...	Unspecified

Figure 7. Simulation Parameters for Android devices.



Type: server

Attribute	Value
x position	-21.9201333005
y position	12.869752224
trajectory	NONE
color	white
bearing	0.0
trajectory speed override	disabled
ground speed	
ascent rate	
threshold	0.0
icon name	svr_wless_manet.chassis
creation source	Object Palette
creation timestamp	12:11:27 Jul 10 2014
creation data	
pitch	0.0
yaw	0.0
roll	0.0
label color	black
AD-HOC Routing Parameters	
IP	
IP Multicasting	
Applications	
Application: Destination Preferences	(...)
Application: Supported Profiles	(...)
Number of Rows	1
Agent	...
Application: Supported Services	(...)
Application: Transaction Model Tier C...	Unspecified
CPU	
VPN	
DHCP	
TCP	
NHRP	
SIP	
SIP Proxy Server Parameters	(...)

Figure 8. Simulation Parameters svr_wrless_manet chassis.

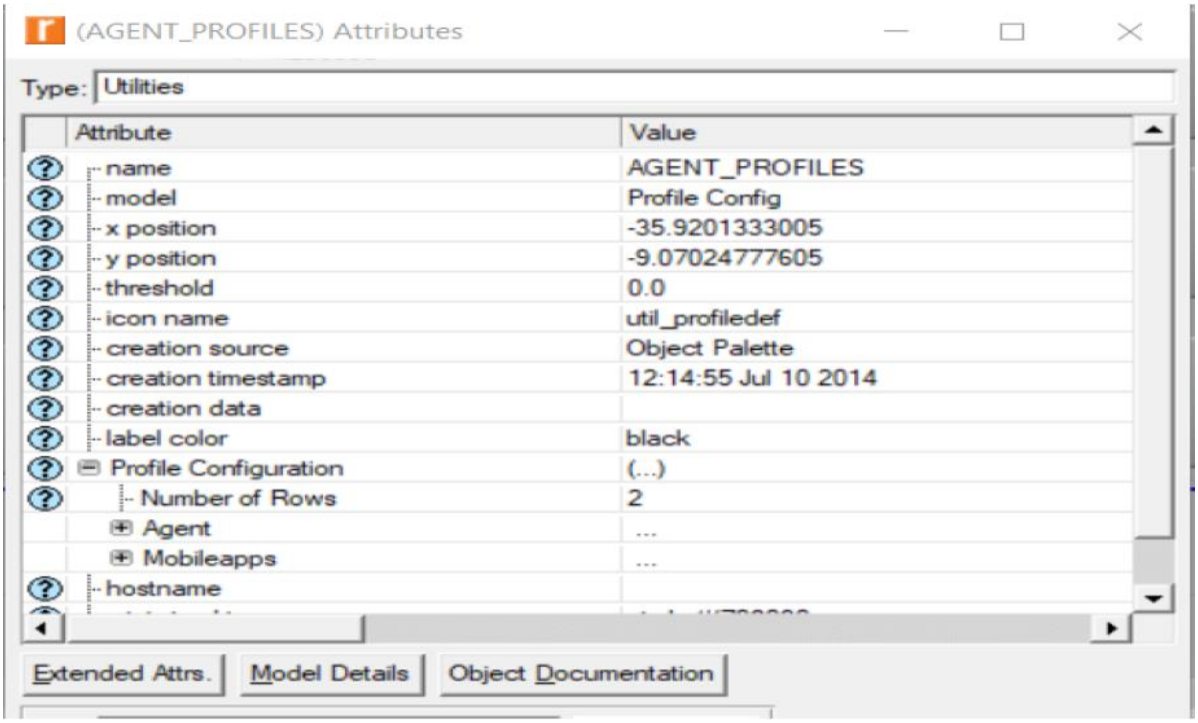


Figure 9. Simulation Parameters for Profile Configuration.

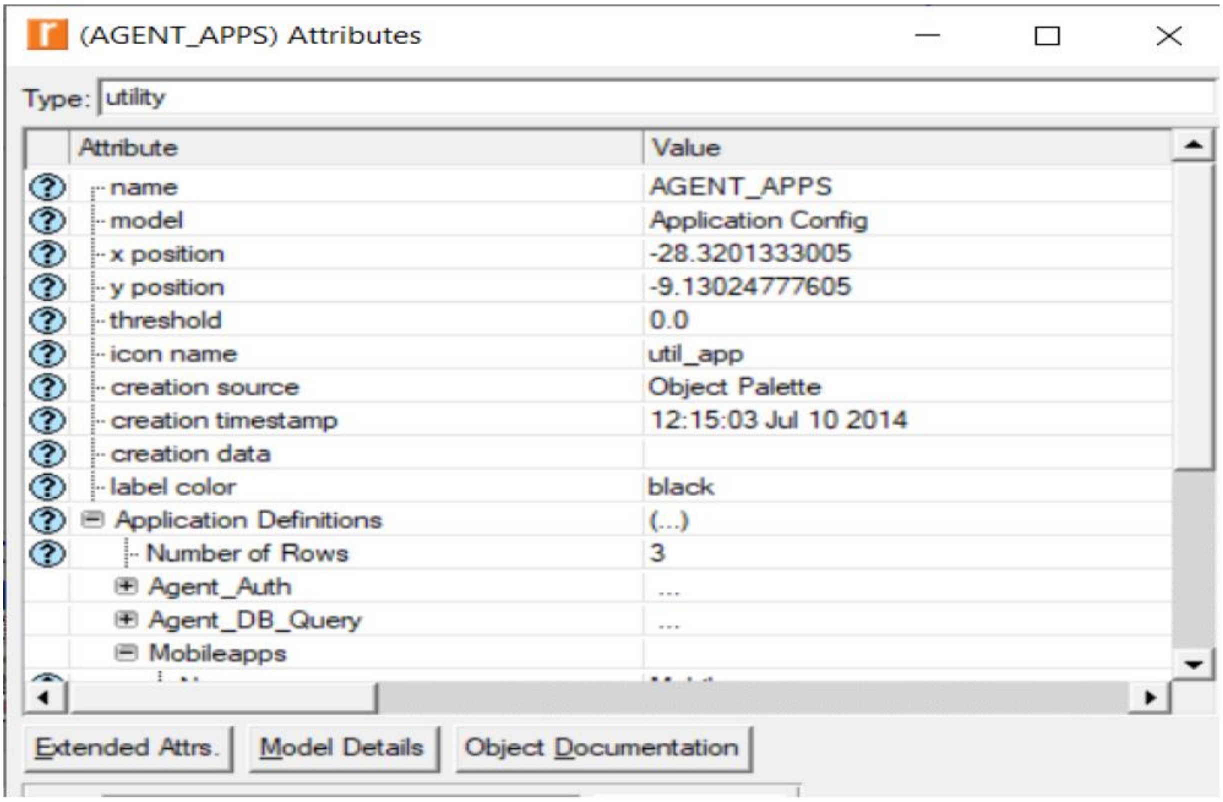


Figure 10. Simulation Parameters for Application Configuration.

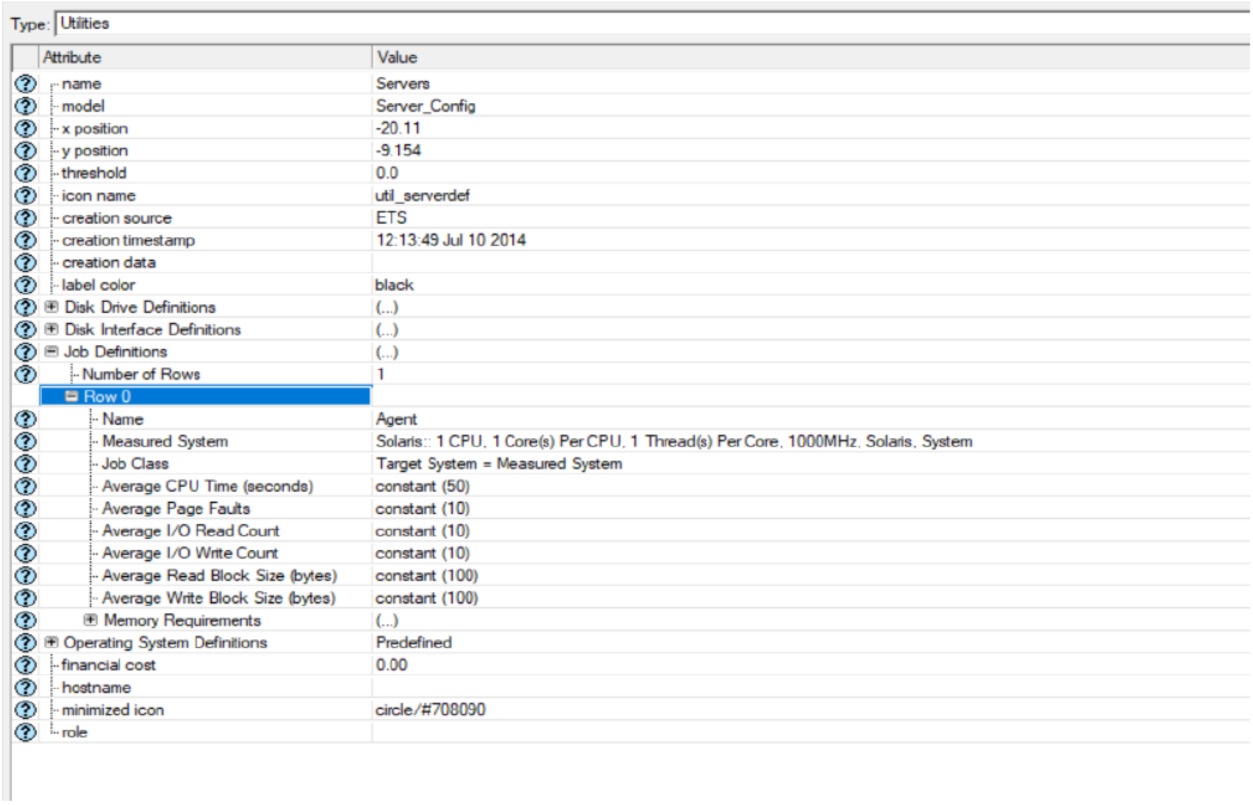


Figure 11. Simulation Parameters for Server Configuration.

2.2. Choosing Statistics

There are two types of statistics that can be collected in Riverbed Modeler, Global statistics and Object statistics. Global statistics were collected from the entire network while object statistics were collected from individual nodes. When desired statistics were chosen, the simulation was run to record the statistics. The Global statistics of Database Query, Email, OLSR, Remote Login and Wireless LAN attributes were configured for result and the Object statistics of Server Email, Server Remote login and CPU were configured for result.

2.3 Simulation Setup

Riverbed Modeler 17.5 was employed in the various simulations. A single scenario was considered in this simulation which was set to run for forty five minutes at 100 values per statistic. The Profile configured for our nodes was Mobileapps. The applications configured include Database (High load), Remote login (High load) and Email (High load) respectively.

3. Results and Discussion

After running the simulation, the collected results are viewed and analysed. This is done by either right clicking in the project editor workspace and choosing ‘View Results’ or by clicking on ‘DES’, ‘Results’ then ‘View Results’. A results browser then pops up as shown in Figure 12.

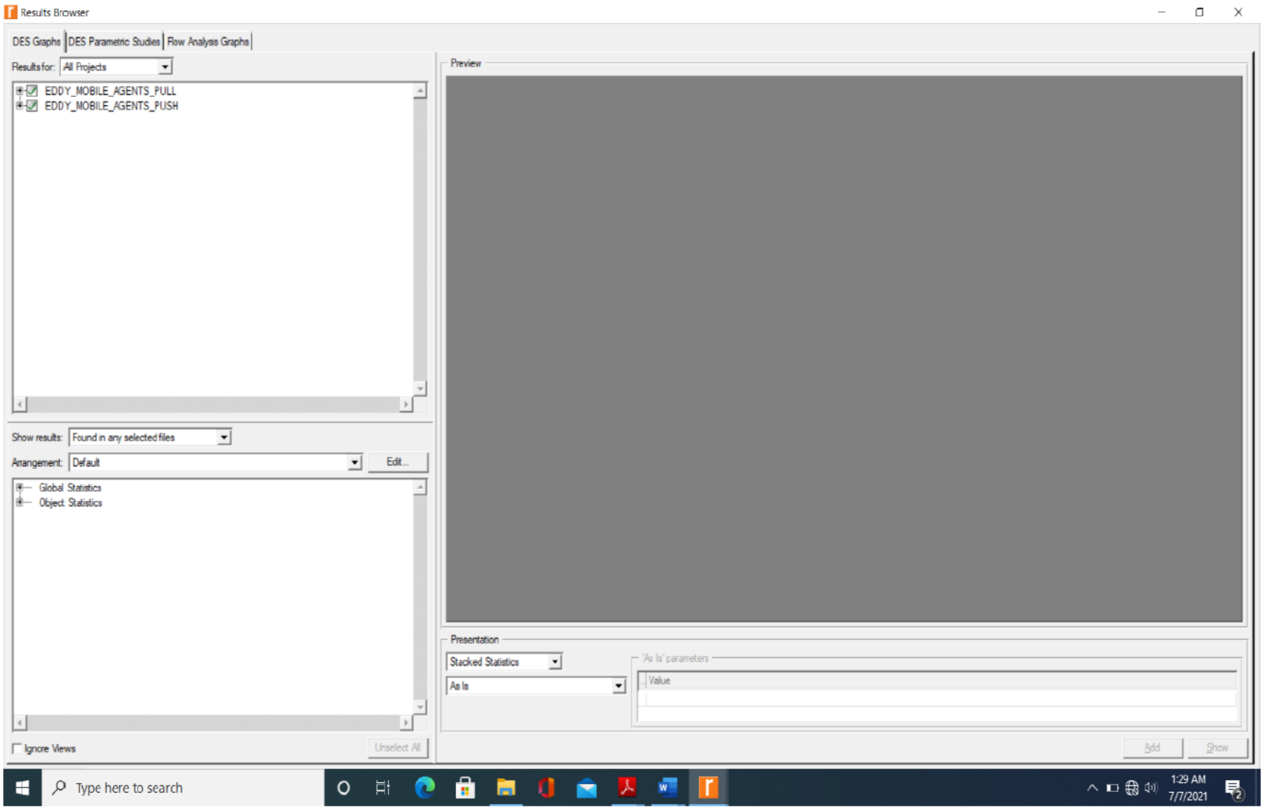


Figure 12. Riverbed Modeler Results Browser.

The performance of the OLSR based MANET was measured in terms of various metrics described below and the graphs shown in Figures 13 to 28 describe the various result outputs in terms of the selected performance metrics. Discussion of results after each collection of statistics follow thereafter.

3.1 Performance Metrics

3.1.1 Traffic Received

The amount of data moving across the network to the destination measured in bytes/sec or packets/sec.

3.1.2 Traffic Sent

The amount of data moving across the network from the source measured in bytes/sec or packets/sec.

3.1.3 Response Time

This is the total amount of time it takes to respond to a request for service measured in seconds.

3.1.4 Download Response Time.

This is the time that passes between a client node sending a request in a packet and receiving its reply.

3.1.5 Upload Response Time.

The time that elapses when data is being uploaded into the server.

3.1.6 Hello Traffic Sent.

Hello traffic represents the flow of packets that are sent out periodically from a router to establish and confirm network adjacency relationships.

3.1.7 Total Hello Messages Sent.

The total number of hello packets sent.

3.1.8 Routing Traffic Sent.

This represents the amount of data moving across the network from the sending node at a given point in time.

3.1.9 Load

This is a measure of the amount of computational work that a computer system performs.

3.1.10 Throughput

This is an actual measure of how much data is successfully transferred from source to destination. It is the total amount of the data received by the receiver from the sender until the end of last packet transmission.

3.2. Global Statistics

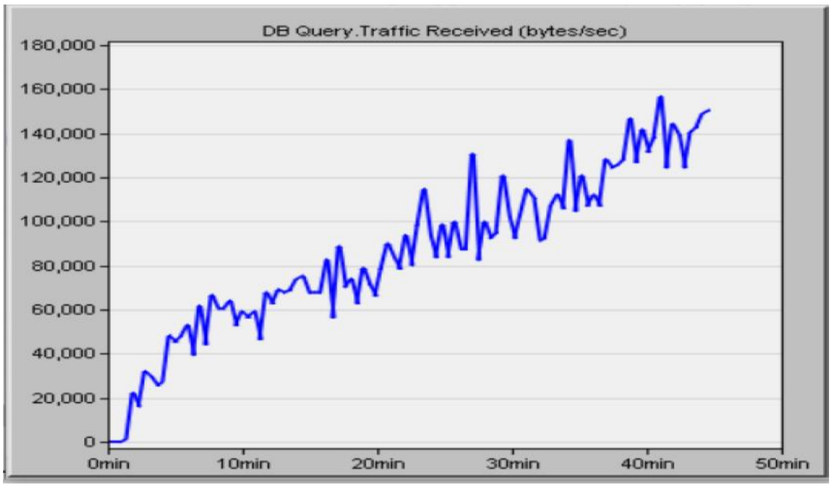


Figure 13. Database Query Traffic Received.

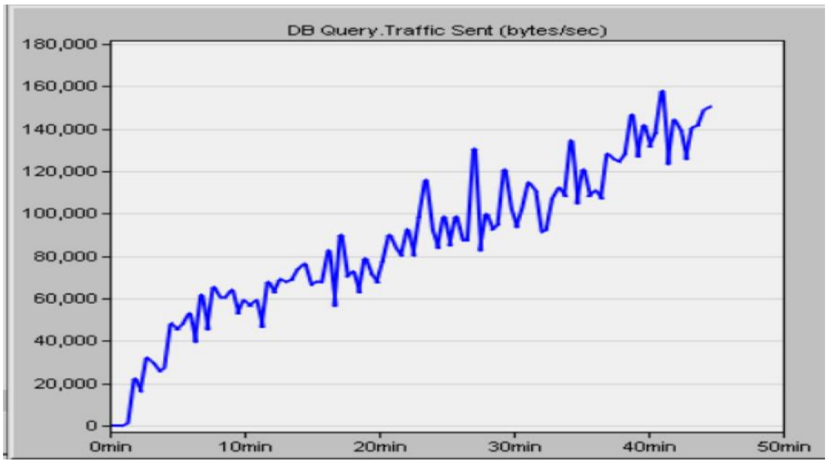


Figure 14. Database Query Traffic Sent.

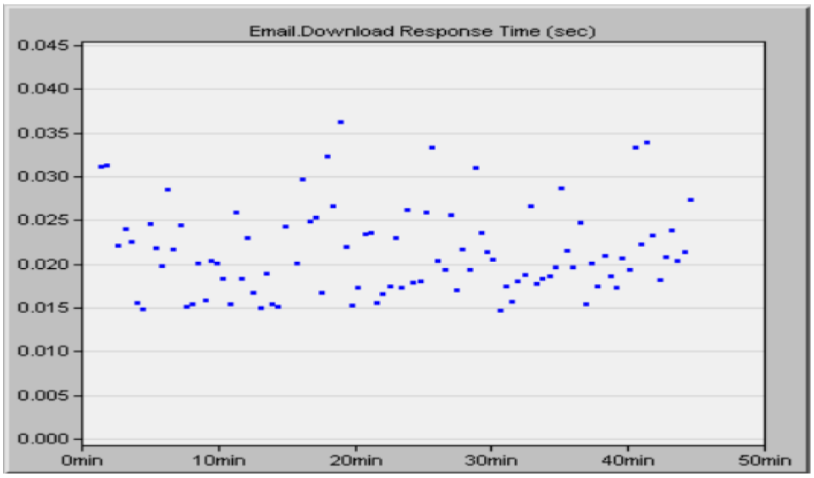


Figure 15. Email Download Response Time.

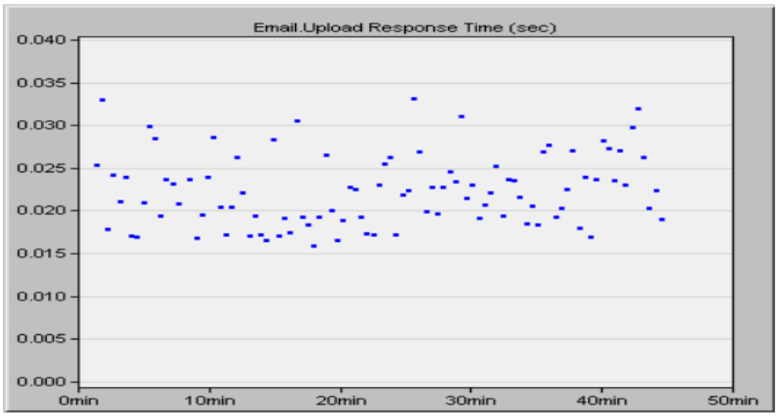


Figure 16. Email Upload Response Time.

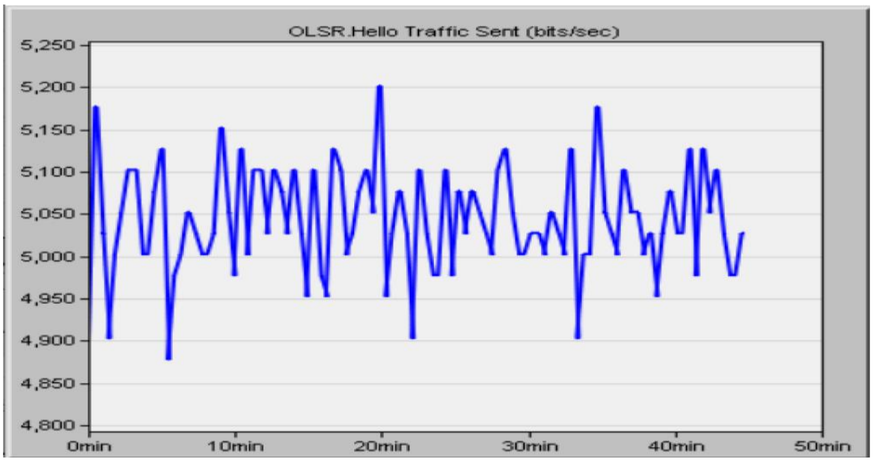


Figure 17. OLSR Hello Traffic Sent.

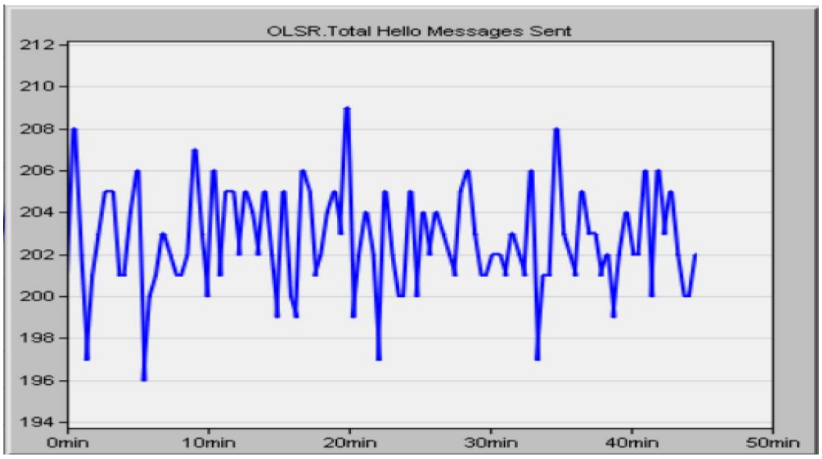


Figure 18. OLSR Total Hello Messages Sent.

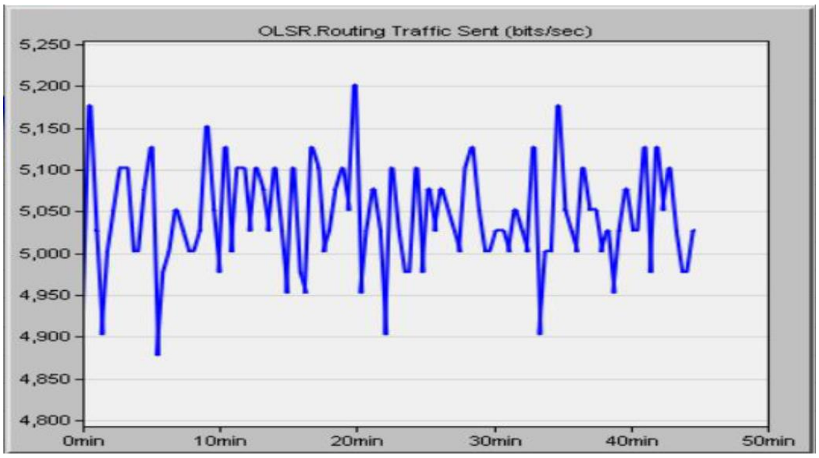


Figure 19. OLSR Routing Traffic Sent.

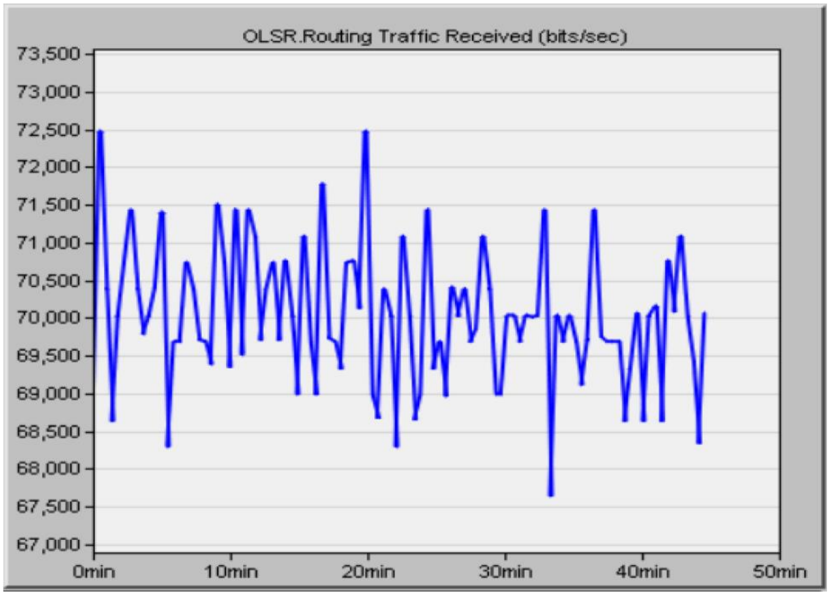


Figure 20. OLSR Routing Traffic Received.

3.3. Object Statistics

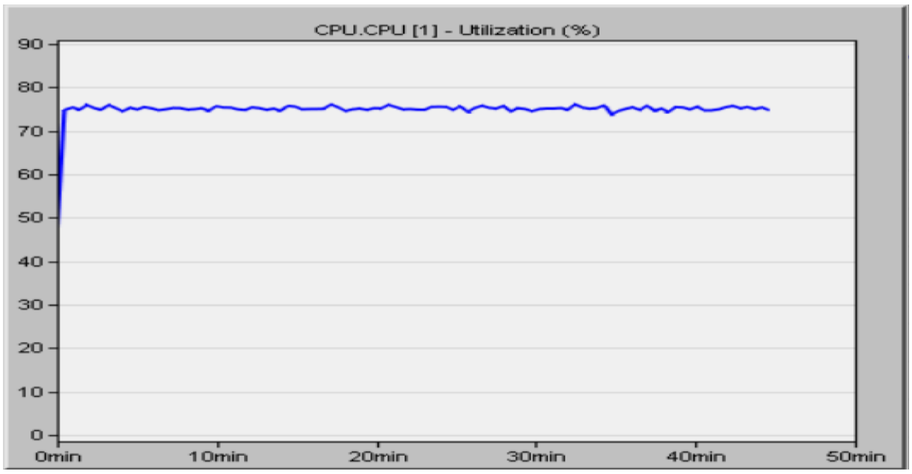


Figure 21. CPU Utilization for iPhone Node.

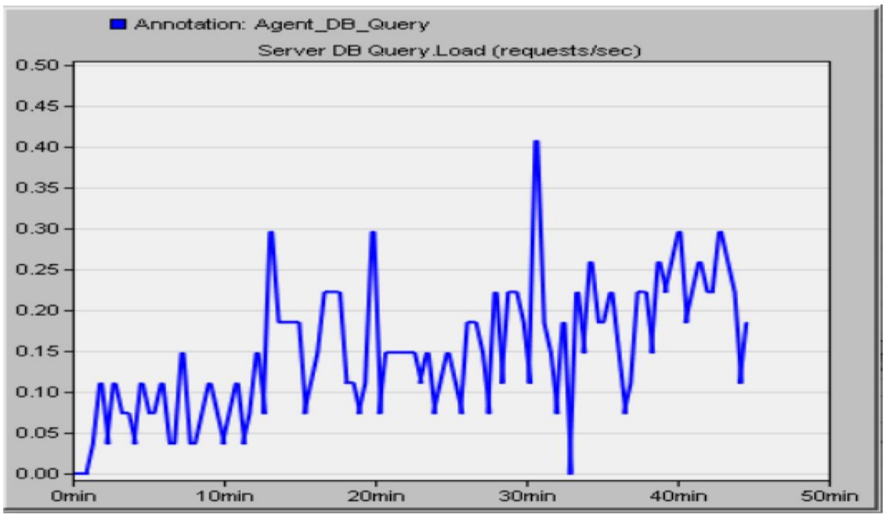


Figure 22. Database Server Query Load for iPhone Node.

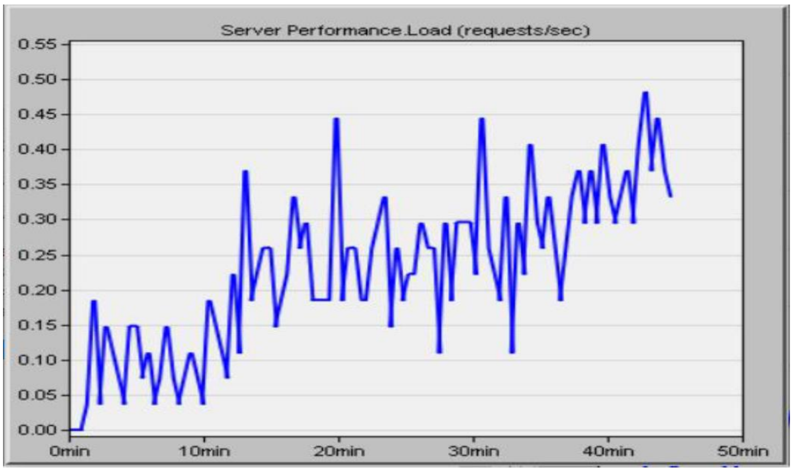


Figure 23. OLSR Load Performance for iPhone in Requests per second.

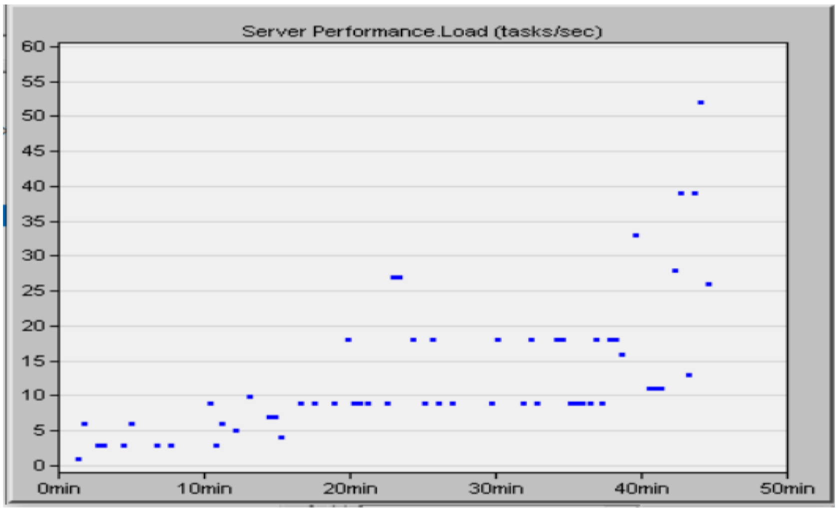


Figure 24. OLSR Performance – Load in tasks per seconds for iPhone.

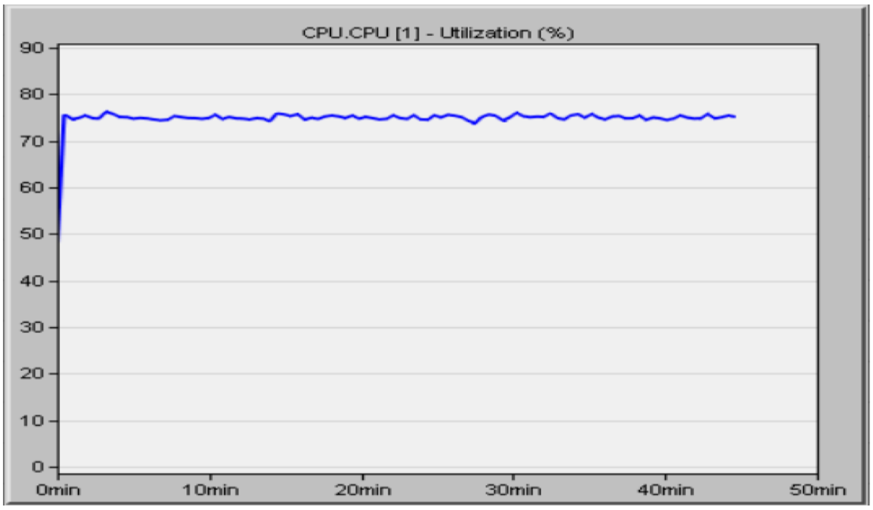


Figure 25. CPU Utilization for Android Node.

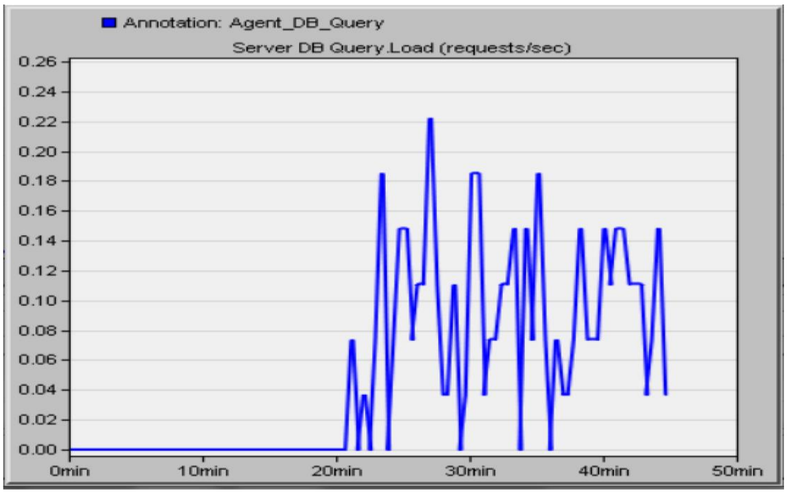


Figure 26. Database Query Load for Android Node.

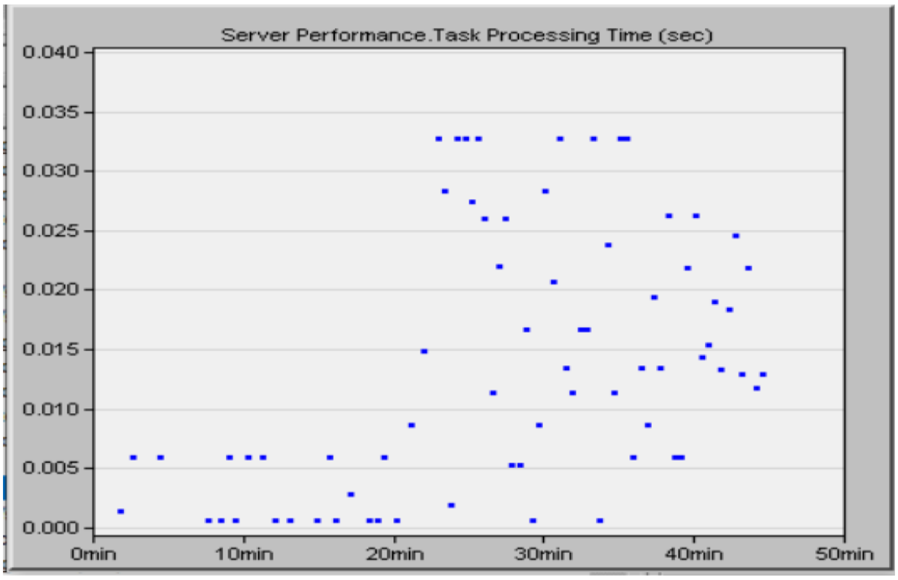


Figure 27. OLSR Performance – Task Processing Time for Android Phone.

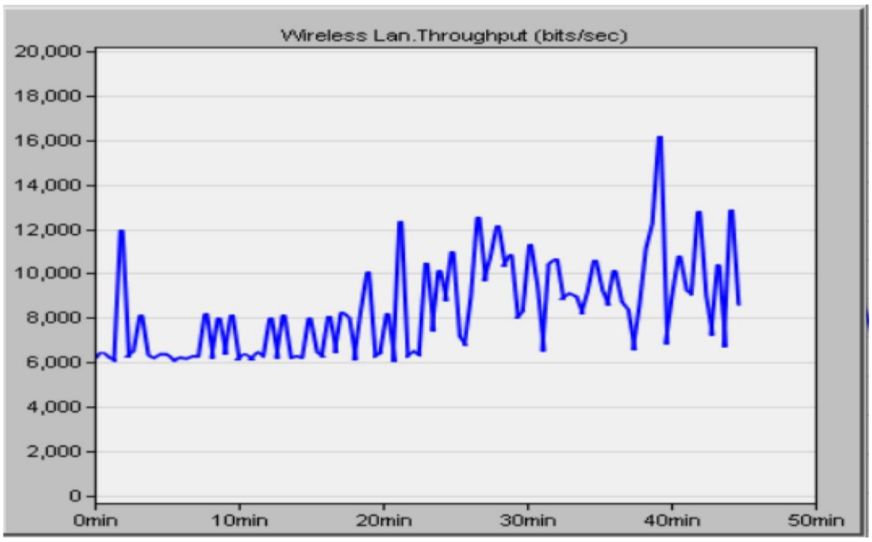


Figure 28. Wireless LAN Throughput for Android Node.

3.2 Discussion

The results displayed above for global statistics are interpreted as follows: Database Query Traffic sent and received are 160000 and 160000 bytes per second respectively. The Email maximum and minimum download response time are 0.036 and 0.015 seconds respectively. The Email maximum and minimum upload response time are 0.033 and 0.016 respectively. OLSR Hello Traffic Sent is 5200 bits per second while total OLSR Hello Messages Sent are 209. OLSR Routing traffic sent ranged from 4875 to 5200 bits per second. OLSR Routing traffic received ranged from 67600 to 72500 bits per second.

The results displayed above from the object statistics are interpreted as follows: CPU Utilization for iPhone Node is about 75 percent, Database Server Query Load for iPhone Node is peaked at 0.41 requests per second, OLSR Load Performance for iPhone (in Requests per second) is about 0.48 requests per second, OLSR Performance (i.e., Load in tasks per seconds for iPhone) ranged from 2 to 52, for OLSR Performance maximum Task Processing Time for iPhone was 0.0325 seconds. CPU Utilization for Android Node is 85 percent, maximum Database Query Load for Android Node is 0.22 requests per second. In terms of OLSR Performance, Load in Request per seconds was 0.3 while maximum task processing time was 0.0325 seconds. Android node wireless LAN values was 16000 bits per second maximum for throughput. The performance metrics so analysed above present a more elaborate demonstration on the capacities of OLSR as a routing protocol compared to the work of authors in literature. The author in [5] considered packet delivery, delay and throughput, whereas this paper considers delay, throughput and several other metrics such as download and upload response, Traffic sent and Received, etc. Although the author in [6] considered improved Quality of Service (QoS) the work involved a single metric namely bandwidth. The author in [7] considered delay and throughput only.

4. Conclusion and Recommendation

This paper demonstrates the modelling and development of a Mobile Ad-hoc Network (MANET) using Optimized Link State Routing Protocol (OLSR) as the routing protocol. The various parameters measured proved that the MANET is functional and OLSR is a highly effective routing protocol for MANETs. This work demonstrated the routing capacities of OLSR in a fifteen node MANET and proposes it as a routing protocol for Mobile Network planners. However, as a future projection, it is recommended that there be a comparative analysis between various routing protocols for the fifteen node MANET implemented in this project. This comparative analysis would help network designers make further informed preferences regarding the fifteen node MANET designed.

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