Performance Evaluation of Wireless IEEE 802.11(b) used for Ad-Hoc Networks in an E-Learning Classroom Network

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Abstract

Evaluation of wireless networks for performance evaluation is a popular research area and a wealth of literature exists in this area. Wireless networks in infrastructure mode as well as Ad-hoc networks such as MANETs are considered extensively. Simulation results are provided for E-learning scenarios for cases where wireless networks in infrastructure mode are employed, however the possibilities of using ad-hoc networks and performance evaluation of e-learning scenarios with ad hoc networks are not considered. This paper presents an evaluation of the performances for wireless Ad-hoc networks employed in typical e-learning environment by using the OPNET modeller. Numerical simulation results, discussions and comparisons are provided. The results can be of great help for optimisation studies in typical e-learning environments. The performance issues are considered together with scalability concerns.

Keywords: Ad-Hoc networks, Mobile Ad-Hoc Network (MANET), Wireless Local Area Network (WLANs), Hyper Text Transfer Protocol (HTTP), E-Learning, OPNET 14.0, IEEE 802.11(b).

I. THE INTRODUCTION

In the world of rapid technological changes commercial companies as well as researchers still try to increase the mobility of the users as much as possible. The use of wireless local area networks (WLAN) in common areas such as airports, domestic areas, and especially universities where it is extensively used for education purposes is increasing [4, 8, 9 and 24].

Now the question not only lies in the scope of becoming wireless but at the same time becoming wireless on the move. A great contribution lies in this particular field is of IEEE 802.11 b wireless LANs (WLANs) technologies which is changing the mind-set of people about networks, by giving the users the opportunity to practice in wireless environment. Mobile networking promises its users the full functionality of "anything, anytime, anywhere" [23]. To support the idea of “anything, anytime, anywhere” in mobile networking is the first step towards wireless Internet evolution which emphases on joining the technology to develop into the one and only "wireless Web" and this “wireless Web” comprises of the E-learning classroom in wireless, the campus with wireless, wireless home and the wireless office. It is for the advantage of institutions to improve the learning experience of the students who use laptops and wireless desktops accessing on-line materials such as seminar notes, assignments, examples, demos, and quizzes and reading materials in an e-classroom [26, 27].

Therefore, now to benefit this wireless Internet, this paper investigates Web performance in the perspective of classroom area networks and thus creating the same scenario with Ad-hoc networks and comparing the results. The experiments are based on the dimensions of a small classroom experiment, where a graduate class of 20 students [26, 27] can access course contents and the Internet via Ethernet server which is used in a Wireless LAN setting and the same compared in an Ad-hoc environment. Later the numbers of students were increased to 50 and 100 respectively to analyze and investigate the effects of scalability on performance measures and to see up to how many hosts our considered e-learning scenario can be supported when ad hoc mode is employed.

A performance evaluation study of an IEEE 802.11b WLAN used as a classroom area network is presented in [27]. The simulation is conducted using OPNET Modeller 9.1. The WLAN considered is in infrastructure mode. The IEEE 802.11 WLAN architecture is built around a Basic Service Set which is a set of stations that communicate with one another. Since the Basic service set includes a wireless access point connected to a wired network, and all mobile stations communicate via the access point, the WLAN considered is called as an infrastructure network. OPNET Modeller is used to model a simple infrastructure WLAN with up to 100. The network consists of mobile clients, a wireless Access Point (AP), an Ethernet-based Web server, an Ethernet Hub, and an OPNET ACE Packet Analyzer. 11 Mbps setting of 802.11b standard is used. A one-factor-at-a-time simulation design is used to study the impacts of various factors on wireless LAN performance. The simulation results show that an IEEE 802.11b WLAN can easily support up to 100 clients doing modest Web browsing.

A similar study of an IEEE 802.11b WLAN applied in E-learning classroom is considered in [26] as well. The simulation is again conducted using OPNET IT Guru 9.1. The infrastructure used in [26] is in fact very similar to the one presented in [27]. Web server is located on a 100 Mbps Ethernet LAN segment and the mobile client accesses content from the E-learning and Web server via an access point, using the IEEE802.11b protocol at 11Mbps. This time classes with up to 50 nodes are considered and performance measures such as average of wireless throughput, and average of wireless delay are presented. Results presented in [26] also showed that the WLAN considered can support up to 50 nodes with modest e-learning and web server traffic.

It is desirable to analyze the e-learning environment and provide performance evaluation for similar scenarios which employs ad-hoc networks rather than infrastructure mode.
This paper uses simulations to investigate large scale classroom scenario with ad hoc networks. The experiment uses detailed models of IEEE 802.11b such as Ad-hoc networks and wireless LANs, HTTP and TCP/IP in the OPNET 14.0 modeler setting. The simulation setting was configured according to the E-learning classroom capacity and validated against the experiential dimensions via E-learning and workload models of the web provided in [26, 27]. The experiment further assembles an E-learning and Web client model for browsing purposes and tackles the scalability of the E–learning scenario. The simulation focuses on the throughput, wireless delay and HTTP transaction rate in the wireless network setting, wireless access point delay, and the effects of it in terms of number of clients, and E-learning object size. The same cases were also taken into account in order to compare the results of the WLAN to get to a conclusion as of which one supports e-learning applications better i.e. an Ad-hoc network or a WLAN in infrastructure mode of IEEE 802.11 b standards. Experiments similar to the ones presented in [26, 27] are performed show to investigate whether or not client-server setup can easily support up to 50 clients and even up to 100 clients with self-effacing E-leaning and Web browsing performance.

Unlike the previous studies, the performance evaluation is also performed for various Ad-hoc routing protocols such as Ad hoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR) protocols [17].

The rest of this study is organized as follows: In section two the background information is provided for the technologies employed. The proposed simulation methodology is explained in section three. Numerical results are provided for comparison of various Routing Protocols in section four and WLANS in Infrastructure with the Ad-hoc networks (MANETs) in an e-learning scenario in section five.

II. BACKGROUND AND RELATED WORK

a) BACKGROUND

The Web and Web Performance: The Internet traffic basically originates from the World Wide Web which is the (WWW). The Internet is available to all people by giving platform-independent, time-independent, and location-independent entry to data. There are three main primary communication protocols for the Web and they are: TCP, IP, and HTTP they all play a very important role [26, 27]. The main Global addressing and routing of datagram release is done by the connection-less network-layer or (IP) Internet protocol. The connection-oriented transport layer protocol provides end-to-end delivery across the Internet it is the Transmission Control Protocol [25]. As one of its features TCP is accountable of congestion, and flow control, error recovery mechanisms and to provide consistent data transmission between sources and destinations. The sturdiness of TCP makes it function in many network environments. Thirdly, it is this protocol the request response application layer protocol called the HTTP which is encrusted above TCP. Therefore, it is this HTTP protocol which is responsible for all the transferring of the documents to-from servers and clients. HTTP 1.0 [19] and HTTP 1.1 [20] are the versions available.

Wireless Internet and IEEE 802.11b WLANs and MANETs: IEEE 802.11b standard is one of the most popular technologies in the wireless LAN market. Wireless technologies come from the IEEE 802.11 standards families which are showing an incremental role in the global Internet infrastructure. This "WiFi" (Wireless Fidelity) is another famous name in this technology which provides low-cost wireless Internet facility for end users, with up to 11 Mbps data transmission rate at the physical layer [26, 27]. The IEEE 802.11b standard classifies the channel access protocol used at the MAC layer, namely Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) [26]. 802.11b standard also identifies the frame formats used at the data link layer: 128-bit preamble, 16-bit Start-of- Frame delimiter, 48-bit PLCP (Physical

Layer Convergence Protocol) header, followed by a 24-byte MAC-layer header and variable size pay load which is used for transporting IP packets[26, 27]. Frames that are appropriately established over the shared wireless channel are permitted (almost immediately) by the receiver. Unacknowledged frames are re-sent by the sender after a diminutive timeout (typically a few milliseconds) using the same MAC protocol [26, 27].

Wireless E-learning Web Performance: The overall performance of the behavior of the E-learning Web depends on the E-learning Web clients, the E-learning Web server, and the network in between. The principal test in the wireless Internet context is the distinctiveness of the wireless channel. Communication over wireless links often undergo from limited bandwidth, high error rates, and interference from other users on the shared channel and sometimes noisy irruptions in shared channels [25]. The evident concern is of that the TCP and HTTP performance may go down over wireless networks as the distance is one of the main issues in wireless LANs [26, 27]. The main focal point of this paper is on the performance of wireless E-learning Web access and in an E-learning classroom area network. The primal importance is on performance problems due to the wireless network congestion and perceptive to how these problems affect user-perceived performance.

Now before shifting this discussion towards methodology used for the experiments and its results, it is imperative to first to have a detailed discussion on what MANETs are? And how the Ad-hoc networks and WLANs networks route their traffic and how they select which routing protocol to follow.

b) AD HOC NETWORKS

A Mobile Ad-hoc Network i.e. as the name suggests are “MOBILE” i.e. free to move around independently which means the mobile nodes are free to correspond with each other over limited bandwidth wireless links without any centralised base station. This is why it is one of the main factor for having several hops or multi-hop feature to ensure the transmission of the data packets between nodes and another reason being of limited radio range and invariable movement of the mobile nodes which is why the mobile nodes have to double as routes in order to link between nodes. The MANETs have another well-known feature of being dynamic in nature as the nodes are free and independent [23]. Therefore, due to this dynamic nature of the MANET routing protocols, they should be able to acclimatize to these changes and still retain routes even though their nature of changing network connectivity [2].

There are different routing protocols in support of MANETs, now below are those same proposed protocols that can be categorised into *Proactive*, *Reactive* and *Hybrid Routing protocol* [5, 6, 7, 13, 14, 15].

The spotlight of this study shifts towards the Reactive protocols especially Dynamic Source Routing (DSR) and Ad-hoc On-demand Distance Vector Routing (AODV).

The main advantage of using Dynamic Source Routing is that it saves on bandwidth utilization by managing the packets by (control restriction) and doesn't need the periodic table to update as it is used in table driven approaches. The DSR's primary function is to simply begin a path creation only when the source node desires to broadcast; after the source has requested to transmit it will set up a path with flooding the Route Request (RREQ) packets intended for the destination [5, 6, 7, 13, 14, 15]. Now, if the request RREQ packet gets delivered to the destination nodule, then only it will be able to send the source the Route Reply (RREP) with the RREQ received message to pass through the already defined route. Similarly, AODV also employs the On Demand Route Request packets, but it works on slightly different grounds than the DSR what it does is it brings into play a number as sequence number, which is a unique number supplied with the destination to recognize the current path taken. As concluded from the different discussion held before it is known that AODV exercises the hop by hop method to find the best route and with every data flow of packets it saves the next hop details to the source and other in-between nodes [5, 6, 7, 13, 14, 15].

In this study one will see how the network performance will come across problems as the number of clients and the network load increases significantly with the changes in the performances of the routing protocols of both AODV and DSR routing protocols. There is enough evidence to support our arguments for AODV and DSR with a simulation to evaluate the performance of both AODV and DSR [5, 6, 7, 13, 14, 15]. With the growth in scale of network it becomes difficult to maintain the routes especially between the source and the destination where several nodes are concerned which gives rise to another issue of link-breakage and due to the mobility of the node it is quite possible that the node itself goes out of reach i.e. MANET area or trajectories or node collapse. Hence, it is quite obvious that there is a need to test these kind of situations and to test the pros and cons of a perfectly working network model in real-life scenario, which can be done by simulating the same scenario in OPNET modeller by scrutinizing the connection of source and destination and packets exchange between them, throughput, route discovery time, delay and optimal path and efficiency before implementing [5, 6, 7, 13, 14, 15].

c) PREVIOUS STUDIES FOR PERFORMANCE EVALUATION OF ROUTING PROTOCOLS

In this section, the main concentration is on the qualitative and quantitative analysis which has already been done in this field using different constraints and using different simulation scenarios. Many students, computer scientists, and researchers have come across many findings as far as the Ad-hoc networks are concerned but here basically we are going to justify all the research done and critically analyse those research findings provided by different authors. The reader will notice that there is considerable amount of mix reaction in support for On Demand routing protocols and there is considerable amount of comparative study done to prove that proactive routing protocols perform better.

Johansson et. al provides a comparative study for load of traffic and mobility of nodes in [13]. They used three routing protocols DSDV, DSR and AODV. The focal point of the experiment was to show parameters like delay in network, throughput, overheard of routing and loss of packets. The results were predictable as in this experiment AODV performed better than DSDV and DSR when higher network load was concerned. On the other hand in lower loads DSR performed better than others.

Lee et. al used TORA routing protocols, DSR and AODV, taking video, voice, sensor and text as traffic load working with only 20 nodes [16]. The data rate used is from 2Kbps to 4.8Kbps to show the average delay, packets sent and received and routing load. Interestingly when the author conducted this experiment the results came out somewhat different than expected with regards to routing load. AODV performed more than DSR with 4.8Kbps and it came out to be other way round with 2Kbps rate, DSR performed with high colours than AODV. Therefore in this experiment it was obvious that with difference in routing load, the packets generation rate also gets affected.

AODV, DSR and TORA routing algorithms are used in this Ahmed S. and Alam M. S. [1] who carried out a similar simulation with OPNET modeler 10.5 but using all available features. In this paper, the authors decided to simulate with 40 nodes first and then 80 and final increased the amount of nodes to 100. This experiment also had a limited mobility of about 10 sq meters and a constant traffic at 40. It was predictable that the experiment was going to have a lot of variation as far as the results were concerned. The authors found a range of conclusions starting with TORA routing protocol, with the increase in network load, increased the number of ULP sent and received increased, as well as the number of packets increased for controlled traffic [1]. For Dynamic Source routing, the load has not much to do with number of hops and route discovery time, all basically depends on the algorithm it uses but at the same time the overall controlled traffic and the ULP increased with increase in load. Now finally for the AODV, with the increase in number of client had no effects on the route discovery time neither on the hops per route [1].

Broch J. Maltz A. Johnson D. B. Hu Y-C and Jetcheva J the authors of "*A Performance Comparison of Multi-hop Wireless Ad Hoc Networks*" used network simulation-2 environment to scrutinised the four routing protocols DSR, AODV, DSDV and TORA with 50 clients in their experiment [3]. They used namely three parameters in their experiment like number of hops used to reach to destination, overhead of routing and number of packet delivered to destination. In this authors found comprehensive results as there were swap over among packets overheads and byte overheads but still DSR managed to get an upper hand over AODV.

In [3] AODV and DSR routing protocols are evaluated with only 5 clients and the end to end delay and overhead of control traffic measures are illustrated. CPN simulation environment is used in experiment and the results were quite simple and clear in terms of better performance over mobility. The study showed that, when it came to the question of mobility of course AODV performed better than DSR but at the same time DSR was not too far behind when it came to question of route discovery time, it over came AODV.

The studies given above conducted by different authors appear to give sufficient proof to justify our arguments to support our experiments in this study yet it is always difficult to predict complex network structures, especially when wireless ad-hoc networks are considered. AODV and DSR routing protocols are considered together with modest e-learning traffic and simulation results are provided in the following sections.

III. THE PROPOSED SIMULATION METHODOLOGY

The main aim of this paper is to compare the performance of the Ad-hoc networks, and networks in infrastructure mode, to specify up to how many nodes Ad-hoc networks can support and finally, to compare the performances of various MANET routing protocols in an e-learning environment.

The OPNET Modeller is intended for the modelling of protocols and the simulation of protocols, communication network and devices. The software uses an approach that is more object-oriented while the graphical editor reflects the configuration of the original networks and its components [18]. The OPNET Modeller is immense as it is software that encompasses a wide-ranging set of functions intended to sustain general network modelling as well as to offer detailed support for unique kinds of network simulations. OPNET Modeller offers an all-inclusive progression in its environment for the purpose of performance-evaluation in terms of communication networks as well as distributed systems and modelling. The software comprises of a variety of tools, independently responsible to operate specific features of a modelling assignment [18].

In terms of network edition, the initial editor created is the Network Editor, which diagrammatically symbolizes the main framework of a communication network. Networks comprise of node (switch/router, server etc.) and links model (FDDI, Ethernet, and ATM etc.) [18]. It is not difficult to handle complex networks with limitless network branching from it nesting like, city, state, building, floor, etc. thus, it is possible to state that network editors offer a blueprint view, along with the material characteristics of the networks. Subsequent to that, the node editor portrays the internal structural design of each node by illustrating the stream of data from the practical essentials, i.e. modules [18]. Modules can be classified as processes that produce, transmit, and accept packages from different modules so as to execute administrative tasks between each node [18]. Modules symbolise protocol layers, applications, and material resources like ports, buffers etc. Conduct as well as proficiency of each module is illustrated within the Process Editor. Process Editor's employ a Finite State Machine (FSM) in order to portray each protocol right up to every detail [18]. The State and transitions symbolize each process's tendencies, wherein dynamic state is modified in terms of inward bound events. Every state of process consists of C or a C++ system for organization. Numerous libraries are employed for the purpose of protocol programming. In order to create detailed libraries, statistical data as well as variables are available [18].

When the simulation scenario of this study is considered, the objectives are:

1) To evaluate the performance of IEEE 802.11 (b) Infrastructured networks with Mobile Ad-hoc Networks with regards to E-Learning Applications.
2) To examine the features of AODV and DSR protocols with regards to the parameters used and the different trajectories deployed in MANET.
3) To study the discrepancy of the stricture conditions to facilitate the consequence of the network load.
4) To quantify and critically evaluate the performance between the two routing protocols used in the MANET as which one is best suited for E-Learning environment.
5) To configure and run simulation tests in OPNET Modeler 14.0 with regards to E-Learning scenario and compare the results.

The experimented simulations were run and outcomes are collected to compare with each other. The Modeling was done in an organized manner considering a real-life scenario model of the two routing protocols in OPNET Version 14.0 so as to compare which is best suited for our MANET model for e-learning.

In figure one the WLAN in infrastructure mode is illustrated. There is an Ethernet server, used for database, http, file transfer, video streaming applications. Since the scenario is in infrastructure mode, there is an access point. There are five nodes in the first scenario but in the experiments the number of nodes is increased up to 100 for both WLAN scenarios in infrastructure and Ad-hoc modes respectively. The application definition specifies the parameters for each kind of selected application. Finally the profile definition describes the activity pattern of the users in terms of applications run over a period of time.

In figure two the WLAN in ad-hoc mode is illustrated. There is a MANET router used to connect the mobile nodes to wireless server. The main responsibility of the MANET router is to provide communication between the wireless nodes which are in Ad-hoc mode and the IP network. The MANET router has AODV routing protocol as default. The mobile nodes can use the routing protocol specified in MANET router, and it is possible to change the default value in order to employ DSR as the routing protocol.

Our standard scenario will be made first containing:

1) At first 20 Mobile MANET Workstations (Ad-hoc routing set to ADOV and DSR depending on conditions set to obtain desired results) and later increased to 50 nodes.

2) One Router used as MANET router gateway (To connect MANET to IP Network for web browsing)

3) One Wireless Server to host the Applications

4) The Workstation will connect wirelessly to the MANET router which acts as a gateway 11bps.

5) The Wireless Network will have the BSS Identifier of 0 along with the MANET router’s BBS Id set to 0 as well to match up in the same network.

6) The Gateway will communicate over to the Wireless Server as the MANET router’s default gateway option is enabled.

6) The scenario will take place in an Office of size 500m x 500m (for a Classroom Scenario).

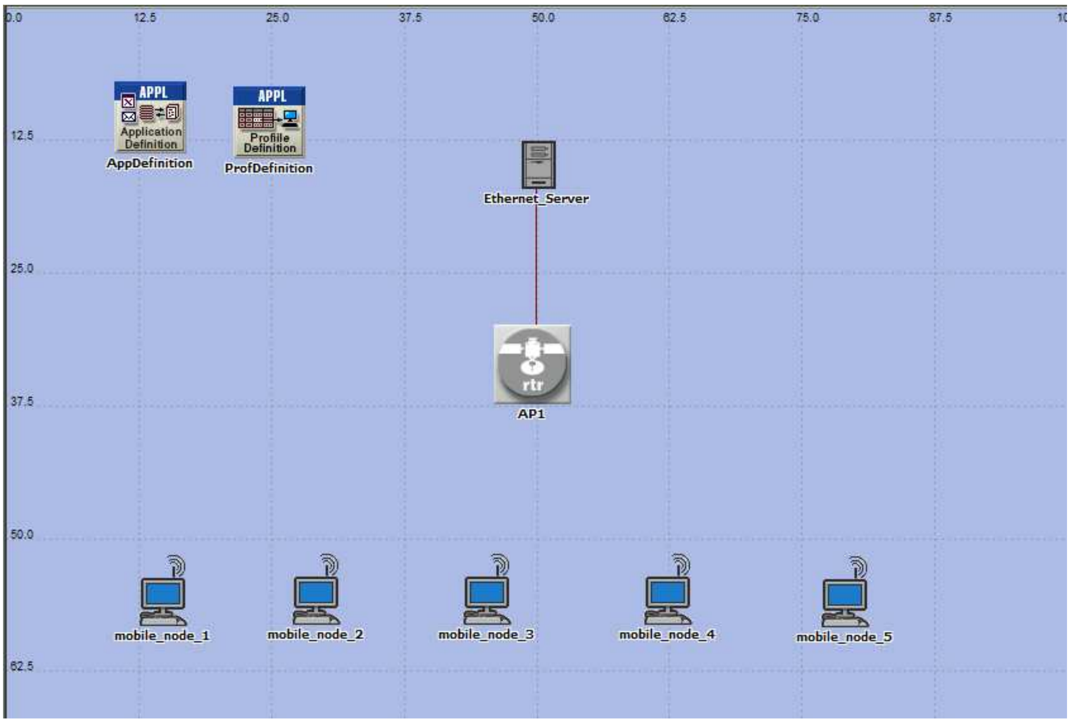

Figure 1 The Infrastructured mode (WLAN) Scenario in an E-Learning classroom area

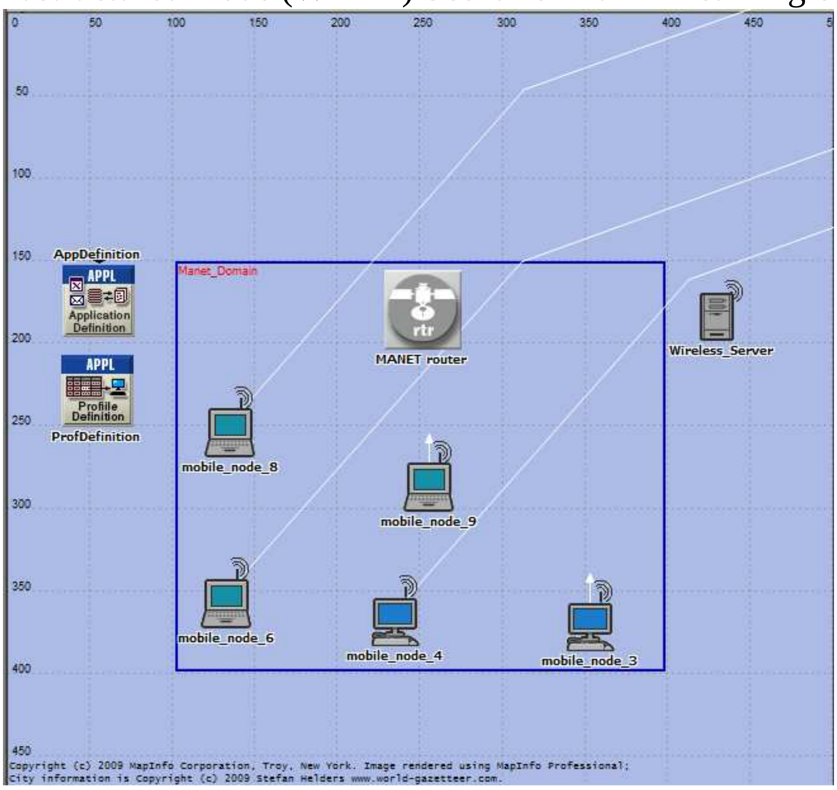

Figure 2 The Ad-hoc mode (MANET) Scenario in an E-Learning classroom area

IV. THE COMPARISON AND ANALYSIS OF THE RESULTS FOR ROUTING PROTOCOLS

A. Data Throughput from Source to Destination

Data throughput is calculated on end to end basis of packets reaching destination from the source in the network. There were 2 main networks created one with 20 nodes and the other with 50 nodes and both of the networks were simulated with AODV once and DSR routing protocol once.

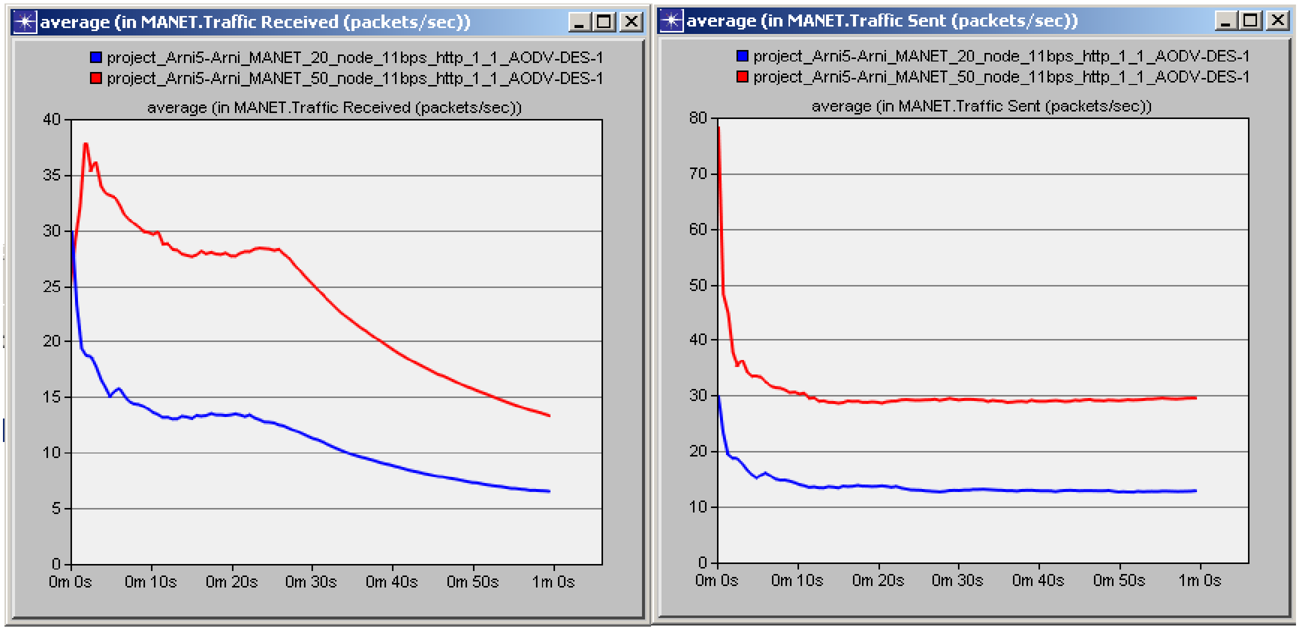

Figure 3 AODV end-to-end data throughput

In the figure 3, above one can easily make out how the AODV routing protocol faces complexity in sending data packets to destination node from the source node with only 20 nodes in the network. Out of 12 data packets as many as 6 data packets are lost because of the random mobility of the nodes and its random trajectories (in fact some of the nodes even go out of range from the specified area) and only 6 packets could be sent to the destination. After this, the numbers of nodes were increased to 50 nodes in the other network with same AODV protocol to see the effects on the network. Out of 30 data packets sent out only 13 packets could reach the destination which means the AODV lost almost 17 packets with increase in number of nodes which in turns proves that AODV protocol performs well under pressure. From our findings of AODV protocol can be employed when it comes to heavier traffic in Ad-hoc networks.

Now our next set of results are compared for DSR routing protocols where DSR had almost same results as AODV in the network with just 20 nodes where out of 11 packets sent, only 6 packets were received at the destination with a loss of 5 packets. On the other hand, in the figure below it demonstrates that in DSR as the network size increased from 20 nodes to 50 nodes there were less data packets lost than AODV where out of 30 packets sent only 16 data packets were lost which is for this experiment less than AODV's 17 data packets loss for 50 nodes.

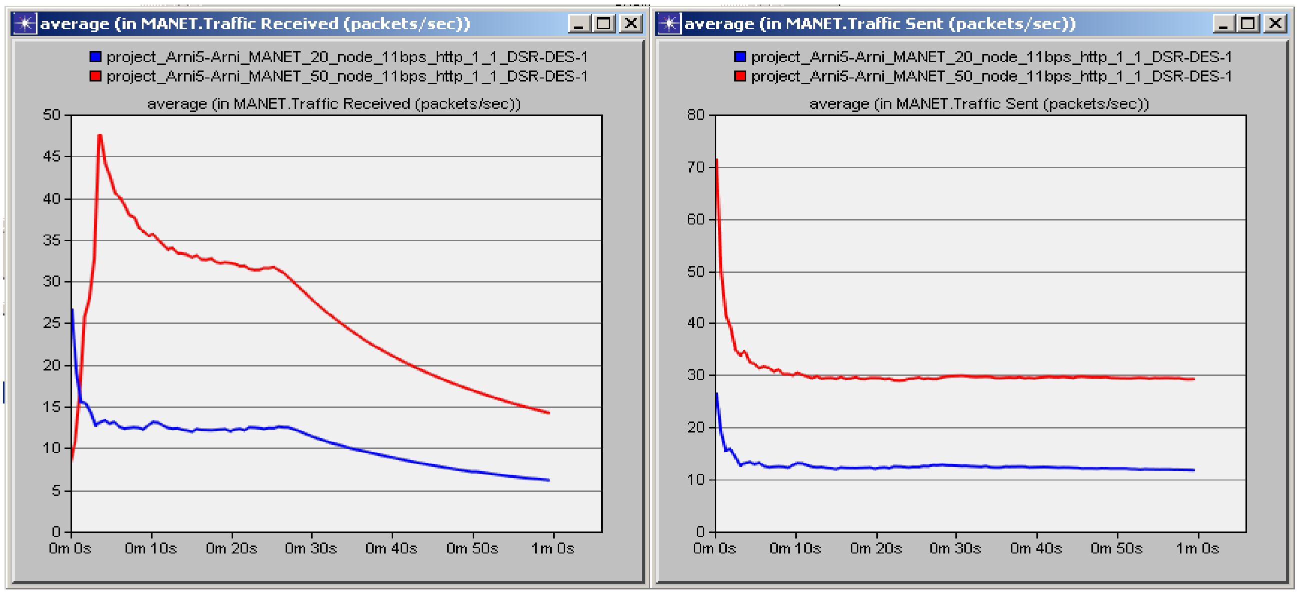

Figure 4 DSR end to end throughputs

B. *Delay in Data Transmission*

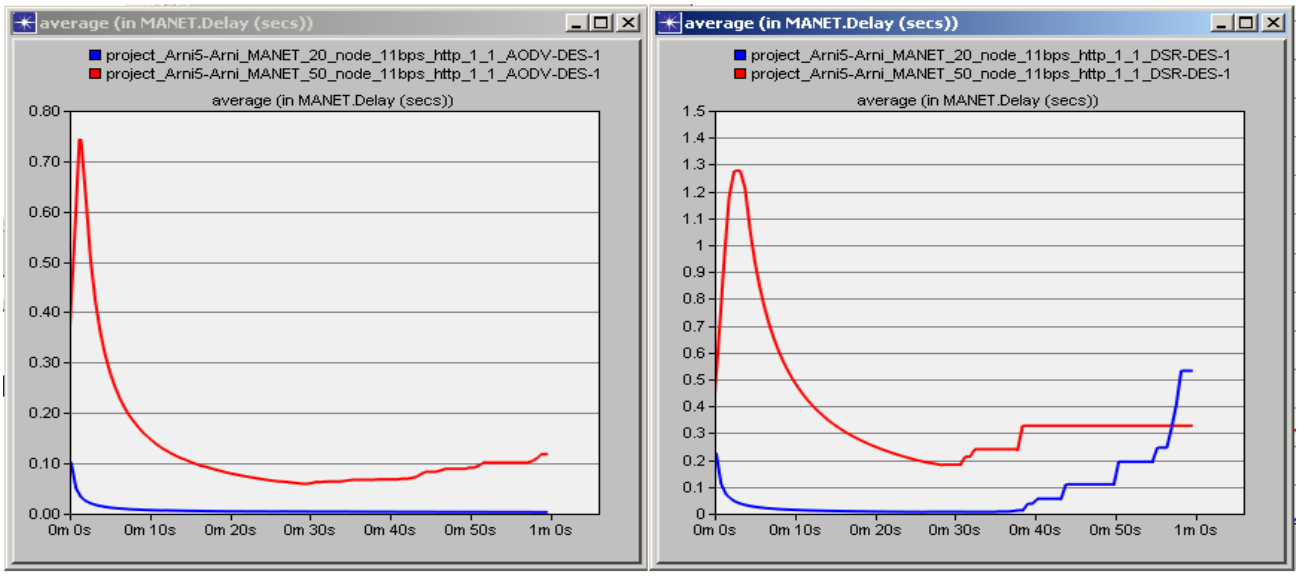

Figure 5 AODV/DSR delay patterns

From the above figure it is obvious that AODV routing protocol has advantage over DSR, as in theory AODV finds only one route to destination node giving it an advantage of having less delay and no cache overheads. Let us take a look at the results obtained from the experiment conducted above. Comparing the two different networks for AODV first, the network with 20 nodes has a delay of almost 0.0 seconds, and second network with 50 nodes has almost 0.11 seconds due to the increase in number of nodes and random mobility of nodes. In AODV route information are not saved as in DSR and all the lost routes are dropped or made redundant with same broadcast number or with same source address.

On the other hand DSR has much higher delay than AODV as according to the above statistics show, that network with 20 nodes has a delay of 0.52 seconds in comparison to delay of AODV which was almost 0.0 seconds and the network with 50 nodes has a delay of almost reaching 0.31 seconds compared to 0.11 seconds of delay of AODV with 50 nodes which proves our point for the previous section where it had been mentioned that DSR looks for multiple routes to destination with any (RREQ) route request packet and takes time to gather information about these multiple routes which it stores in the overhead cache of the nodes to destination.

C. Route Discovery Time

Route discovery time is one of the most essential parameters when talking about routing protocols as this is the feature which will show AODV or DSR or routing protocols perform better. By the statistics obtained from the tests conducted it gives sufficient proof that AODV is better than in comparison to DSR in terms of "*route discovery time*". From figure 6 one can see how the network with 20 nodes in AODV takes only 0.03 seconds to discover a valid route since it uses single path with (RREQ) packet and it makes all the other routes to the destination redundant, whereas the network with 50 nodes has a higher up to 0.08 seconds to discover a route to the destination due the increase in number of nodes and random mobility.

Now if the DSR is considered, it has a lot higher "*route discovery time*" in the both the networks, it goes up as high as 3.1 seconds in the network with 20 nodes in comparison to AODV and in the network with 50 nodes it reach the maximum limit of 6.2 seconds to discover a route to destination as DSR discovers multiple route and also stores the route information from its previous nodes so of course it is quite obvious and proving our earlier points that it takes much greater time to reach destination than AODV.

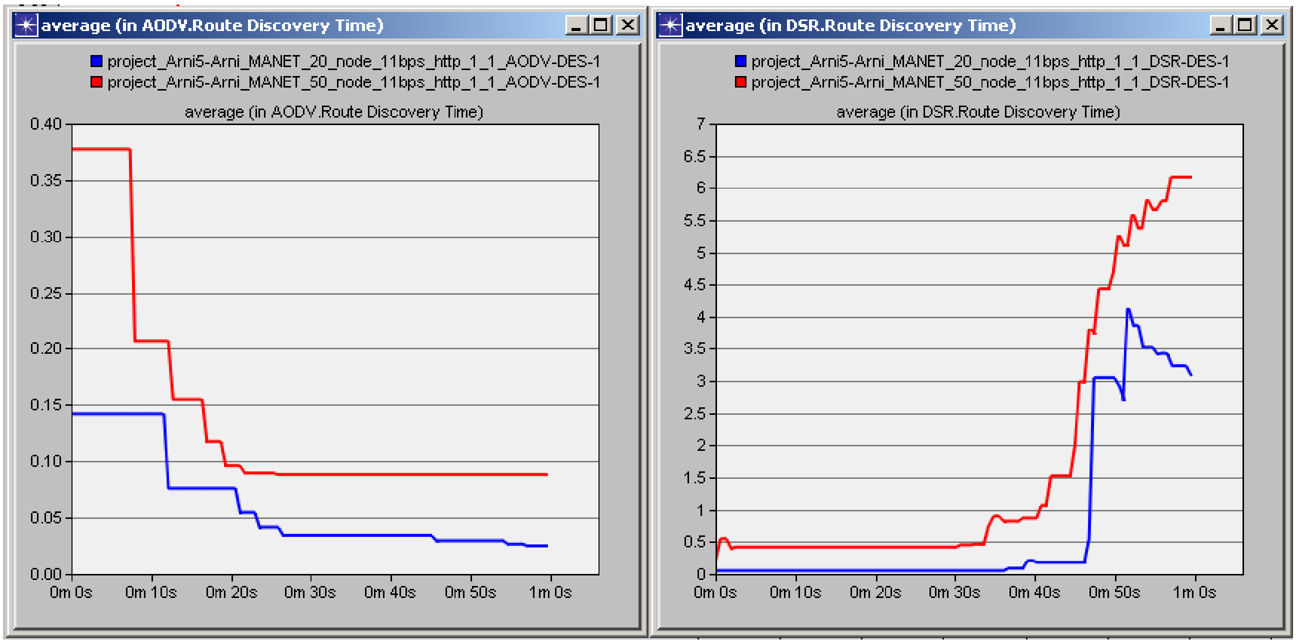

Figure 6 AODV/DSR Route discovery time

D. *Efficiency of Data Delivery*

When examining the efficiency of the data delivery it is quite obvious that DSR makes sure that most of the data is delivered properly no matter how much time it takes because of its multiple paths to its destination. So therefore, DSR hardly drops any packets of just 1 according to stats shown below. The result obtained here justifies our tests conducted earlier as well.

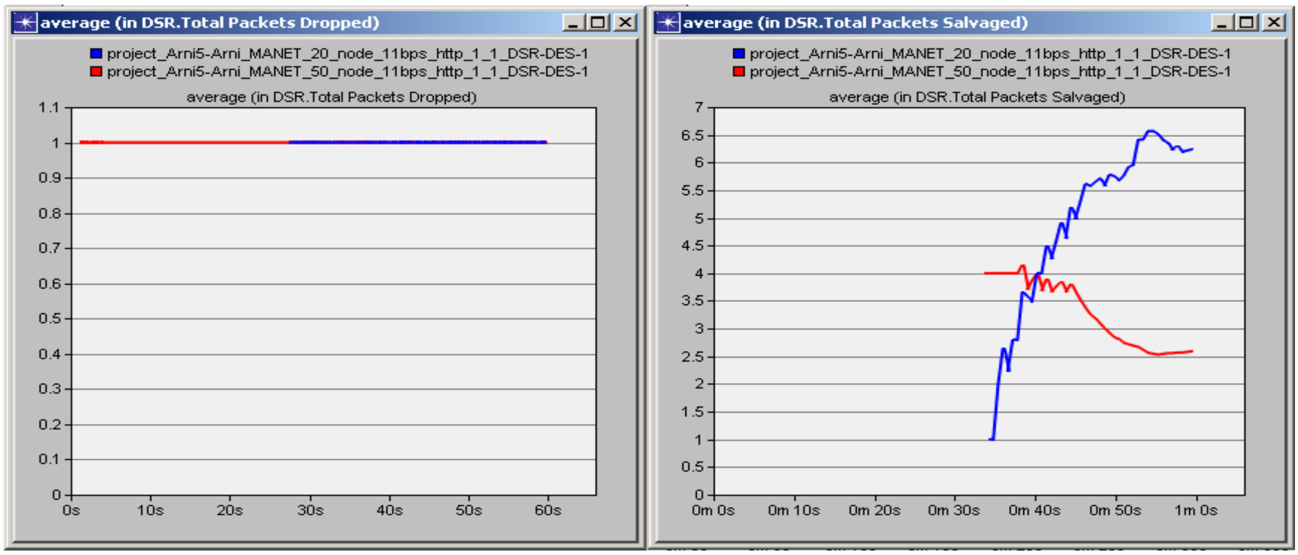

Figure 7 DSR dropped/salvaged packets

On the other hand, in the figure above one can notice the total number of salvaged packets considerably increase, with increase in number of nodes. Starting with the network with 20 nodes there were only around 6.2 packets are salvaged whereas as in case of 50 nodes the number of salvaged packet are around 2.6 packets. This shows and supports our argument of DSR from the previous sections that in DSR, there is a mechanism to handle this problem with increase in number of nodes more routes are salvaged than dropped i.e. packets are re-broadcasted and DSR uses its node cache to find an alternative route if one fails to comply.

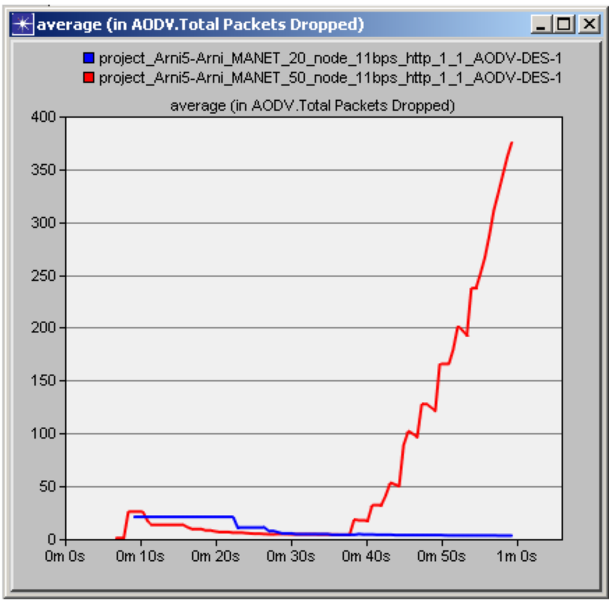

Figure 8 AODV dropped packets

As according to statistics shown in the above figure AODV on the other hand, has no mechanism to store the route information from the node cache and if there is a break in between the links it just sent a new (RREQ) route request. AODV only uses single route of hop by hop mechanism. So comparing the two networks it was concluded that the network with 20 nodes has the same number of packets dropped just 1packets in comparison to DSR's 20 nodes network but, when the number of nodes were increased to 50 nodes there was a drop of 360 packets in AODV due to its nature of frequently drooping packets and making them redundant and requesting of fresh new (RREQ) packets and due to the moving nature of the mobile nodes in the network.

E. Most Favourable Path or "Optimum path"

By the term "Optimum path" we mean the first and favourable route derived and not the shortest or the cheapest route. The wireless router selected for the experiment to connect the Internet IP network with the MANET (Wireless MANET Gateway) could not carry out the DSR routing, but had the option of simply AODV routing protocols. This was the only router that could connect to Wireless Server through the MANET router. The figure below demonstrates how some of the packets hops from one node to another in DSR routing to destination. The important thing here is, due to the random movement of the nodes and the different trajectories set for the nodes it becomes quite difficult to follow the genuine path taken by each node from source to destination. Figure nine shows the paths for the nodes following DSR routing mechanism.

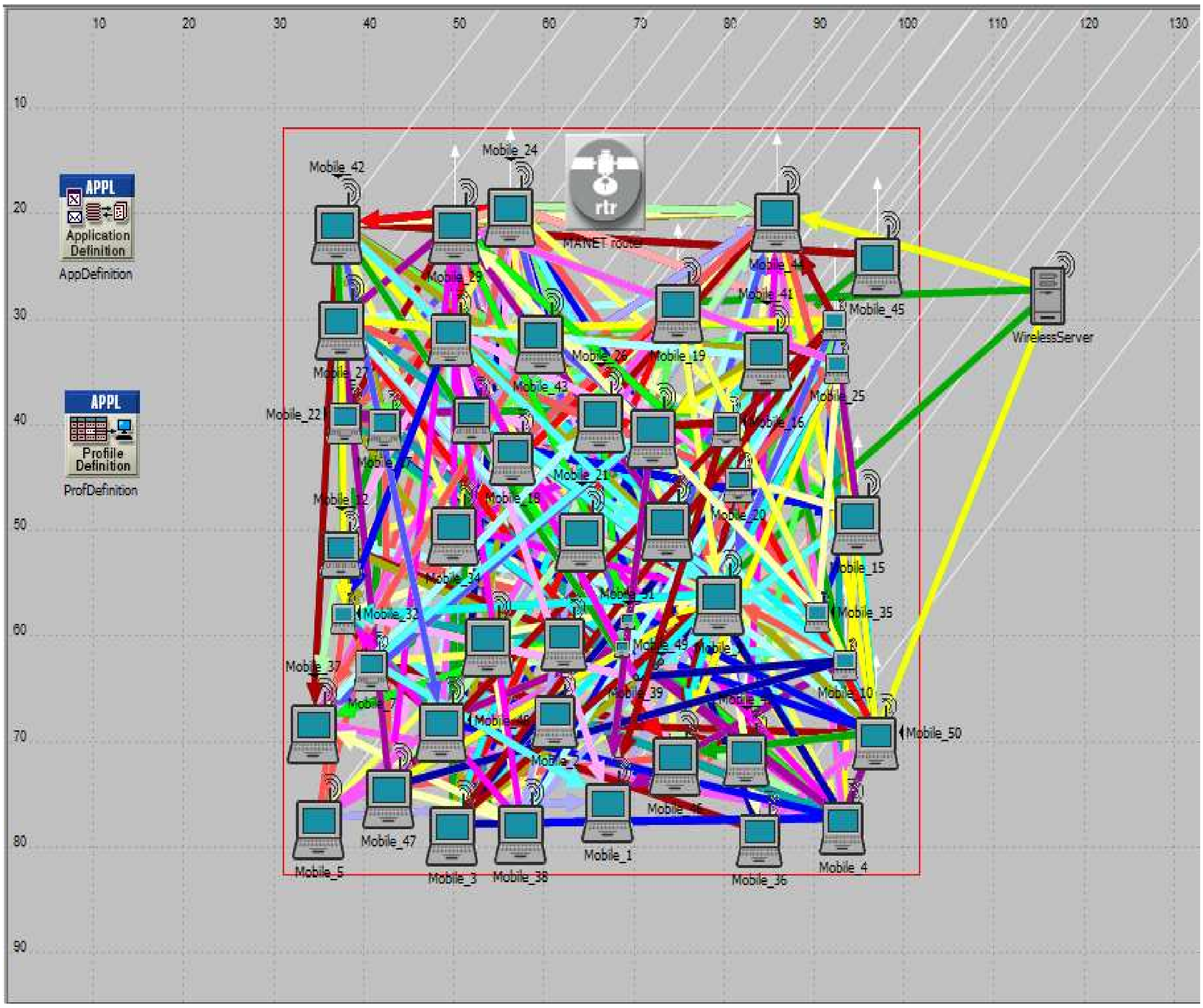

Figure 9 Data packets routes

V. THE COMPARISON AND ANALYSIS OF INFRASTRUCTURED NETWORKS (WLANS) WITH THE AD-HOC NETWORKS (MANETS) IN AN E-LEARNING SCENARIO

In this section we will test the two network models in an e-learning scenario with AODV routing protocols, as learned from the above results that AODV is best suited routing protocol in a large network with proof of our own results from simulation justifying the experiments. In this section one can see how the experimented simulations were run and outcomes are collected to compare the Ad-hoc and infrastructure mode WLANs. Here a real-life scenario model of the two network models of one Infrastructured and the other Ad-hoc were created in OPNET Version 14.0 in order to compare which is more suitable for e-learning applications.

Our Second standard scenario contains:

1) At first starting with 5 mobile workstations were selected for this purpose and later 20 nodes, 50 nodes and with the maximum limit of 100 nodes were selected to show heavy load. This same setup was created both for our Infrastructured network (in this case WLANs) and for Ad-hoc network (in this case a MANET).

2) One router used as Access Point in WLANs to connect the mobile node to the Ethernet Server and one router used as MANET router gateway (To connect WLAN to IP Network for web browsing)

3) One Ethernet Server to host the Applications with 10BaseT link in WLANs and one Wireless Server for MANETs.

4) The Workstation will connect wirelessly to the MANET router which acts as a gateway 11bps and in WLANs the mobile workstations will connect through access point AP1.

5) The Wireless Network will have the BSS Identifier of zero along with the Access Point's BBS Id set to zero as well to match up in the same network. The same is applied to Manet's model both the BBS Id's of the MANET router and the mobile nodes is set to zero to make sync between them.

6) The scenario will take place in an Office of size 500m x 500m (for a Classroom Scenario).

A. Average of Wireless and MANET Delay (sec)

There were 4 main networks created for this purpose, simulations were run in network one with 5 nodes and the other with 20 nodes, third network with 50 nodes and the last network with 100 nodes to test the maximum limits it can go to.

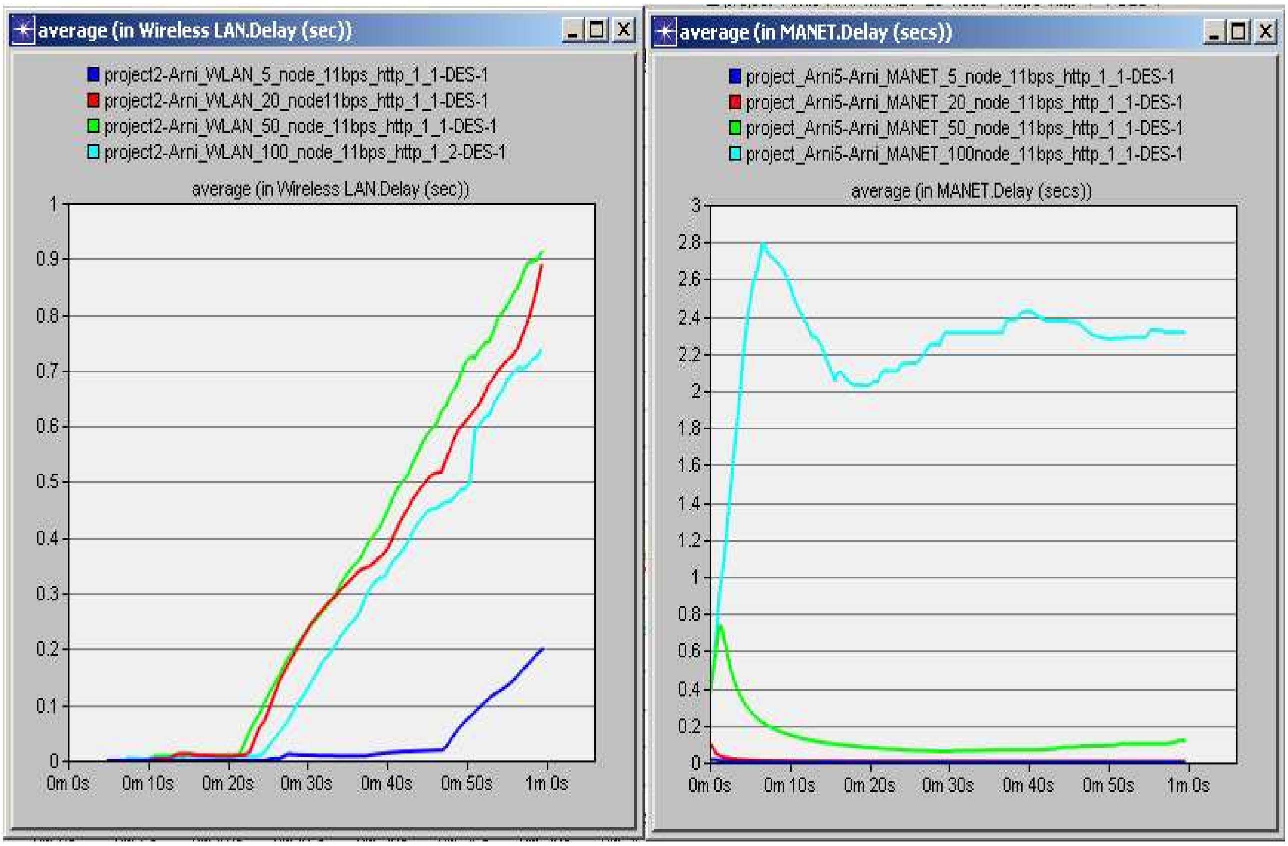

Figure 10 Average wireless delay WLAN (infrastructure)/MANET

In figure ten illustrates the numerical results obtained by the second experiment of comparing the Infrastructured (WLAN model) with the Ad-hoc (MANET model) to support e-learning application in a classroom scenario. Here as the results show that in network with just five nodes in WLAN structure has an average wireless delay of just 0.2 seconds whereas the network setup with 20 nodes has a delay of 0.9 seconds due to the slight increase in number of nodes. But if we look at the results of network with even higher load of 50 nodes the delay goes as high as upto 0.93 seconds which was expected due to the heavy traffic and the network with 100 nodes tested the maximum limits of a WLAN Infrastructured network architecture to see if it is possible to support 100 nodes in an e-learning scenario which came out to be successful with a delay of just 0.7 seconds which was neither too high as in network with 50 nodes nor too low as in network with 5 nodes. Another reason for having a mixed result is that this was an

Infrastructured setup which did not have any routing protocol or any trajectories i.e. the nodes were mobile nodes but were fixed.

On the other hand, the MANET setup (Ad-hoc model) had somewhat varied results. With the network with 5 nodes had a wireless delay of almost 0.0 seconds and same was the case in network with 20 nodes this is due to the AODV routing protocol used in the MANET helps find route very quickly in large network as it has its mechanism of broadcasting the network with its (RREQ) packets and dropping of broken links and requesting fresh routes. As a result, the same was seen in the network with 50 nodes where the delay of just 0.1 seconds for such a large network was experienced which justifies our previous experiments results too. But at the same time there was a slight difference in the result of the network with 100 nodes where a very high delay of 2.2 seconds was experienced. The reason of this is increased number of nodes with high mobility and different trajectories also increased the number of broken link between nodes to destination.

B. *Average of Wireless Throughput (bits/sec)*

As shown in the figure 11 below, demonstrates a very similar result in terms of average throughput. As the numerical figures of the graphs below show that the network with 5 nodes in the Infrastructured (WLAN setup) network has throughput i.e. average rate of successful message delivery over a communication channel of 850,000 (bits/seconds) whereas the network with 20 nodes has less throughput of 380,000 (bits/seconds) even though the with 20 nodes there is a considerable increase in the number of nodes, this might be because in network with 5 nodes there are way too less nodes than the other network so the possibility is that all the data packets in such a small network gets properly delivered to the destination and another fact being that it’s in a Infrastructured (WLAN) model. Now with network with 50 nodes and 100 nodes both have high throughputs of 850,000 (bits/seconds) and 1,350,000 (bits/seconds) respectively as both have a large number of nodes so it is expected that a lot of the data packets get delivered.

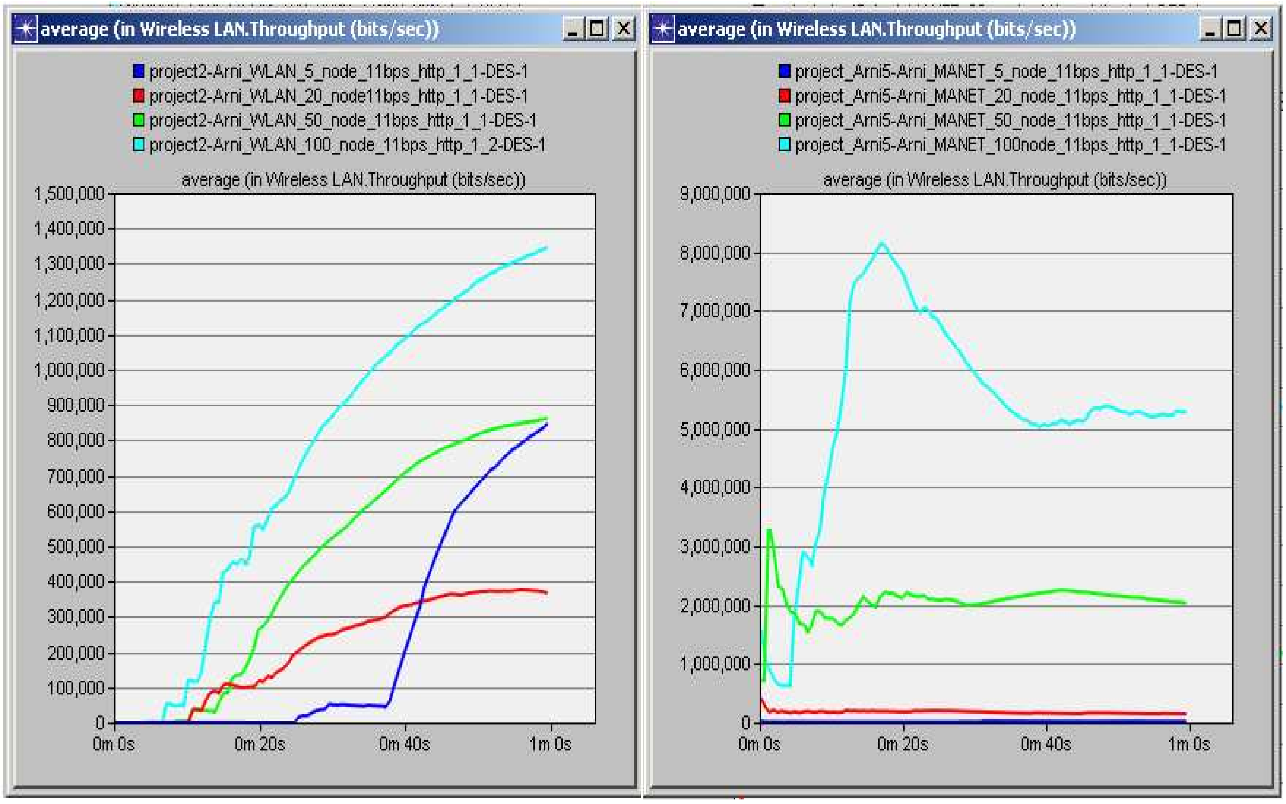

Figure 11 Average throughput WLAN(infrastructure)/MANET

For the Ad-hoc (MANETs setup), network with 5 nodes and 20 nodes have almost no throughput of 0.0 (bits/seconds) and 0.1 (bits/seconds) respectively as in MANETs as we learned earlier that they have trajectories for each nodes to move about in the network. Therefore it becomes very difficult for them to deliver the data packets with small networks. But, on the other hand network with 50 nodes and 100 nodes both have considerably increased throughputs of 2,000,000 (bits/seconds) and 5,400,000 (bits/seconds) as with large networks AODV routing protocols with much better and most packets get delivered.

C. E-Learning HTTP1.1Page Response Time (sec)

This experiment is the key experiment where it tests the e-learning applications for WLAN and MANET setup. First we will look into the Infrastructured model (WLAN) where the network with 5 nodes has a HTTP response time of 0.039 seconds and the network with 20 nodes has the highest response time of all network with 0.23 seconds as 20 nodes network is a medium sized network so all the nodes come in perfect range of the access point, for this reason all the nodes try to connect to the HTTP page at the same time. Whereas, the other two networks with 50 nodes and 100 nodes have a response time of 0.05 seconds and 0.06 seconds respectively which is idle for large networks in an Infrastructured networks; figure 3.3 is shown as below.

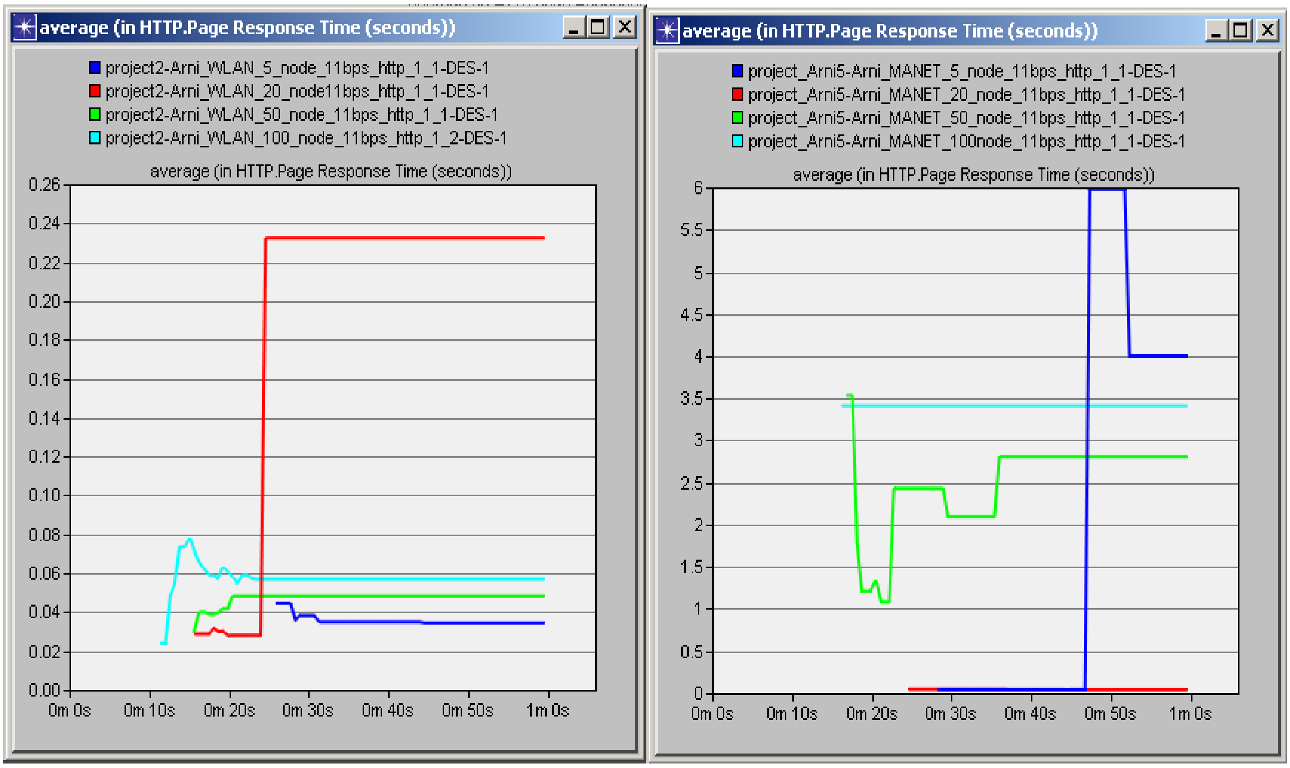

Figure 12 Http Response time WLAN(infrastructure)/MANETs

As far as the MANET model is concerned, one can notice from the above figure 12 how the network with 5 nodes has the highest page response time touching the mark of 6 seconds alone and gradually come down to a point of 4 seconds because of the fewer nodes available in MANET and due to their highly Ad-hoc nature of the nodes. While network with 20 nodes has 0.0 seconds page response time. The results obtained from the network with 50 nodes show a page response time of 2.8 seconds which is greater than in the WLAN 50 nodes network the reason being the nodes are continuously moving within the network and AODV routing protocol used in this MANET setup has the tendency of making redundant of the broken links, so it takes more time for HTTP page response. The page response time with 100 nodes is set to 3.4 seconds which is expected to higher as doubling in number of nodes. These simulation results shown above justify all our experiment conducted above and satisfying the reasoning of the justification given.

D. Wireless Access Point (AP1 and MANET router) Delay (sec)

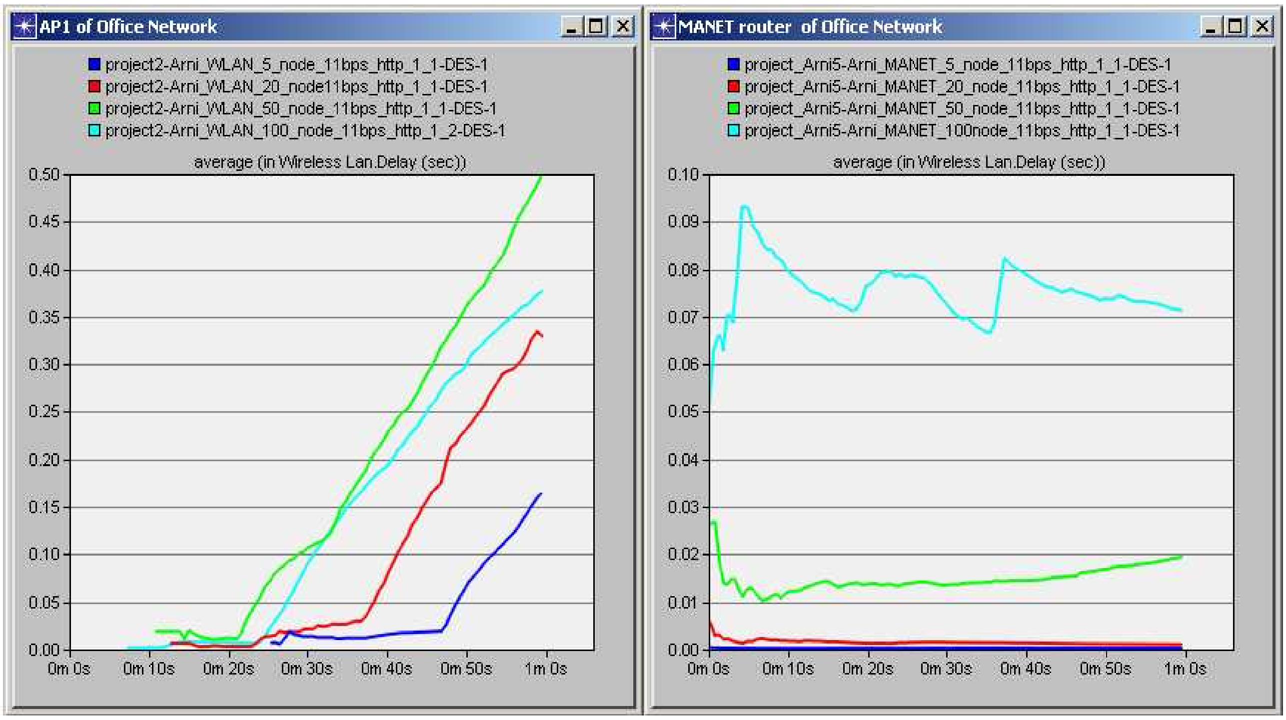

Figure 13 Router delay times WLAN(infrastructure)/MANETs

Above in figure 13 the results depict a very gradual increase of pressure on access point and MANET router with a steady increase in number of nodes. First let us consider the Infrastructured model of WLAN exhibit that the network with 5 nodes has the lowest delay of 0.13 seconds as it has only 5 nodes to support. As we increase the number of nodes the delay significantly increases. Now the network with 20 nodes has access point delay of 0.33 seconds which is due to the increase in traffic load accessing the access point at the same time. On the contrary, the network with 50 nodes show a sudden inclination on the graph where access point delay reaches its maximum limit of 0.50 seconds as predictable with increase in number of nodes although with 100 nodes the wireless LAN delay stood at 0.36 seconds.

In contrast, according to the figure 13 in MANET model the network with 5 nodes took more or less 0.00 seconds delay as the MANET model uses the AODV routing protocol which helps in broadcasting with (RREQ) packets to all possible routes to destination unlike DSR routing protocol. Coming right next to that mark is the network with 20 nodes where delay is just about 0.02 seconds as in MANETs AODV routing protocol come into play at this point of time. When third network with 50 nodes is considered a little increase in delay to 0.02 seconds is experienced. This is because increase in the number of nodes and in addition their movement within the network which is still less seeing at the delay point as compared to the WLAN Infrastructured model which are static. When the network was increased to it maximum limit of 100 nodes the results obtained showed a sharp increase in delay time of 0.07 seconds. The reason of this is 100 nodes in the network and all operating on AODV routing protocol which uses the mechanism of broadcasting the network with request packets thus flooding the network. This also adds to the advantage of MANETs as it still manages to find the quickest path to the destination and maintains a route table with eliminating unnecessary broken links unlike WLANs.

VI. SUMMARY AND CONCLUSIONS

This paper presented a simulation study of an IEEE 802.11b wireless LAN in an E-Learning classroom network scenario. The simulations, conducted using OPNET modeler 14.0. The simulation results show that an IEEE 802.11b WLAN can easily support up to 100 clients doing modest E-learning and Web browsing in both infrastructure and Ad-hoc modes.

The results also show that it is not an easy decision to make whether to choose infrastructure mode or Ad-hoc mode. Detailed explanations for various scenarios are provided in the results section.

When routing protocols AODV and DSR are considered, it is obvious that AODV performs better in cases of heavily loaded networks. This is mainly due to the route table entry mechanism employed.

It is desirable to extend these studies further to evaluate the performance of WLANs in Ad-hoc mode. Especially in order to classify the mobility of the wireless nodes and try to optimize the performance by using mobility thresholds

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