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# Performance Assessment of Routing Protocols in Ad Hoc Network with Impression of Ad Hoc Cloud and Internet of Things

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***Abstract***: *Ad hoc network is a decentralized network in which organization of network, message transmission and delivery is executed with nodes themselves. Routing is a critical issue that determines the performance of the network. This paper is a multifold, impression, study, and simulation based paper. At first impersonation of Ad hoc, Cloud, Ad hoc cloud and Internet of Things (IoT) is done. Then a study is done to identify the most important and effective performance parameters, metrics, factors and issues of Ad hoc network. In the last part the routing protocol named AODV, DSR, TORA, OLSR and GRP are simulated, implemented and then performance analysis of these protocols are done considering important parameters that are identified in this study.*

***Keywords: Ad hoc network, Ad hoc On-Demand Distance Vector (AODV), Ad hoc cloud, cloud network, Dynamic Source Routing (DSR), Geographic Routing Protocol (GRP), Optimized Link State Routing (OLSR), Temporally Ordered Routing Algorithm (TORA).***

## I. INTRODUCTION

Ad Hoc network is a wireless network that does not need any centralized architecture. In this network each node acts as a router and forward data for the other nodes. Hence the network is ad hoc. Based on the network connectivity, it is determined dynamically which node forwards data. So it is very much different than the wired networks where router is needed to perform the task of routing. Also it is different from the managed wireless network where the access point manages data communication among other nodes. Fig. 1 shows simple examples of Ad hoc network [1].

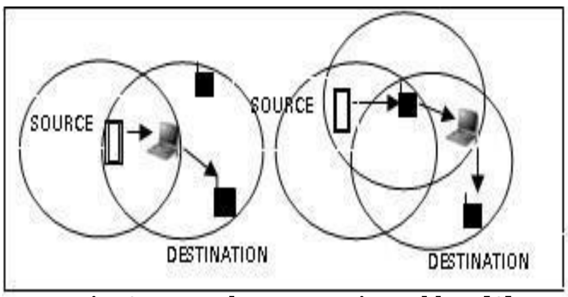


**Fig. 1 Network representing ad hoc [1]**

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Ad hoc network has a dynamic structure due to which routing in ad hoc network is a difficult task. So there are different categories in such type of network as shown in Fig. 2

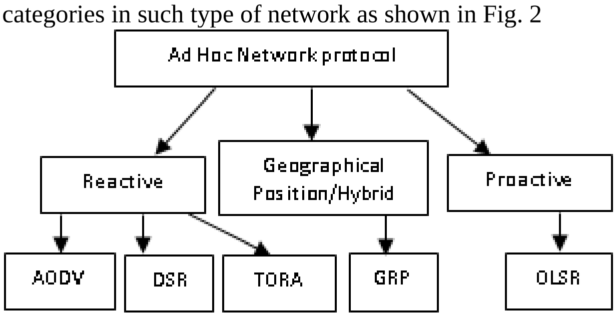


**Fig. 2 Classification of Ad Hoc routing Protocol**

Cloud computing is a concept that uses "pay as per use" model and store data and service on elastic data centers. These services can be accessed through authentication.Cloud services are composed of very adaptable and configurable resources.Fig. 3 show the concept of cloud computing using computer network diagram [2].

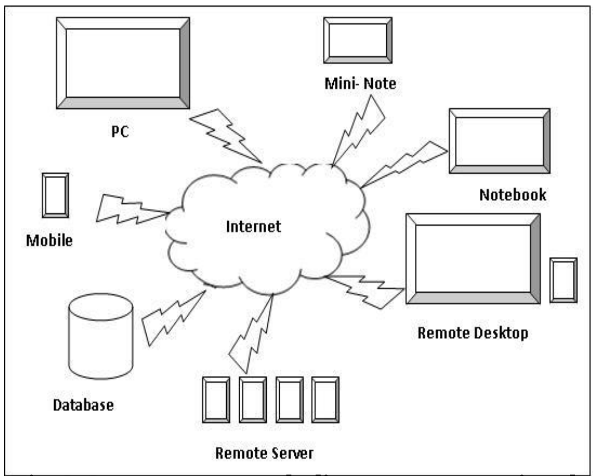


**Fig. 3 Computer network diagram representing the concept of cloud [1]**

Ad hoc cloud is a term formed when ad hoc network runs cloud services [3].In this kind of network, existing heterogeneous hardware are used to run the cloud services. The Ad hoc clouds allows existing infrastructure as cloud accommodating, the resources available in the environment are used extrusive. This concept can be used to improve their infrastructure efficiency and utilization; furthermore can be used to reduce costs by improving their return on IT investments. This concept is also very useful to those who are not able to use the commercial or private cloud [4].

The Ad hoc cloud architecture is shown in Fig. 4 .Ad hoc cloud has various advantages as mentioned in Fig. 5.

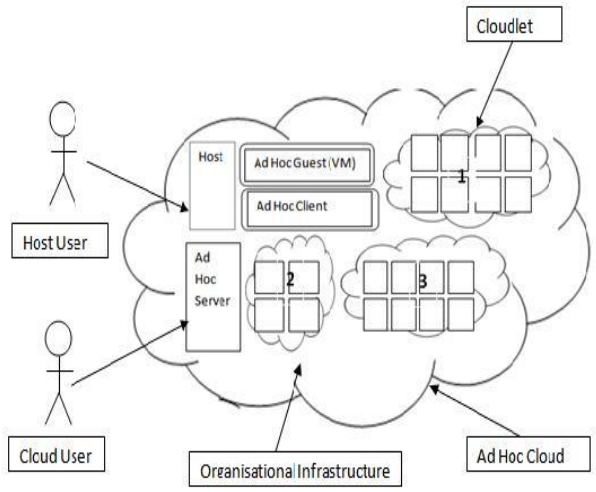


**Fig .4 Architecture of the ad hoc cloud [1]**

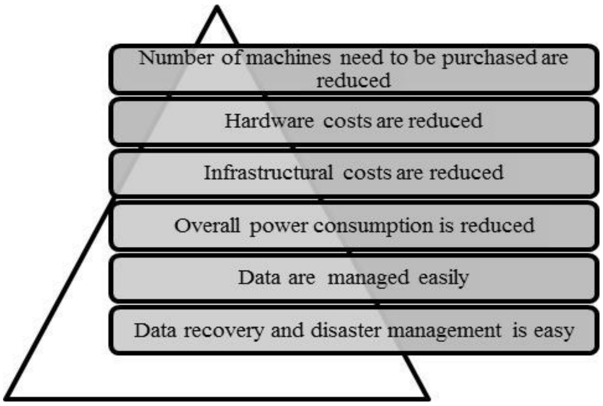


**Fig. 5 Advantages of Ad Hoc Cloud**

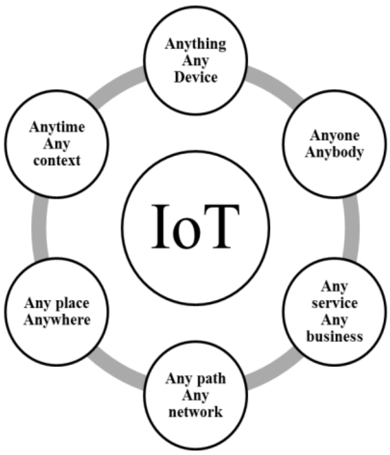


**Fig. 6 Internet of Things**

Internet of Things (IoT) is an emerging area that involves all of the above concepts. "Internet of Things" is devised from two words "Internet" and "Things". The internet is defined as a network of networks that are linked by various communication media, mode to communicate and share resources and data. The second word, Things can be any object or person that can be discernable by the real world. Things can be living things like human, animal, plant or non-living things like building, electronic devices, etc. There is no universally accepted definition of IoT. Fig. 6 shows the concept of IoT [5].

Ad hoc network is dynamic in nature and so is the IoT. Ad hoc network is self-organizing and so is the IoT with self-healing feature. All these concepts are immerging very fast and are going to design an urban IoT system and Smart cities that aims at exploiting the most advanced communication technologies to support the authority and citizens [6].

In this paper, at first the concept of new emerging technologies are discussed, in the next section study on the performance metrics, factors and parameters that affect the performance evaluation of the network is done and then at last evaluation and analysis of the performance of the protocols mentioned in Fig. 2 of ad hoc network is performed. The ad hoc network simulated for this paper consists of wireless fixed and mobile nodes.

## II. LITERATURE REVIEW

**Table I: Summary of papers [7] to [10]**

| Author | Protocols | Performance Metric and Parameters | Conclusion |
|---|---|---|---|
| Jyoti Raju, J. J. Garcia-Luna-Aceves (2000)[7] | DSR,WSR-Lite | Packet delivery ratio, Control packet overhead, Hop Count, End to End Delay.<br>Packet Size, Traffic type, Pause time, Speed, Simulation Area, Number of nodes Simulation time, Mobility model | WSR-Lite is better than DSR |
| Dmitri D. Perkins, D. Hughes Herman, B. Owen Charles (2002)[8] | AODV, DSR | Average Throughput, Average Routing Overhead, Power Consumption<br>Mobility model, Simulation time, Number of nodes, Simulation Area, Speed, Pause time, Traffic type, Packet Size, Rate, No. of traffic source, Routing | DSR better than AODV |
| HuiYao Zhang, John Homer, Garry Einicke, Kurt Kubik (2006)[9] | DSDV, DSR,AODV,TORA | Packet delivery ratio, End to End Delay<br>Mobility model, Simulation time, Number of nodes, Simulation Area, Speed, Pause time, Traffic type, Packet Size, Rate | DSR is best |
| Abdul Hadi Abd Rahman, Zuriati Ahmad Zukarnain (2009)[10] | AODV, DSDV, I-DSDV | Packet delivery ratio, End to end delay, Routing overhead.<br>Mobility model, Simulation time, Number of nodes, Simulation Area, Speed, Pause time, Traffic type, Packet Size, transmission Range | I-DSDV Perform better than DSDV but not than AODV. |

There are various Ad Hoc network routing protocol and performance metrics, parameters and factors that affect these protocols. The variables that affect the outcome of the experiment are termed as performance factors and the actual outcomes as performance metrics.

**Table 2: Summary of papers [11] to [16]**

Performance parameter quality characterizes a particular attribute of the performance metric. Various authors had worked on the performance of Ad Hoc network routing protocol in various applications considering various performance metrics and performance factors. Few of these papers are summarized in this section mentioned above in Table 1 and Table 2.

| Author | Protocols | Performance Metric and Parameters | Conclusion |
|---|---|---|---|
| | | | |
| Ahmed A. Radwan, Tarek M. Mahmoud and Essam H. Houssein (2011)[11] | AODV, FSR, LAR | Routing Message Overhead, Average End-to-End Delay, Throughput Packet Size, Traffic type, Pause time, Speed, Simulation Area, Number of nodes Simulation time, Mobility model, Rate | AODV perform better w.r.t throughput, LAR perform better w.r.t end to end delay and FAR perform better w.r.t control overhead. |
| G. Kioumourtzis, C. Bouras and A. Gkamas (2012)[12] | OLSR,DSR,AODV | Packet delivery ratio, Normalized routing, Normalized MAC, Average End to End Delay. Mobility model, Simulation time, Number of nodes, Simulation Area, Speed, Pause time, Traffic type, Packet Size, Rate, No. of connections | DSR better than others |
| Vikas Goya, Shaveta Rani, Paramjit Singh (2013)**[13]** | GRP and TORA | Traffic sent, Traffic received, Jitler, Voice MOS Value, Packet Delay Variation, Data dropped, Network load and Throughput Simulation time, Number of nodes, Traffic type, Data Rate, Network Scale, Network Size, Technology used, Physical characteristics | TORA perform best for all metric except throughput, GRP perform better w.r.t throughput. |
| Muhammad Asif Mehmood, Ahmed Mateen Buttar, and Muhammad Ashraf (2014)[14] | OLSR, GRP and TORA | Throughput, network load, media access delay and retransmission. Simulation time, Simulation Area, varying physical characteristics, nodes speed, pause time and number of nodes | OLSR perform outstanding w.r.t. throughput. TORA perform better w.r.t retransmission attempt and media access delay than OLSR and GRP. |
| Gayatree Rana, Bikram Ballav, Binod Kumar Pattanayak (2015)[15] | AODV, AOMDV, DSR, PAAODV, DSDV | Packets delivery ratio, energy conservation, throughput and average delay. Simulation time, Simulation Area, Number of mobile nodes , Channel type , Radio-propagation model , Network interface type , Interface queue type , Link layer type , Antenna , Maximum packet , Source type , MAC type , Initial Energy. | DSR perform better w.r.t end to end delay and packet delivery ratio, AODV performs better w.r.t throughput, PAAODV perform better w.r.t residual energy. |
| Adel Aneiba and Mohammed Melad (2016)[16] | AODV, OLSR, DSR, GRP | Delay and Throughput. Simulation time, Simulation Area, Number of nodes, mobility model, data rate and application | OLSR perform better than others |

## III. PERFORMANCE METRIC, PARAMETERS, FACTORS AND ISSUES

Based on the above comprehensive study on the performance factor, metrics and parameters of Ad hoc network, the main observations of the study are listed in Table 3.

**Table 3 List of Performance Metric, Parameter, Factors and Issues of Ad Hoc Network**

| S. No. | Most effective performance metrics | Important parameters that highly influence the performance | Most effective factors and issues |
|---|---|---|---|
| 1 | Throughput | Traffic type | Storage capacity |
| 2 | Network Load | Traffic received/ sent (packets/s, bytes/s) | Security |
| 3 | Wireless LAN Delay | Response time | Workload |
| 4 | Routing message overhead | Application | Scalability |
| 5 | End to End Delay | Number of nodes | Location |
| 6 | Packet delivery ratio | Mobility type | Network bandwidth |

The performance metrics among metrics mentioned in above Table 3 that are considered in this paper are:-

- Throughput
- Network Load
- Wireless LAN Delay

## IV. METHODOLOGY, SIMULATION ENVIRONMENT AND SIMULATION SCENARIOS

OPNET (Optimized Network Engineering Tool) modeler 14.5 has been used as a simulation tool to implement the network and protocols. It uses the object oriented approach to create and map the network graph. It can be used to design and study the communication networks, application and network devices with a high degree of flexibility. Its graphical editors provide a clear view of network and network components. One reason for choosing OPNET is as a result of its key attributes such as integrated GUI based debugging, customizable and scalable wireless simulation and modeling. [18]

There are five scenarios used in this experiment. Each scenario consists of thirteen fixed wireless nodes and four mobile nodes as shown in Fig. 7. There are two routers node_0 and node_1 and a switch node_16.

Fixed nodes from node_2 to node_7, mobile nodes mo-bile_node_2 and mobile_node_3 have the same attributes (Fig. 8 left) and fixed nodes from node_8 to node_14, mobile nodes mobile_node_0 and mobile_node_1 have the same attributes (Fig. 8 right), also mobile nodes have the same attributes as shown below in Fig. 9.

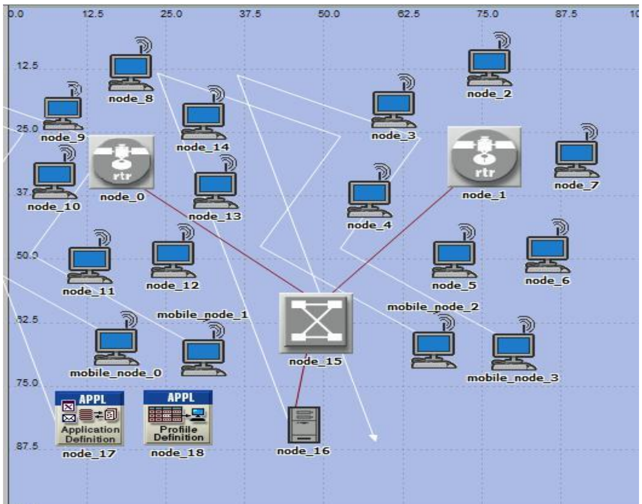


Fig. 7 Simulation Environment for all scenarios

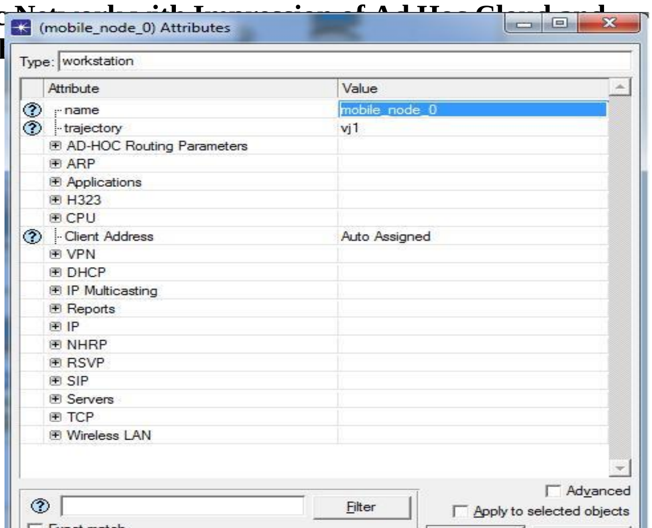


Fig. 9 Wireless LAN Parameter trajectory for fixed and mobile nodes

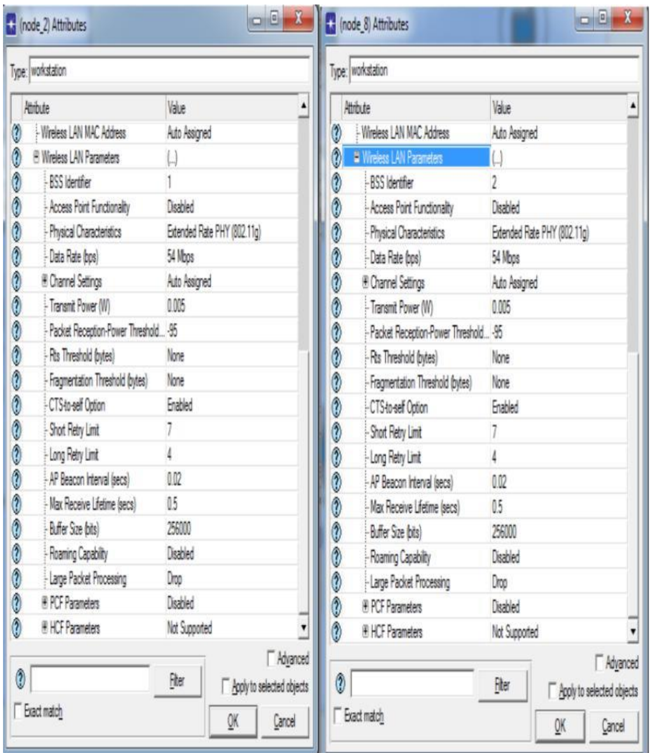


Fig. 8 Wireless LAN Parameter BSS2 (left), BSS1 (right

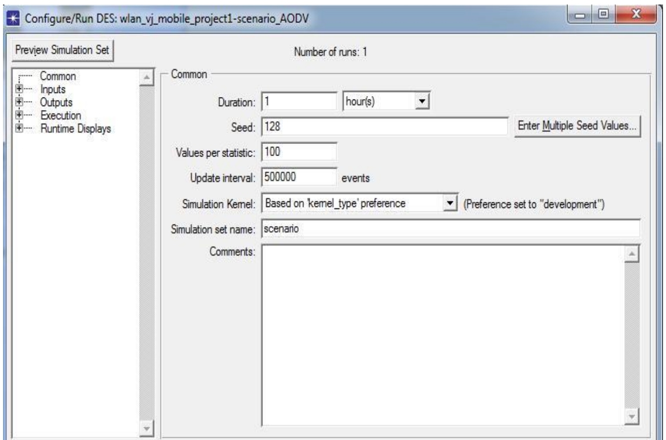


Fig. 10 Simulation configuration window

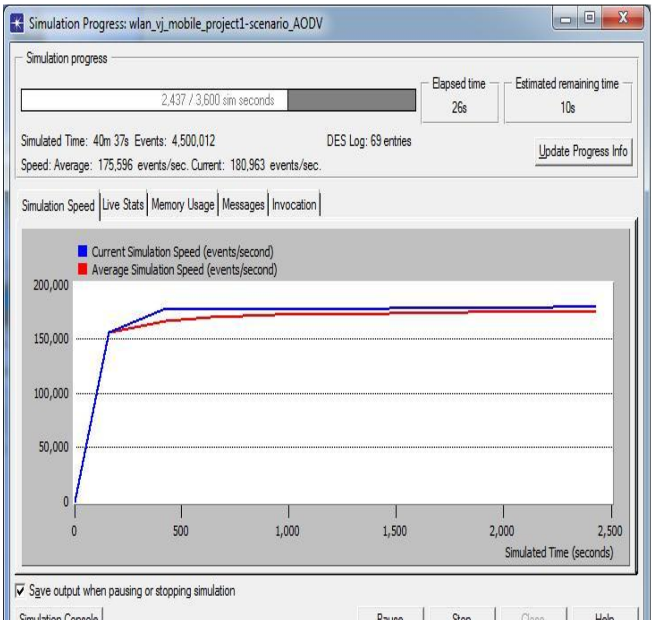


Fig. 11 Simulation speed window

There are five scenarios used in this experiment. Each scenario consists of thirteen fixed wireless nodes and four mobile nodes. In the five scenarios AODV, DSR, TORA, OLSR and GRP, .five different Ad hoc network protocol has been implemented.

Time duration for simulation considered in this work is 1 hour; 500000 events are update interval; 128 is seed; 100 are values per statics; preference for simulation kernel is based on kernel type; “scenario.” is the name of simulation set. This entire configuration is shown in Fig. 10. The simulation speed of is shown in Fig. 11 and simulation message for the scenarios is shown in Fig. 12. Fig. 13 and Fig. 14 shows the 2D animation of packet flow and node flow of the subnet and the 2D animation of node model respectively.

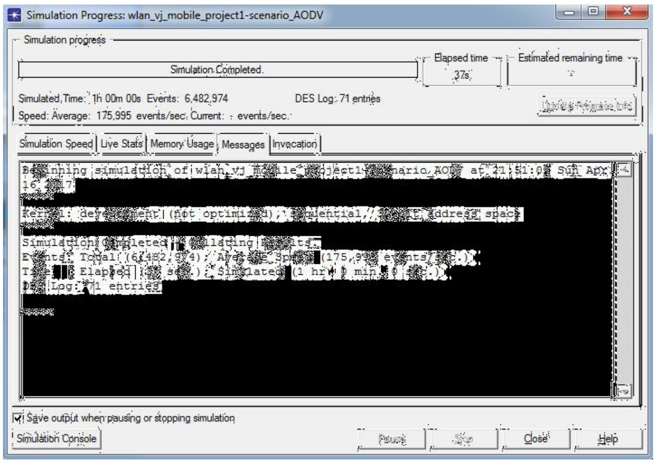


Fig. 12 Simulation message window

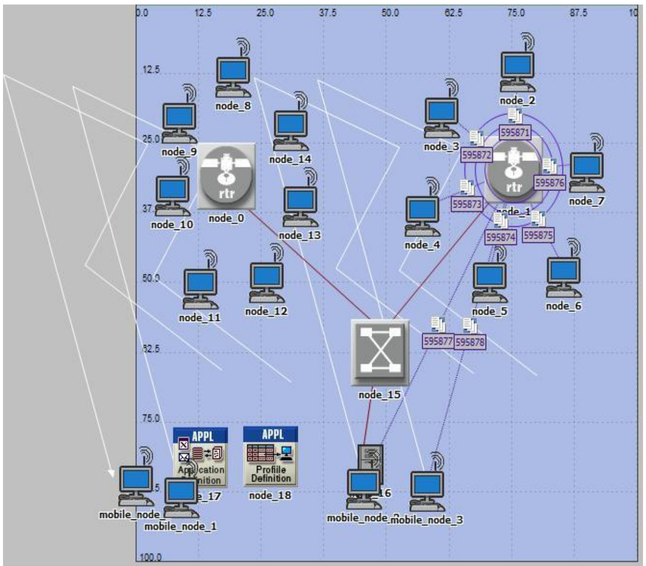


Fig. 13 2D Animation of packet flow and node movement of the subnet

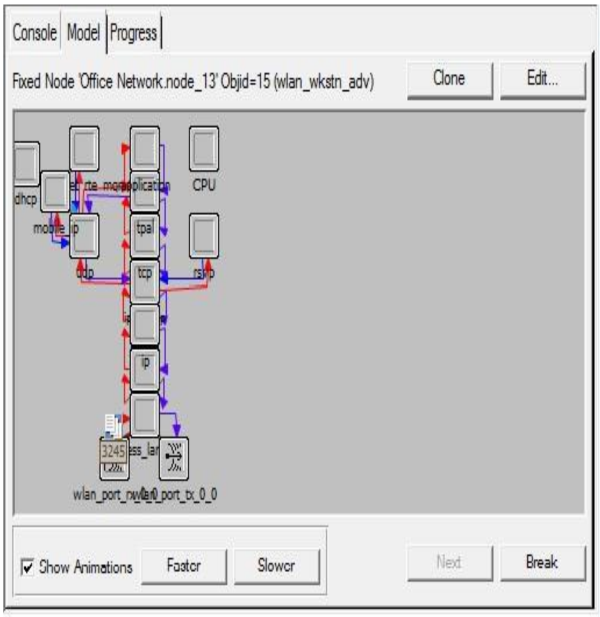


Fig. 14 2D Animation of Node model of the subnet

## V. RESULTS AND DISCUSSIONS

The performance metrics that are used in this paper are wireless LAN delay, network load and throughput. Graphs are generated based on the simulation performed using five scenarios namely scenarios_AODV-DES-1, scenarios_DSR-DES-1, scenarios_GRP-DES-1, scenar-ios_OLSR-DES-1 and scenarios_TORAV-DES-1 (as shown above in Fig 7), and then the result is analyzed. Also the Table 4 shows their average, maximum and minimum values.

### A. Wireless LAN Delay

This is the first and essential performance metric considered in this paper to measure the performance of the network. All the WLAN nodes in the network have the wireless LAN MACs whose packets receives end to end delay and forward it to the higher layer. Wireless LAN delay is the performance metric that signifies this whole process.

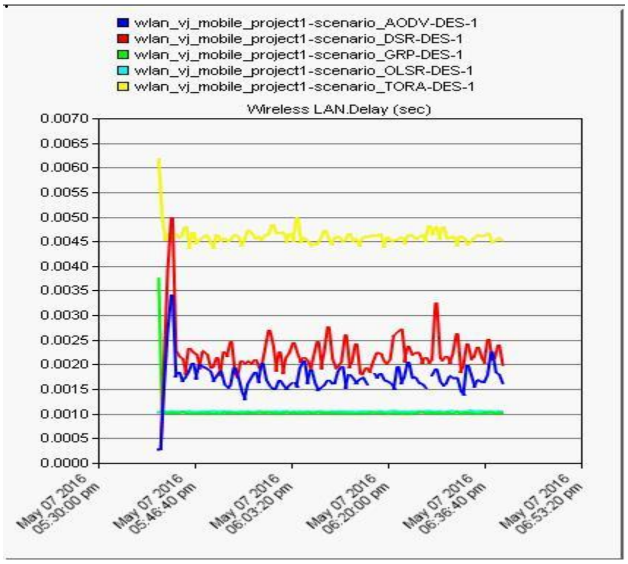


Fig. 15 Wireless LAN Delay (As is)

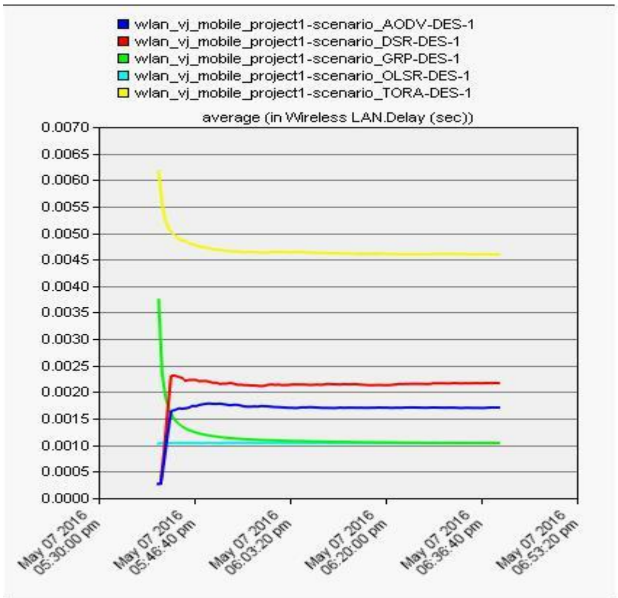


Fig. 16 Average Wireless LAN Delay

As seen in Fig. 15 and Fig. 16, OLSR has least average delay while GRP is the second most protocol that has less average delay among other protocols that are AODV, TORA and DSR.

The reason being OLSR is a proactive type of protocol which is designed for mobile ad hoc networks and this protocol distributes topology information over entire network whereas GRP is position based hybrid routing protocol that divide networks into zones and it transmits the messages to geographic location in the place of network address. TORA has the maximum average delay among these five protocols followed by DSR. The reason is that TORA is a source initiated on demand routing protocol whose main objective is to limit control message propagation in the highly dynamic mobile computing environment and thus can have multi path routing without loop as information could not sent from bottom up approach whereas the working behavior of DSR is more or less alike to AODV like it forms a path only when it is required and uses the two main mechanism, "route discovery" and "route maintenance". Source routing is used instead of routing table at each neighbor node. AODV has a medium average delay as compared with other four protocols. Since OLSR has lowest average delay so is concluded that performance of OLSR is better than other routing protocol with respect to average delay in this network.

### B. Network Load

This static is the second essential performance metric considered for performance evaluation in this paper. It is dimensioned statics as it measures the separate network load for each Basic Server Set (BSS) and represents whole WLAN BSS overall data traffic in terms of bits/sec.

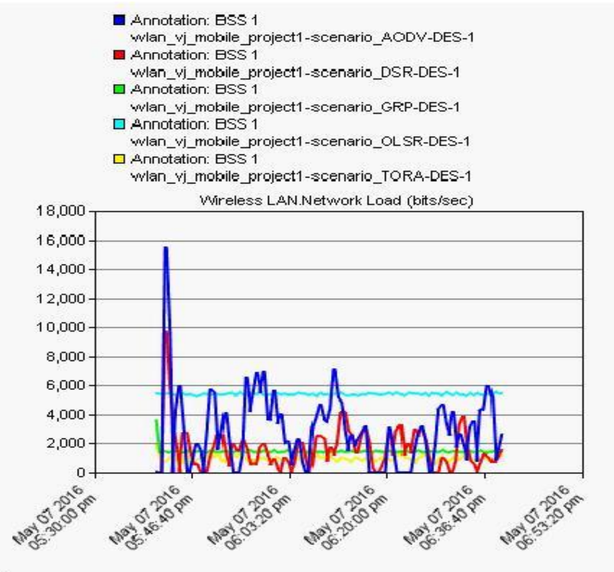


**Fig. 17 Network Load of Wireless LAN in BSS1 (As is)**

Fig. 17 and Fig. 19 just shows network load of wireless LAN in BSS1 and BSS2 respectively however according to Fig. 18 and Fig. 20, it is observed that average network load (BSS1 and BSS2) are least for TORA followed by GRP and DSR while OLSR have the highest average network load followed by AODV. However AODV start with a minimum value of 0 but reaches the maximum value of 15509 bits/Sec (for BSS1) and 19223 bits/Sec (for BSS2) maintaining the average of 2674 bits/Sec (BSS1) and 3634 bits/Sec (BSS2). OLSR is stable as compared to other protocol but have the highest average network load as it is a proactive type of protocol which is designed for mobile ad hoc networks and this protocol distributes topology information over entire network. This concludes that TORA has lowest average network load.

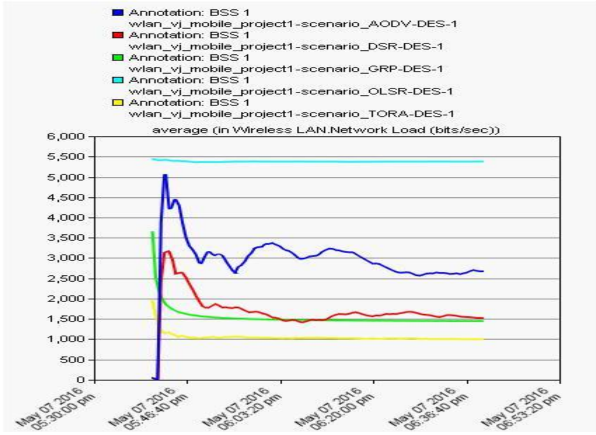


**Fig. 18 Average Wireless LAN Network Load BSS1**

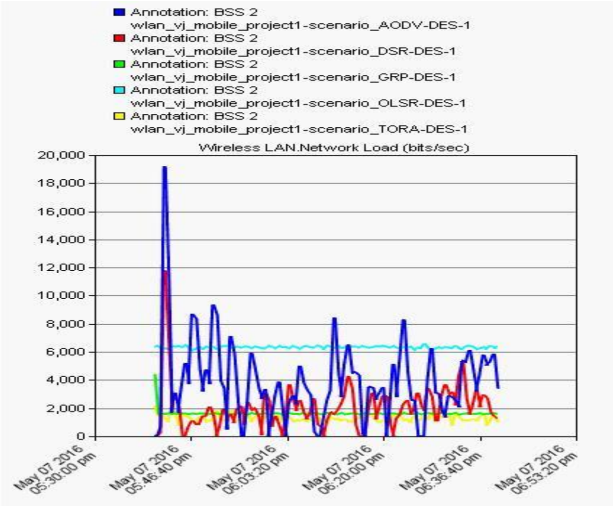


**Fig. 19 Network Load of Wireless LAN in BSS2 (As is)**

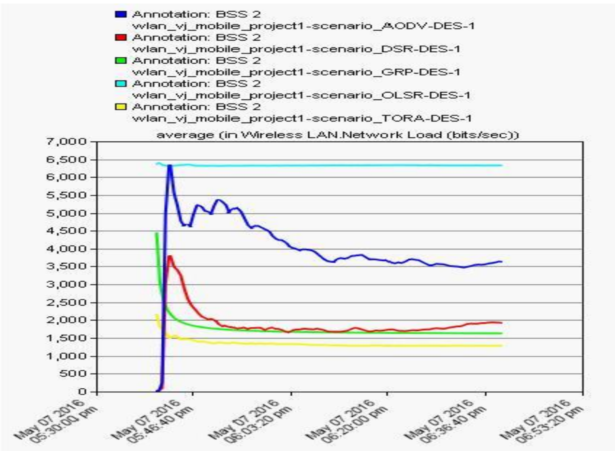


**Fig. 20 Average Network Load of Wireless LAN in BSS2**

### C. Throughput

Throughput is third and most important performance metric that is considered for measuring the performance of the network. It is significant as it measures how much data actually travel within network from wireless LAN layers to higher layers in bits/sec.

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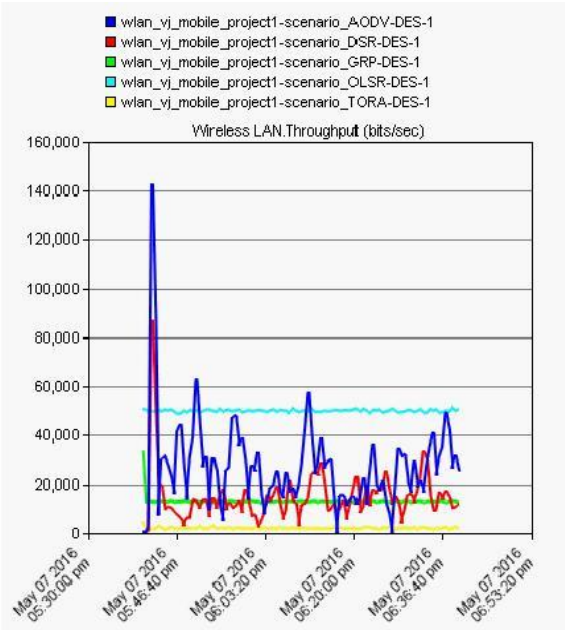


**Fig. 21 Throughput of Wireless LAN (As is)**

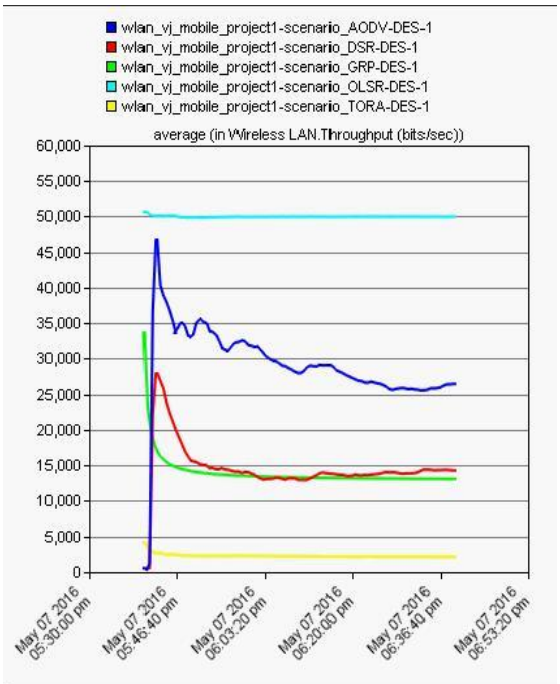


**Fig. 22 Average Throughput of Wireless LAN**

As seen in Fig. 21 and Fig. 22, OLSR has the highest average throughput, followed by AODV and DSR. TORA has the lowest average throughput, followed by GRP. However AODV starts with minimum throughput value of 0 bits/Sec and rises to maximum value of 143065 bits/Sec but average throughput is 26468 bits/Sec that is lower than OLSR that have the highest average of 49,985 bits/Sec. OLSR is stable as compared to other protocols as it is a proactive type of protocol which is designed for mobile ad hoc networks and this protocol distributes topology information over entire network. However, AODV incorporates the advantage of two main mechanisms that is “route discovery” and “route maintenance” and also uses sequence number, the hop by hop routing and periodic beacons. Based on the results, it is observed that OLSR has the highest average throughput. Table II lists the results that show, OLSR gives high throughput and less delay, however TORA gives lowest network load as compared to other protocols.

## VI. CONCLUSION

This paper is a study based simulation and experimental paper. In this paper, an outline of the present and future interrelated technologies are given, a study is done to identify the important and most effective parameters, metrics, factors and issues of Ad hoc Network and then simulation and implementation of five protocols and their comparison are done using important parameter metrics identified in this study for wireless fixed and mobile nodes in Ad Hoc Network. Such a comparative study provides help to network operator and mobile application developers to make decisions on selecting the suitable routing protocols to optimize the network performance that helps to enhance the end user experience. The simulation results indicate that OLSR is the optimal performance protocol as compared to AODV, OLSR, DSR and GRP for the proposed simulation environment. **Table 4 Summery of Simulation Result**

Future enhancement of this work will be to simulate the same protocol in multi-hop network in the Ad Hoc cloud network so as check the performance of these protocols in the Ad hoc cloud environment and it would be important to increase the utilization of the underutilized resources or infrastructure of an organization. Further enhancement can be done by combining the IoT to these technologies so that prediction can be done based on the analysis and this will help to design smart technologies and smart cities.

| **Delay of Wireless LAN in terms of sec** | | | |
|---|---|---|---|
| **Protocol** | **Average** | **Maximum** | **Minimum** |
| AODV | 0.0017095 | 0.0034195 | 0.0002688 |
| DSR | 0.0021693 | 0.0049861 | 0.0002688 |
| TORA | 0.0045971 | 0.0061866 | 0.0043587 |
| OLSR | 0.0010409 | 0.0010614 | 0.0010264 |
| GRP | 0.0010376 | 0.0037581 | 0.0009911 |
| **Network Load of Wireless LAN in BSS1 in terms of bits/sec** | | | |
| **Protocol** | **Average** | **Maximum** | **Minimum** |
| AODV | 2,674 | 15,509 | 0 |
| DSR | 1,523.2 | 9,726.2 | 0.0 |
| TORA | 1,005.9 | 1,968.0 | 640.0 |
| OLSR | 5,379.6 | 5,525.3 | 5,226.7 |
| GRP | 1,444.6 | 3,663.6 | 1,368.9 |
| **Network Load of Wireless LAN in BSS2 in terms of bits/sec** | | | |
| **Protocol** | **Average** | **Maximum** | **Minimum** |
| AODV | 3,634 | 19,228 | 0 |
| DSR | 1,923 | 11,831 | 0 |
| TORA | 1,277.8 | 2,180.4 | 720.0 |
| OLSR | 6,327.1 | 6,609.8 | 6,101.3 |
| GRP | 1,629.2 | 4,449.3 | 1,540.0 |
| **Throughput of Wireless LAN in terms of bits/sec** | | | |
| **Protocol** | **Average** | **Maximum** | **Minimum** |
| AODV | 26,468 | 143,065 | 0 |
| DSR | 14,279 | 87,554 | 184 |
| TORA | 2,156.5 | 4,408.0 | 1,573.3 |
| OLSR | 49,985 | 51,298 | 48,661 |
| GRP | 13,102 | 33,770 | 12,418 |

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