Implementation and Performance Analysis of Multi Hop Ad Hoc Cloud Network and Servers using Ad Hoc Network Protocols

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Abstract*: *Wireless technologies such as Ad hoc network and cloud network are popular in the present era, so is the emerging technology ad hoc cloud is gaining popularity. This article implements the ad hoc network that runs the cloud services that is termed as Ad hoc cloud. To implement this concept, five adhoc network protocols used are TORA, DSR, AODV, GRP and OLSR. Performance of the network as well as the applications are monitored and analyzed and based on the results, an optimal solution is proposed. Optimized Network Engineering Tool is used to perform the simulations.

Index Terms*: *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 [1] is a wireless network that configures itself and does not need any centralized infrastructure network. Each node acts as a router and forward data for the other nodes and so the network is called as 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 access point manages data communication among other nodes.

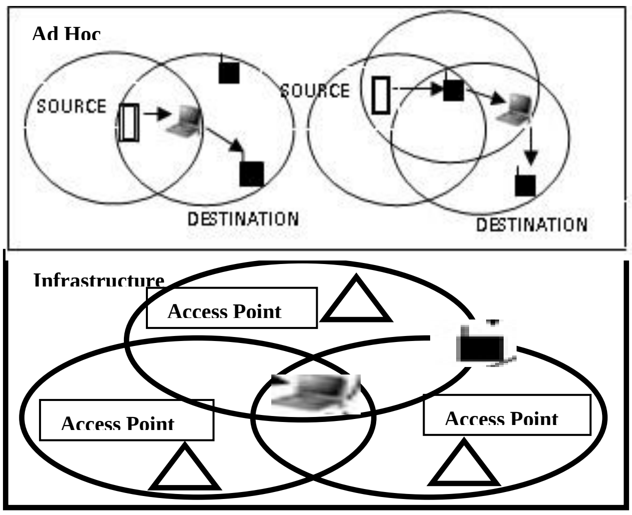

Fig.1 Ad Hoc Network vs. Infrastructure network

Fig. 1 shows simple examples of wireless network. Ad hoc network has no access point however it sends its packet vie nodes in its range that will work as router from source to destination to route the packet. On the other hand, infrastructure wireless network, access point is required for packet transmission from source to destination.

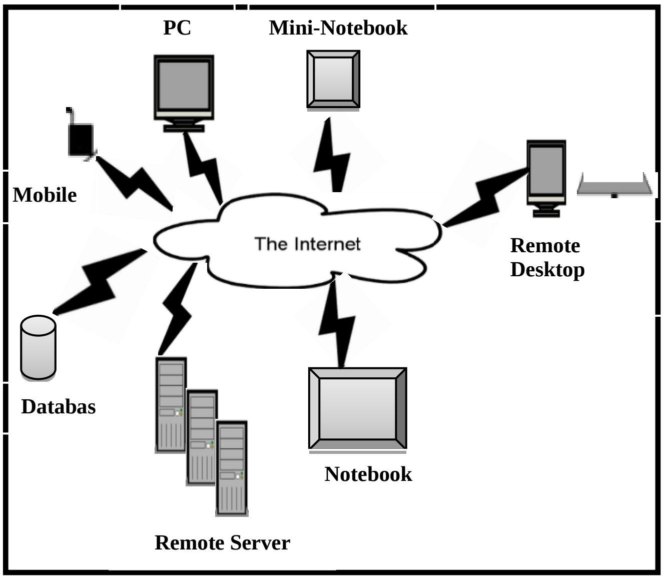

Fig.2 Computer network representing internet as a cloud

Fig. 2 shows the diagram of computer network representing internet as a cloud [2]. NIST defines cloud computing as a model that allows on-demand easy network access to share various computer components and resources, services application, storage, networks etc. that can be provided to the user with minimum management effort.

When cloud services are allowed to run on existing heterogeneous hardware, it is known as ad hoc cloud [3]. In other words when cloud services runs on ad hoc network then it is termed as ad hoc cloud. General purpose computers and hardware devices utilization is increased by using this concept. Architecture of ad hoc cloud is shown in Fig. 3 in which organizational infrastructure are the end user infrastructure that consists of ad hoc hosts, ad hoc guests (VM), ad hoc clients, and cloudlets. Tasks such as host processes are performed by ad hoc hosts whereas protection for host and guest processes while executing cloud tasks are offered by virtual machines known as ad hoc guests. Ad hoc guests also reap and utilize every host's unused resources. Set of connected ad hoc guests known as cloudlets are the mobile data centers within the organizational

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infrastructure that provides execution environment and a particular service. All cloud jobs are submitted to the ad hoc cloud platform by the cloud users that are further sent to the suitable cloudlet for execution.

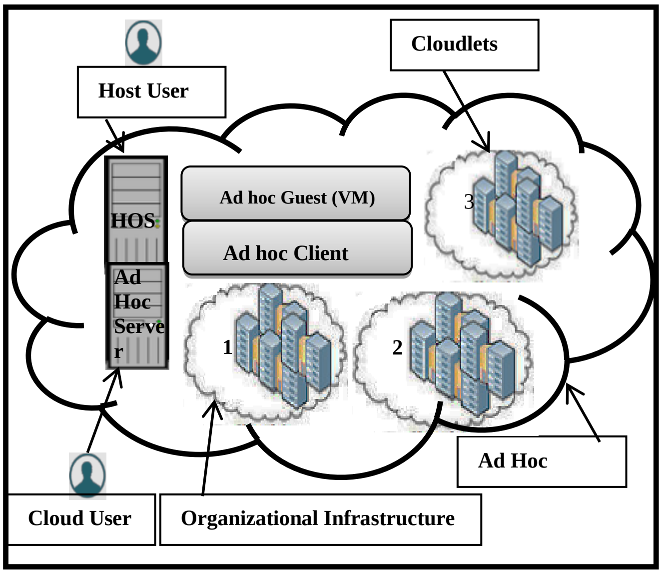

Fig.3 Architecture of the ad hoc cloud

Table I Advantages of ad hoc cloud

Advantages of Ad Hoc Cloud
Number of machines need to be purchased are reduced
Hardware costs are reduced
Infrastructural costs are reduced
Overall power consumption is reduced
Data are managed easily
Data recovery and disaster management is easy

As shown in Fig. 3, 1,2 and 3 are cloudlets which in turn is the part of organizational infrastructure, it is depicted that there may be several cloudlets that several ad hoc hosts can deploy it. As depicted in the figure above cloudlet members are not co-located rather are to be distributed across an infrastructure. However, a host may either be attached to many cloudlets or devoted to a single cloudlet to allow applications from different domains to run simultaneously upon the same host. It has various advantages are given in Table I.

II. LITERATURE REVIEW

Bhardwaj et al. in 2012 [4] performed performance analysis using OPNET 14.5 modeler using performance metrics such as network load (bits/sec or packet/sec), media access delay and throughput of OLSR and AODV. Based on their performance evaluation analysis OLSR have better performance than AODV.

Goya et al. in 2013 [5] have used routing protocol TORA and GPR and performance metrics Jitler, Packet , network load, delay variation, voice traffic sent, voice traffic received, data dropped and throughput based on Database and Voice Data. According to their result, TORA is best performance routing protocol in terms of performance metrics packet delay variation, network load, Jitler packet, voice traffic sent, voice traffic received and data dropped and GRP is best in terms of performance metric throughput.

Mehmood et al. in 2014 [6] used various performance parameters such as pause time, nodes speed and number of nodes and considered various quantitative performances metric such as throughput, network load, retransmission attempts and media access delay. Routing protocols that were used in this study namely TORA, OLSR and GRP. Based on the analysis result performance of OLSR were outstanding in terms of network density, pause time and network speed and throughput. In terms of retransmission attempt and media access delay, TORA perform better than OLSR and GRP.

Rana et al. in 2015 [7] analyzed the performance of five protocols namely Ad hoc On-Demand Multipath Distance Vector (AOMDV), AODV, Power Aware Ad hoc On-Demand Distance Vector (PAAODV), DSR and DSDV. Four performances metric were used such as Packets delivery ratio, throughput, energy conservation and average delay. Based on their work, they concluded that DSR perform better than other protocols with respect to end to end delay and packet delivery ratio, performance of AODV was better in terms of throughput, performance of PAAODV was better in terms of residual energy.

Aneiba and Melad in 2016 [8] considered parameters such as simulation time, number of nodes, simulation area, data rate, mobility model, and application. The protocols that were analysed namely AODV, DSR, OLSR and GRP under two different scenarios (20 and 80 mobile nodes) and the performance metric that were used namely delay and throughput under FTP traffic condition. The result showed that OLSR out performs as compared to AODV, GRP, and DSR in terms of throughput and delay under heavy FTP traffic.

In the articles mentioned above, the authors have discussed the performance of network only and that too for ad hoc network. There are various other authors also who have done related work, however this work is different as in this article implementation of multi-hop ad hoc cloud network is done with cloud server and server performance is also considered.

III. METHODOLOGY AND SIMULATION ENVIRONMENT

In this article implementation of multi-hop ad hoc cloud network is done using AODV, OLSR, DSR, TORA and GRP protocols of ad hoc network using cloud servers and the performance of network and servers are monitored and analyzed. Optimized Network Engineering Tool (OPNET Modeler 14.5) is used for simulating the scenarios.

There are five scenarios, each implemented with above listed five different protocols. Each scenario consists of four subnets named subnet_Bangkok, subnet_Sydney, subnet_Tokyo and India_Head_Office as shown in Fig. 4.

First three subnets consist of 50 nodes each as shown in Fig. 5 however India_Head_Office consist of only five ad hoc cloud servers named database, email, HTTP, FTP and print servers as shown in Fig. 6. In this proposed architecture model servers as well as clients both are in ad hoc mode using different ad hoc routing protocol.

Simulation runs for 160 seconds. The global statics considered here in this experiment for monitoring the server performances are mentioned in Table II and

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for network performance is mentioned in Table III.

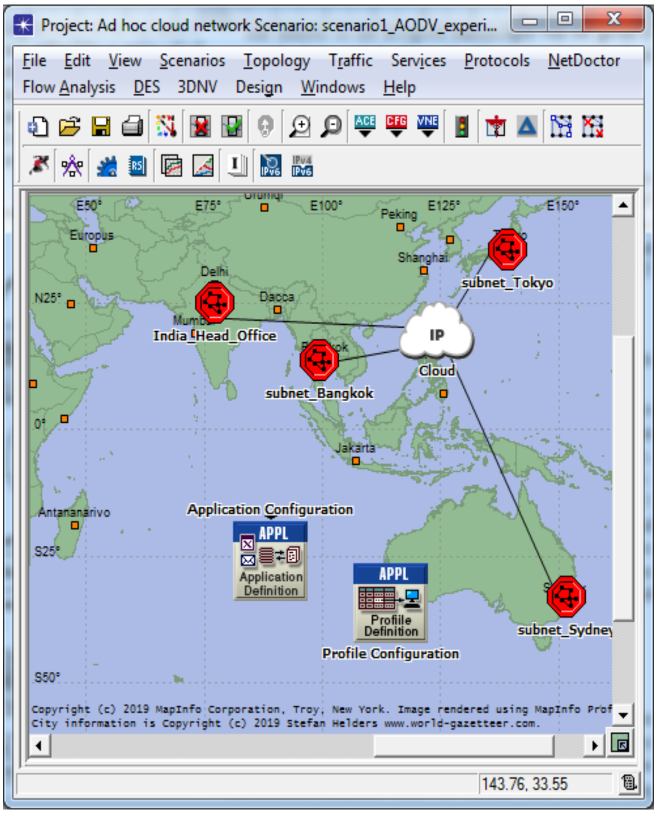

Fig.4 The Ad Hoc Cloud multi-hop network simulation environment with four subnets.

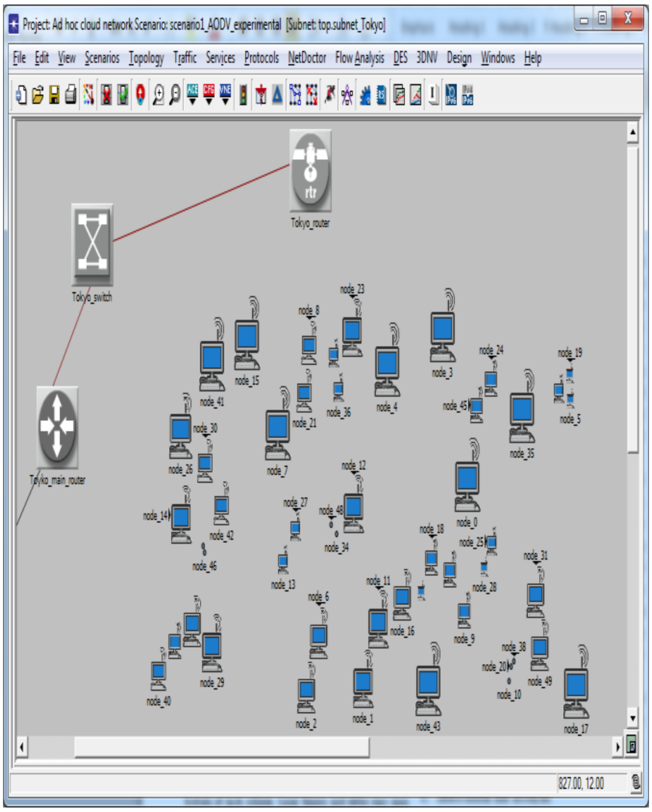

Fig.5. Three subnets with 50 nodes each

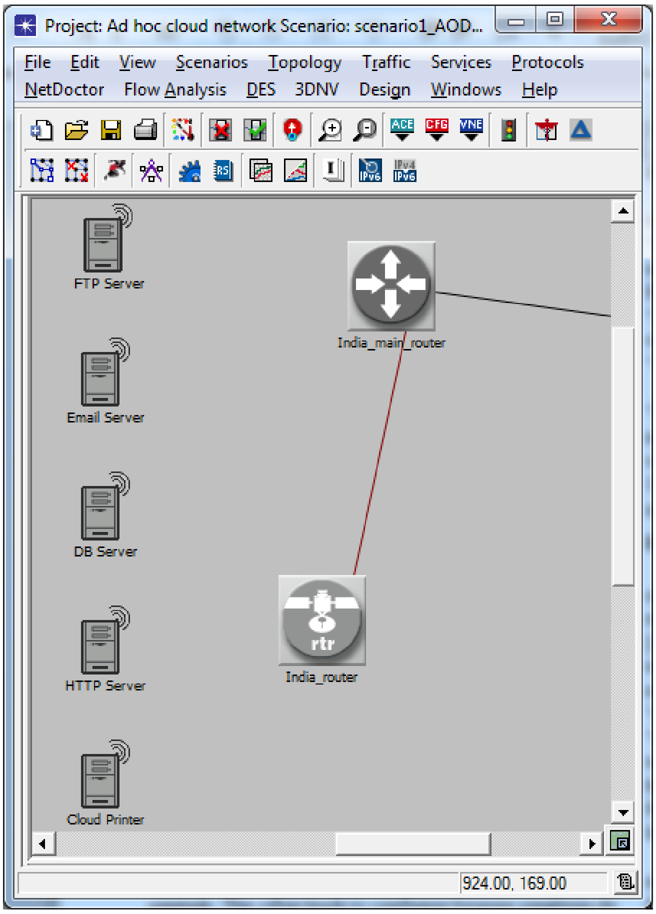

Fig.6. Five ad hoc cloud servers in India_Head_Office subnet

Table II Global statics with their parameters and metric

Global Statics	Parameters and Metric
Email	Traffic received , Traffic sent (bytes per second), Upload Response time ,Download Response Time
DB Query	Traffic received , Traffic sent (bytes per second), Response time
HTTP	,Traffic received, Traffic sent (bytes per second), Page Response time, Object Response time
Print	Traffic received, Traffic sent (bytes per second)
FTTP	Traffic received, Traffic sent (bytes per second), Upload Response time, Download Response time.

Table III Global statics with their parameters and metric

Global Statics	Parameters and Metric
Wireless LAN	Delay, Load, Throughput

IV. RESULTS AND DISUSSIONs

A. Server Performance

The first global static considered in this work to monitor and analyze the performance of DB application is DB Query. According to fig 7, 8, 9 and Table IV, DSR performs best for DB applications compared to other four protocols as its average response time is 0.053595(sec), minimum is 0.050368(sec), and maximum is 0.061954(sec). Also traffic sent and traffic received both are same in case of DSR.

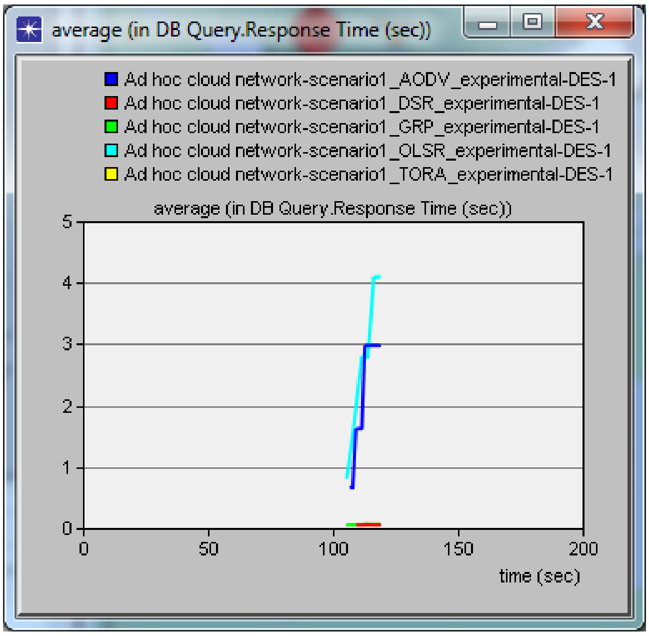

Fig.7. Average response time (sec) of DB Query

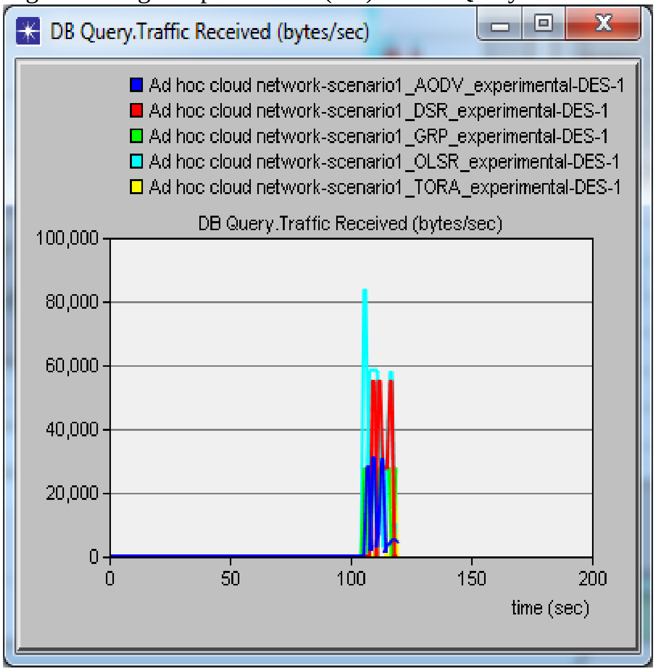

Fig. 8. Traffic received(bytes/sec) of DB Query

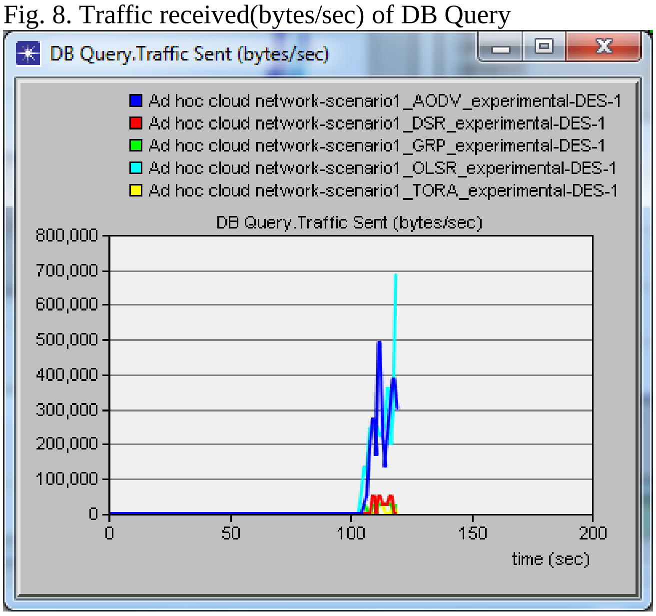

Fig. 9. Traffic sent(bytes/sec) of DB Query

Table IV DB Query Summary

DB Query	Metric and Parameters					
Protocol	**Response Time(sec)**		**Traffic received(byte/sec)**		**Traffic sent(byte/sec)**	
AODV	Avg	2.9757	Avg	1,250	Avg	28,036
	Min	0.6663	Min	0	Min	0
	Max	5.6841	Max	31,573	Max	498,773
DSR	Avg	0.053595	Avg	2,496	Avg	2,496
	Min	0.050368	Min	0	Min	0
	Max	0.061954	Max	55,467	Max	55,467
GRP	Avg	0.059301	Avg	1,946	Avg	2,219
	Min	0.050421	Min	0	Min	0
	Max	0.093895	Max	28,160	Max	28,160
OLSR	Avg	4.0962	Avg	4,326	Avg	32,951
	Min	0.8189	Min	0	Min	0
	Max	8.6620	Max	84,053	Max	691,627
TORA	Avg	0.051727	Avg	832	Avg	832
	Min	0.051400	Min	0	Min	0
	Max	0.052311	Max	27,733	Max	27,733

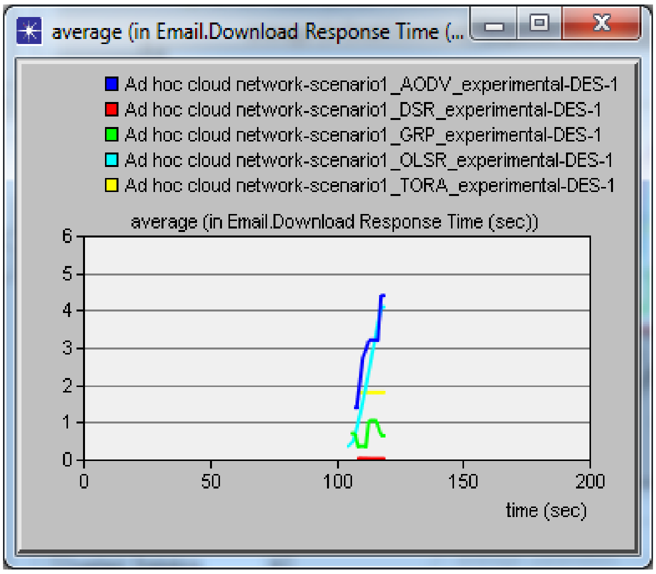

Fig.10. Average downloads response time (sec) of email

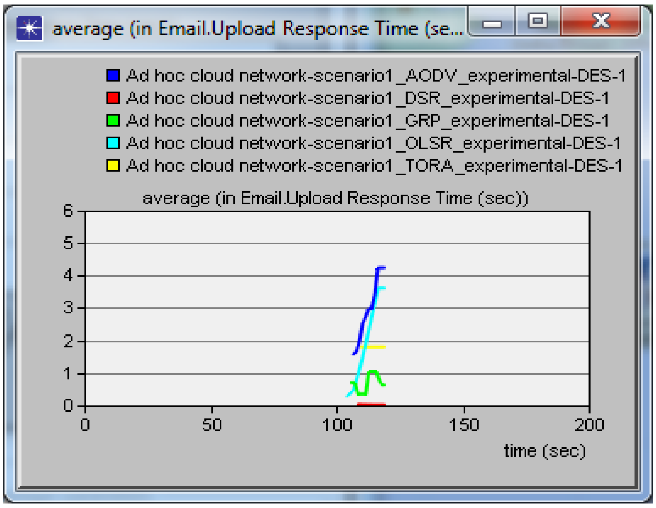

Fig.11. Average email uploads response time (sec)

Table V Email Summary

Email Protocol	Metric and Parameters							
	Upload Response Time(sec)		Download Response Time(sec)		Traffic received(byte/sec)		Traffic sent(byte/sec)	
AODV	Avg	4.2340	Avg	4.394	Avg	3,143	Avg	6,061
	Min	1.5911	Min	1.390	Min	0	Min	0
	Max	9.8683	Max	10.365	Max	58,467	Max	85,147
DSR	Avg	0.017014	Avg	0.019038	Avg	501	Avg	501
	Min	0.012136	Min	0.014004	Min	0	Min	0
	Max	0.026350	Max	0.028605	Max	20,053	Max	20,053
GRP	Avg	0.6286	Avg	0.6293	Avg	501	Avg	0.3333
	Min	0.0107	Min	0.0126	Min	0	Min	0
	Max	2.4131	Max	2.4093	Max	10,027	Max	6.6667
OLSR	Avg	3.6115	Avg	4.0827	Avg	6,167	Avg	9,972
	Min	0.3153	Min	0.3648	Min	0	Min	0
	Max	8.3426	Max	8.6640	Max	78,520	Max	125,200
TORA	Avg	1.7973	Avg	1.7976	Avg	100	Avg	100
	Min	1.7973	Min	1.7976	Min	0	Min	0
	Max	1.7973	Max	1.7976	Max	10,027	Max	10,027

Table VI HTTP Summary

HTTP Protocol	Metric and Parameters							
	Object Response Time(sec)		Page Response Time(sec)		Traffic received(byte/sec)		Traffic sent(byte/sec)	
AODV	Avg	2.0737	Avg	3.603	Avg	1,289	Avg	2,025
	Min	0.0827	Min	0.801	Min	0	Min	0
	Max	8.4566	Max	10.477	Max	31,527	Max	40,192
DSR	Avg	0.0064017	Avg	0.016080	Avg	376	Avg	376
	Min	0.0045920	Min	0.010235	Min	0	Min	0
	Max	0.0082536	Max	0.023108	Max	14,572	Max	14,572
GRP	Avg	0.010853	Avg	0.5560	Avg	366	Avg	366
	Min	0.004108	Min	0.0088	Min	0	Min	0
	Max	0.016734	Max	2.1089	Max	14,408	Max	14,408
OLSR	Avg	2.2873	Avg	4.187	Avg	3,924	Avg	4,898
	Min	0.1325	Min	0.386	Min	0	Min	0
	Max	5.2327	Max	10.179	Max	48,022	Max	68,652
TORA	Avg	0.0064115	Avg	0.013795	Avg	79.1	Avg	79.1
	Min	0.0064115	Min	0.013795	Min	0	Min	0
	Max	0.0064115	Max	0.013795	Max	7,907.5	Max	7,907.5

Table VII FTP Summary

FTP Protocol	Metric and Parameters							
	Upload Response Time(sec)		Download Response Time(sec)		Traffic received(byte/sec)		Traffic sent(byte/sec)	
AODV	Avg	3.3440	Avg	0	Avg	540	Avg	25,553
	Min	3.3440	Min	0	Min	0	Min	0
	Max	3.3440	Max	0	Max	42,947	Max	587,173
DSR	Avg	0.080883	Avg	0.080514	Avg	2,105	Avg	2,105
	Min	0.079669	Min	0.080402	Min	0	Min	0
	Max	0.081946	Max	0.080626	Max	84,187	Max	84,187
GRP	Avg	0.084629	Avg	0.11520	Avg	1,267	Avg	2,100
	Min	0.084629	Min	0.08044	Min	0	Min	0
	Max	0.084629	Max	0.14997	Max	42,093	Max	83,760
OLSR	Avg	2.2324	Avg	6.3146	Avg	1,871	Avg	42,760
	Min	1.3551	Min	2.8485	Min	0	Min	0
	Max	3.1096	Max	9.7807	Max	44,227	Max	587,173
TORA	Avg	0.079796	Avg	0	Avg	421	Avg	421
	Min	0.079796	Min	0	Min	0	Min	0
	Max	0.079796	Max	0	Max	42,093	Max	42,093

Table VIII Print Summary

Print Protocol	Metric and Parameters			
	Traffic received(byte/sec)		Traffic sent(byte/sec)	
AODV	Avg	1,195	Avg	18,011
	Min	0	Min	0
	Max	69,702	Max	300,752
DSR	Avg	1,477	Avg	1,477
	Min	0	Min	0
	Max	52,898	Max	52,898
GRP	Avg	1208	Avg	1208
	Min	0	Min	0
	Max	51,091	Max	51,091
OLSR	Avg	4,016	Avg	28,913
	Min	0	Min	0
	Max	74,732	Max	412,432
TORA	Avg	259	Avg	259
	Min	0	Min	0
	Max	25,918	Max	25,918

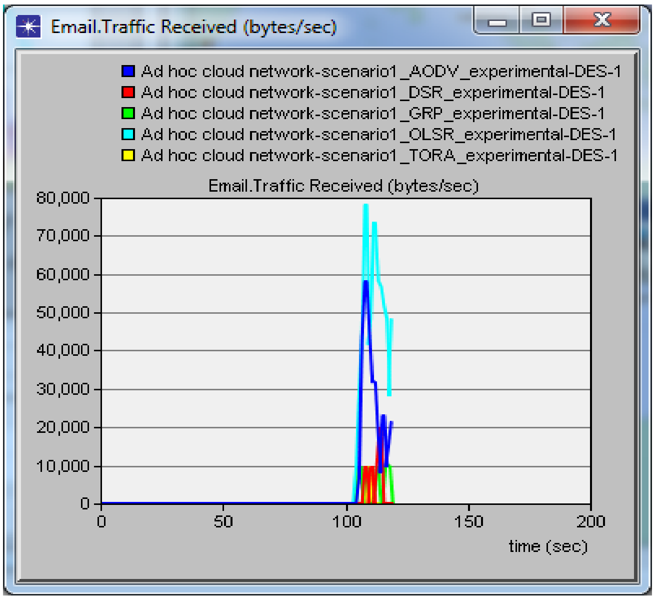

Fig. 12. Email Traffic received(bytes/sec)

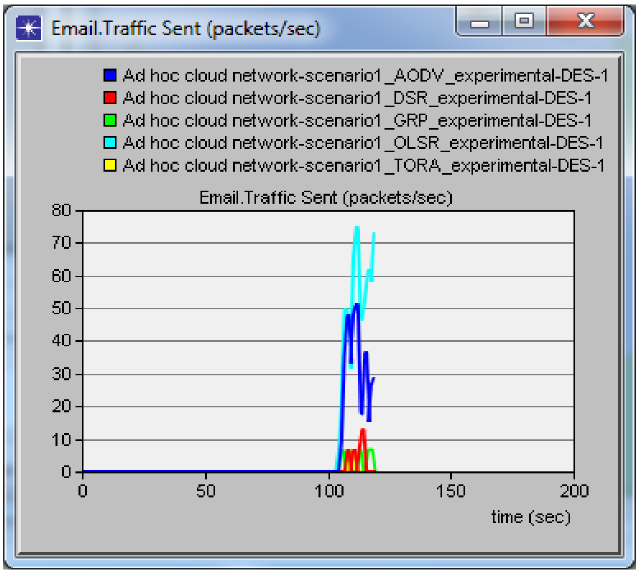

Fig. 13. Email Traffic sent(bytes/sec)

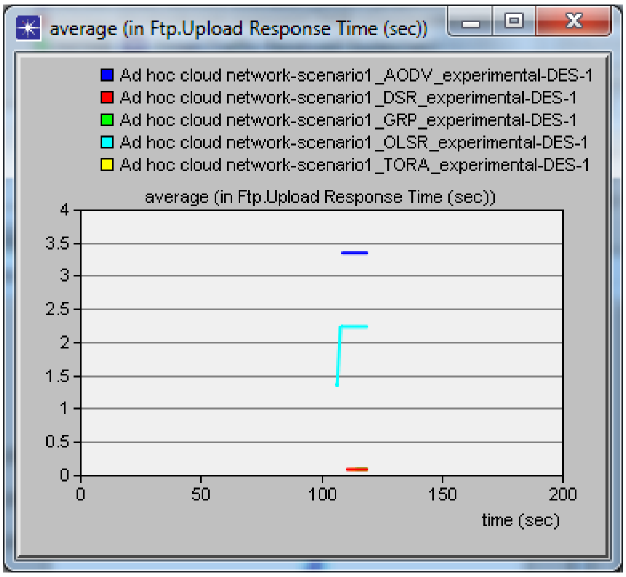

Fig.14. Average FTP upload response time (sec)

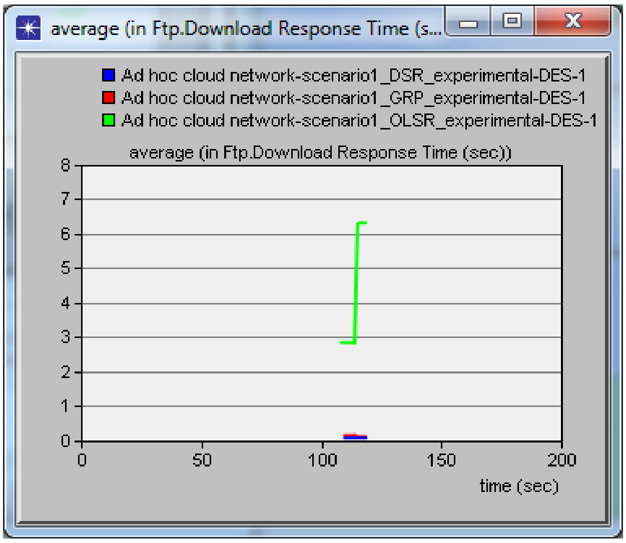

Fig.15. Average FTP download response time

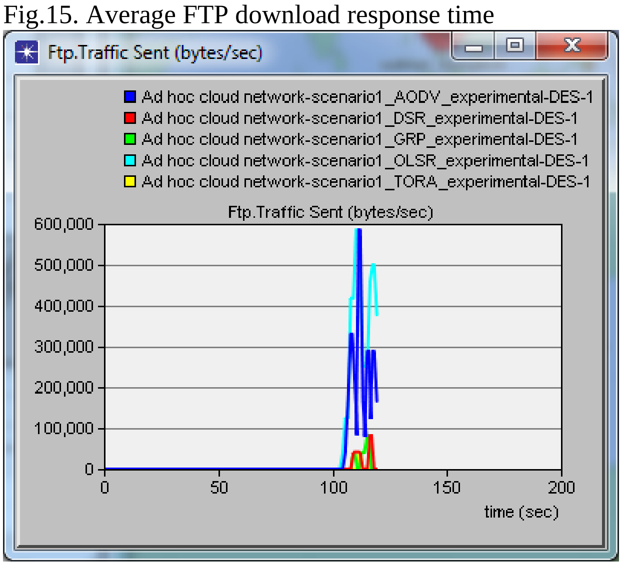

Fig. 16.FTP Traffic sent(bytes/sec)

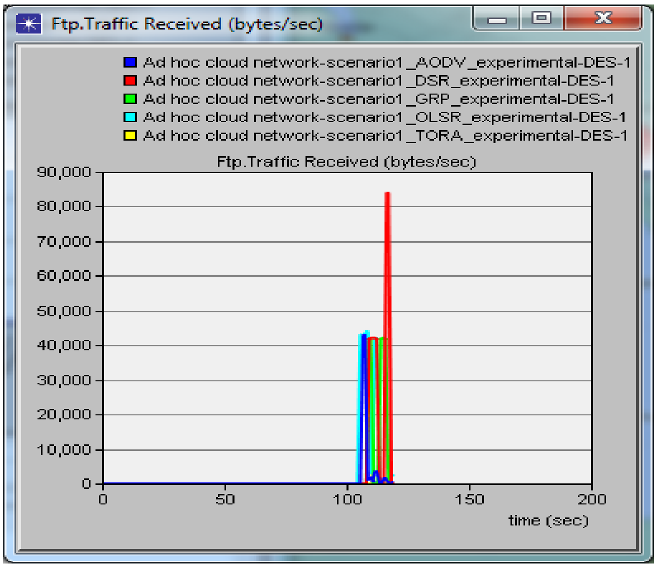

Fig. 17. FTP Traffic received(bytes/sec)

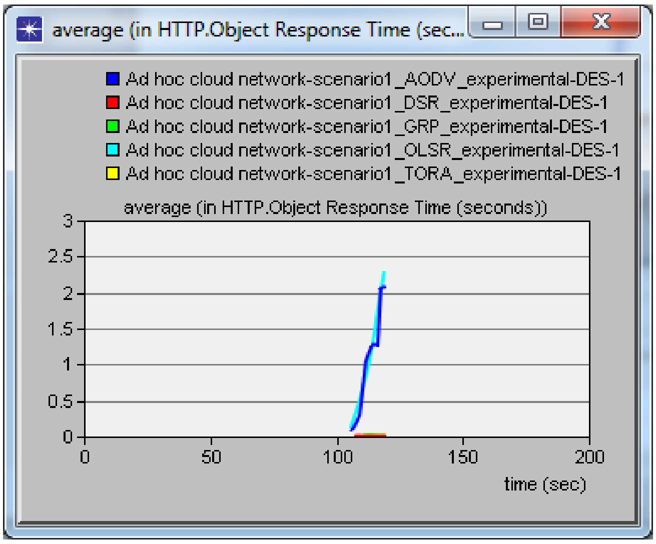

Fig. 18 HTTP object response time

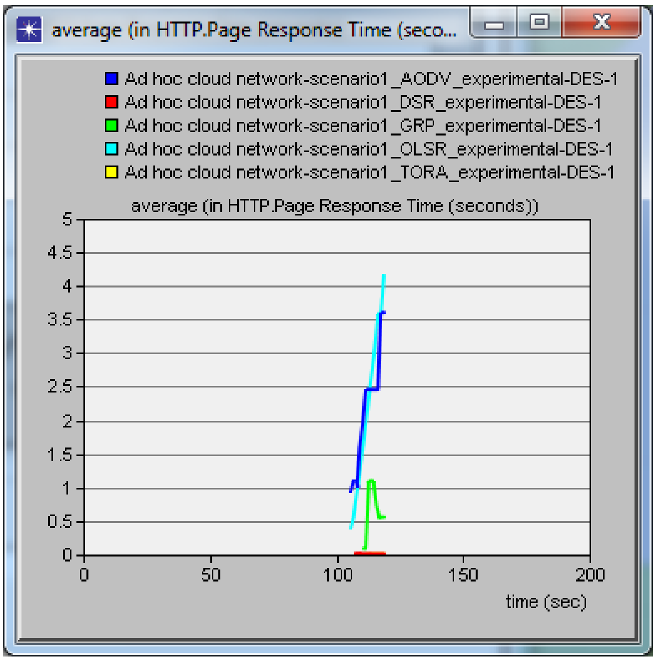

Fig.19. Average HTTP page response time

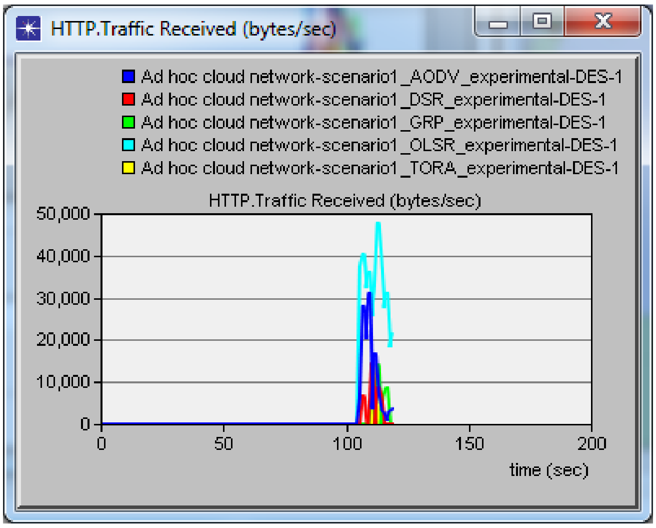

Fig. 20. HTTP Traffic received(bytes/sec)

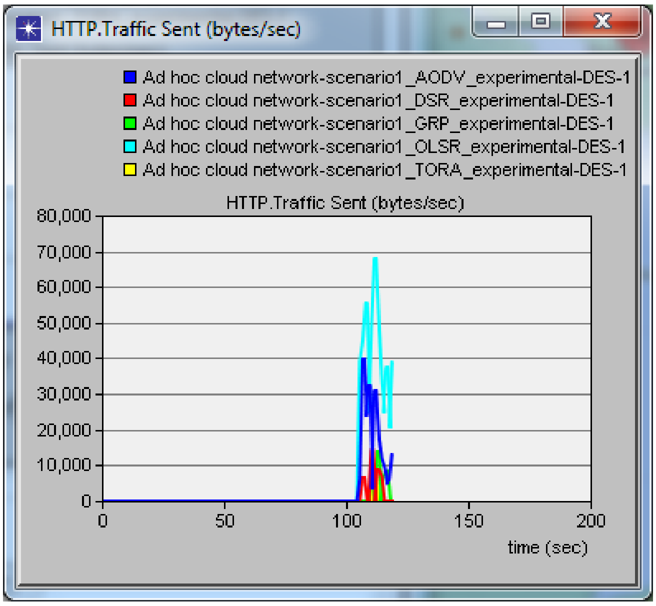

Fig. 21. HTTP Traffic sent(bytes/sec)

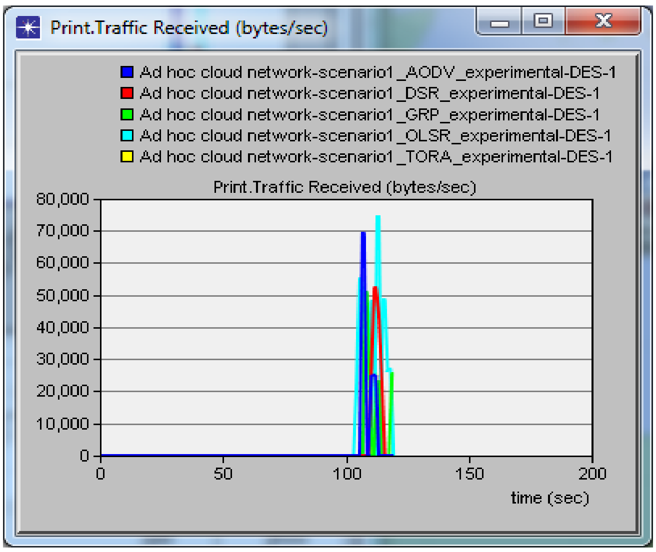

Fig. 22. Print Traffic received(bytes/sec)

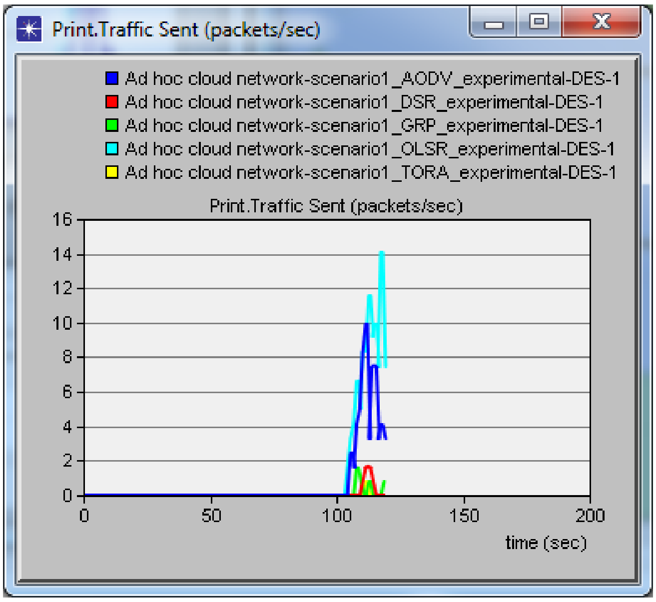

Fig. 23. Print Traffic sent(bytes/sec)

In case of Email application also DSR perform best as it is observed from fig. 10,11,12, 13 and Table V. Average Upload response time of DSR is 0.017014 sec, with maximum value 0.026350 sec and minimum value 0.012136 sec that is least as compaired to other protocols.

Similarly DSR performs best for the other three applications namely HTTP, FTP and print applications according to fig. 14 to fig. 23 and Table VI,VII, VIII.

So DSR is the best routing protocol for these application performance and the reason being that DSR is specially designed for multi-hop wireless network or ad hoc network that is efficient yet simple. The two main mechanism that forms this protocol are "route discovery" and "route maintenance" .

A. Network Performance

Network performance in this article is analyzed by considering wireless LAN delay, load and throughput. According to the fig. 24, 25, 26 and Table IX AODV performs best as the average throughput of AODV is 6,510,929 bits/sec with maximum throughput 97,235,213 bits/sec and minimum 0 bits/sec.

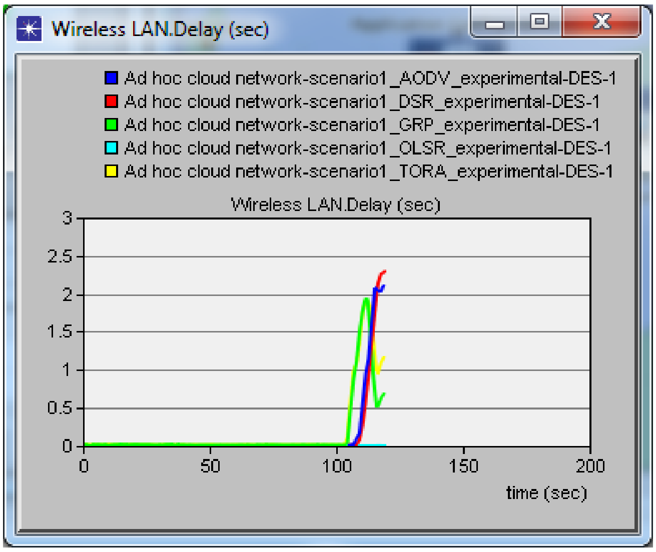

Fig. 24. Wireless LAN delay(sec)

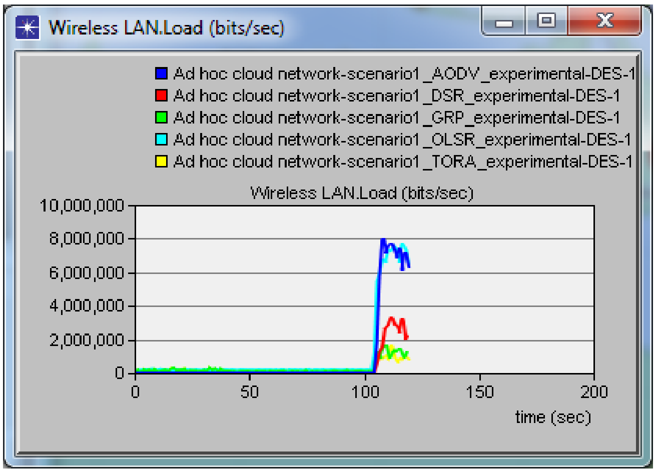

Fig. 25. Wireless LAN load (bits/sec)

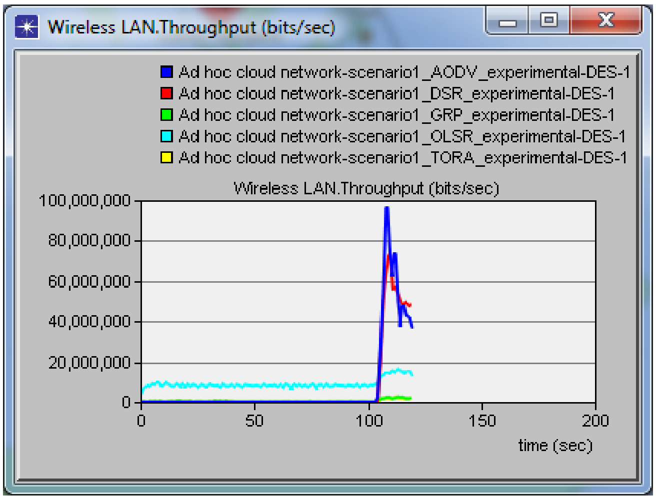

Fig. 26. Wireless LAN throughput (bits/sec)

Table IX Wireless LAN Summary

Wireless LAN	Metric and Parameters					
Protocol	Delay(sec)		Load(bits/sec)		Throughput(bits/sec)	
AODV	Avg	0.9954	Avg	797,487	Avg	6,510,929
	Min	0.0061	Min	0	Min	0
	Max	2.1323	Max	8,031,107	Max	97,235,213
DSR	Avg	0.9101	Avg	280,518	Avg	6,232,988
	Min	0.0069	Min	0	Min	0
	Max	2.2901	Max	3,338,093	Max	73,374,747
GRP	Avg	0.1368	Avg	239,955	Avg	440,103
	Min	0.0021	Min	11,733	Min	26,667
	Max	1.9586	Max	1,691,220	Max	2,511,200
OLSR	Avg	0.000282	Avg	986,169	Avg	9,071,899
	Min	0.000223	Min	75,467	Min	3,721,733
	Max	0.001336	Max	7,731,313	Max	16,280,853
TORA	Avg	0.1652	Avg	197,218	Avg	381,136
	Min	0.0087	Min	13,333	Min	2,519,540
	Max	1.9311	Max	1,640,607	Max	18,800

However delay is least in case of OLSR as the average delay of OLSR is 0.000282 sec with maximum 0.001336 sec and minimum 0.000223 sec.

DSR performance is near about same as AODV as the average throughput of DSR is 6,232,988 bits/sec with maximum throughput 73,374,747 bits/sec and minimum 0 bits/sec. The reason for AODV and DSR being better in terms of throughput than OLSR is because they are on-demand routing protocol. However AODV performs better than DSR in throughput as it incorporates the advantage of two main mechanis that are “route discovery” and “route maintenance” and also uses sequence number, the hop by hop routing and periodic beacons .

V. CONCLUSION

Five cloud servers named HTTP, Email, FTP, database and print servers using three on-demand protocols named DSR, AODV and TORA, one proactive protocol named OLSR and a hybrid protocol named GRP is used in multi-hop ad hoc cloud network. This network is implemented and the performance of applications as well as network, both are monitored and analyzed. Based on this experimental implementations, its graphs and result it is concluded that application performs best in case of DSR and network perform best in case of AODV, however the optimal solution to implement this ad hoc cloud architecture is DSR as application also performs best and network is better as compared to other three protocols.

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