Performance Study of AODV, GRP and OSPFv3 MANET Routing Protocols Using OPNET Modeler

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ABSTRACT
A Mobile Ad hoc Network (MANET) is a collection of mobile nodes, that forms on the fly a temporary wireless multi-hop network in a self-organizing way, without relying on any established infrastructure. In MANET, a pair of nodes exchange messages either over a direct wireless link, or over a sequence of wireless links including one or more intermediate nodes. For this purpose, an efficient routing protocol is required. This paper introduced performance study of three of MANET protocols (AODV, GRP and OSPFv3). This study was one of the newer studies because wireless communication played an important role in today's application and the field of mobile ad hoc network becomes very popular for the researchers in the last years. This study was done using OPNET Modeler v14.5 and the comparison between the protocols was done in terms of throughput, routing traffic received, traffic sent, load and delay with increased number of mobile nodes from 10, 25 and 50 mobile nodes. The results showed that AODV (reactive routing protocol) was better in delay and had smaller load and smaller throughput than GRP (reactive and proactive routing protocols) and OSPFv3 (proactive routing protocols).

Keywords: MANET, routing, traffic, OPNET, load, delay, throughput

دراسة كفاءة بروتوكولات المانيت المتنقلة (AODV, GRP, OSPFv3) باستخدام برنامج المحاكاة الاوبنيت

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الخلاصة
شبكة الـــ (ad hoc) المتنقلة (مانيت) هي مجوعة من العقد المتنقلة التي تشكل في الجو شبكة لاسلكية مؤقتة من الشبكة المتعددة العقد بطريقة ذاتية التنظيم، بدون الاعتماد على أي بنية تحتية ثابتة. في شبكة مانيت فان زوج من العقد تتبادل الرسائل إما على خط لاسلكي مباشر أو سلسلة من الخطوط اللاسلكية متضمنة واحدة أو أكثر من العقد الوسطية. لهذا الغرض فان اتفاقية توجيه كفوء هو المطلوب. يقدم هذا البحث دراسة كفاءة ثلاثة من بروتوكولات المانيت (AODV, GRP, OSPFv3)، وهي واحدة من أحدث الدراسات في الاتصالات اللاسلكية التي تلعب دورا هاما في التطبيقات اليومية وان حقل شبكة الـــ (ad hoc) المتنقلة أصبحت مشهورة كثيرا للباحثين في السنوات الأخيرة. ان هذه الدراسة تمت باستخدام برنامج الOPNET الإصدار (14.5). ان المقارنة تمت بين البروتوكولات من حيث (كمية مرور البيانات بالثانية، توجيه حركة المرور الواردة والمرسلة، الحمل والتأخير الزمني) مع زيادة عدد العقد المتنقلة من 10، 25 و 50 عقدة متنقلة. النتائج أظهرت إن الـــAODV هو أفضل من ناحية التأخير الزمني ويكون الحمل اقل ,و كمية مرور البيانات بالثانية هما الاقل من الـــ GRP والـــ OSPFv3.

الكلمات الرئيسية: MANET (شبكة المحمول المخصصة)، تدوير، المرور، الاوبنيت، الحمل، التأخير، الإنتاجية

1- INTODUCTION

The wireless network can be classified into two types: Infrastructured or Infrastructure less. In Infrastructured wireless networks, the mobile node can move while communicating, the base stations are fixed and as the node goes out of the range of a base station, it gets into the range of another base station. In Ad Hoc wireless network, the mobile node can move while communicating, there are no fixed base stations and all the nodes in the network act as routers. The mobile nodes in the Ad Hoc network dynamically establish routing among themselves to form their own network 'on the fly'. A Mobile Ad hoc Network (MANET) is a collection of mobile nodes, that forms on the fly a temporary wireless multi-hop network in a self-organizing way, without relying on any established infrastructure. This kind of networks can be used in different applications, such as emergency search and rescue operations, communication between soldiers on a battlefield, sharing information in a conference, and data acquisition operations in inhospitable terrains. In MANET, a pair of nodes exchange messages either over a direct wireless link, or over a sequence of wireless links including one or more intermediate nodes. For this purpose, an adaptive routing protocol is required. An efficient MANET's routing protocol must cope with many limitations, related to intrinsic feature of nodes and wireless links, such as: low battery capacity, low bandwidth, high error rates, and time varying channels. Moreover, it must cope with the frequent topology changes engendered by nodes mobility. Therefore, implementing an efficient routing protocol is one of the challenges facing MANETs (Djamel D. et al. , 2006). Nowadays routing is the vital problem while forwarding information from one node to another node in networks (Kiruthika R. et al. , 2010)**.** There are number of MANET routing protocols. This paper introduced performance study of three of MANET routing protocols. There are three classifications of MANET routing protocols (reactive, proactive and hybrid routing protocols). This paper introduced three routing protocols (AODV, GRP and OSPFv3). These protocols were selected because AODV is reactive routing protocol, GRP is hybrid (reactive and proactive routing protocol) and OSPFv3 (proactive routing protocol).

1-1 Paper Outline

The rest of this paper is organized as follows: Section 2 presents related work with this study. Section 3 introduced routing protocol (Link State Routimg) and (Distance Vector Routing). Section 4 presents Mobile Ad Hoc Network and its categories. Section 5 presents introduction to routing protocol simulation. The simulation procedure is described in Section 6 which present the implementation of each of the three protocols taken in this paper (AODV, GRP and OSPFv3). The results are collected and described in section 7 and the results are discussed with the conclusion of this study in section 8.

This simulation study was done using OPNET modeler (v14.5) a suitable tool to study the performance of the three protocols in various scenarios in terms of delay, load throughput, traffic received, sent and other parameters which could be taken for further study.

2- RELATED WORK

Conventional IP based routing protocols are not appropriate for ad hoc mobile networks because of the temporary nature of the network links and additional constraints on mobile nodes i.e. limited bandwidth and power. Routing protocols for such environments must be able to keep up with the high degree of node mobility that often changes the network topology drastically and unpredictably. MANET working group has been formed within the IETF to develop a routing framework for IP based protocols in mobile ad hoc networks. AODV is one such protocol, which is widely established (Nitiket N. et al., 2010). Das et al., have compared two on demand protocols, DSR and AODV. with respect to three key performance metrics: fraction of packets delivery (reliability), the average end-to-end delay, and the routing overhead (Das et al, 2000). Sesay et al. have compared DSDV, DSR, TORA and AODV with respect to end-to-end throughput, delay, control packet overhead and route acquisition time (Sesay et al, 2004). In this regard, Ahn C. W. et al. proposes a simple, but efficient routing protocol in the mobile ad hoc networks. This is (GRP). The aim is to somehow garner the benefits accruing from the short transfer delay of PRP and the small overheads of RRP (Ahn C. W. et al., 2006).

Guangyu P., et al. propose a novel solution which enables OSPFv3 MANET extensions to operate over various IP encryptors (Guangyu P., et al., 2008).

3- ROUTING PROTOCOL

Routing is a process of finding paths between nodes. The new routes are generated based on the factors like traffic, link utilization etc which is aimed at having maximum performance (Cauvery N. K. et al., 2009). Routing protocol is a protocol that specifies how routers communicate with each other, distribute information that enables them to select routes between any two nodes on a computer network, the purposes of routing protocols development are to reduce the time delay, improve the bandwidth usage, reducing power consumption, reduced the packet loss rate, reducing the routing overload, reduce the number of messages exchange and improves throughput. In the last decade many routing algorithms have been developed for traditional wired LANs/WANs and those routing protocols can also be used in ad-hoc networks. Such algorithms generally come under the type of proactive algorithms (Gani1 A. et al., 2011). Routing Methods can be divided into:

- **Link State Routing:** in a link-state algorithm, also called topology-broadcast algorithm, a node must know the entire network topology, shortest path to each network destination (Garcia J.J. et al., 1993).
- **Distance Vector Routing**: In a distance-vector algorithm, a node knows the length of the shortest path from each neighbor node to every network destination, and uses this information to compute the shortest path and next node in the path to each destination (Garcia J.J. et al., 1993).

4- MOBILE AD HOC NETWORK

(MANET) is a collection of wireless mobile nodes forming a temporary/short-lived network without any fixed infrastructure where all nodes are free to move about arbitrarily and where all the nodes configure themselves. In MANET, each node acts both as a router and as a host & even the topology of network may also change rapidly. Some of the challenges in MANET include: unicast routing, multicast routing, dynamic network topology, speed, frequency of updates or network overhead, scalability, mobile agent based routing, quality of service, energy efficient/power aware routing, secure routing. Many protocols have been suggested keeping applications and type of network in view (Taneja S. et al., 2010).

Basically, routing protocols can be broadly classified:

- Table Driven or Proactive Protocols: In Table Driven routing protocols each node maintains one or more tables containing routing information to every other node in the network. All nodes keep on updating these tables to maintain latest view of the network. Some of the existing table driven or proactive protocols are: OLSR, DSDV, DBF, WRP and ZRP (Taneja S. et al., 2010).
- On Demand or Reactive Protocols: In these protocols, routes are created as and when required. When a transmission occurs from source to destination, it invokes the route discovery procedure. The route remains valid till destination is achieved or until the route is no longer needed. Some of the existing on demand routing protocols are: DSR , AODV and TORA (Taneja S. et al., 2010).

The key challenges faced at different layers of MANET are shown in Fig. 1. It represents layered structure and approach to ad hoc networks (Taneja S. et al., 2010).

4-1 Ad-hoc On-demand distance vector:

AODV is another variant of classical distance vector routing algorithm, a confluence of both DSDV and DSR (Gupta A.K. et al., 2010). AODV protocol doesn’t have a fixed topology in a network. This is basically needed for wireless communication for the nodes and links are created when required (Jagdale B..N. et al., 2012).

4-1-1 Working of AODV

In this protocol, each node acts as a specialized router. The routing information maintains two separate counters: a node sequence number and a broadcast-id. When a source node wants to communicate with destination, it increments its broadcast-id and initiates path discovery by broadcasting a route request packet RREQ to its neighbours. The RREQ contains the following fields: (source-addr, source-sequence, dest-addr, dest-sequence, hop-cnt). The RREQ packet is identify uniquely with the help of source-addr and broadcast id pair only. Later the dynamic route entries from source to destination for all nodes are maintained. The intermediate node updates routing information and propagates new RREP only, if the Destination sequence number is greater, or if the new sequence number is same and hop count is small, or Otherwise, it just skips the new RREP. This ensures that algorithm is loop-free and only the most effective route is used**.** In the network, all nodes maintain routing table for each destination of interest in their routing table. Each entry contains the following info: Destination, Next hop, Number of hops, Destination sequence number, Active neighbours for this route, Expiration time for the route table entry Routing table contains the source and destination sequence number as well as it also maintains soft-state information which is associated with routing entries (Jagdale B..N. et al., 2012). Fig.2 shows AODV Protocol Messaging.

4-2 Geographic Routing Protocol (GRP)

The idea is to rapidly collect network information at a source node at an expense of a small amount of control overheads (Ahn C. W. et al., 2006). This approach is widely known as hybrid routing protocol, because it can simultaneously use the strengths of reactive routing and proactive routing protocols (Harmanpreet kaur, et al., 2012).

4-2-1 Working of GRP

In this procedure, source node sends a destination Query toward the destination through network. It works like AODV using RREQS (Reverse Request Query by Source). In it, when destination Query reached to the destination, destination sends a packet called Network Information Gathering (NIG) which approach through network. When NIG packet reached at a router, router gives it all the information about the network and its resources. There are many nodes called Effective Outgoing Links (EIL) where NIG packet does not riches, routers send this information to these EILs. At last NIG reaches at source node and source node get all the information (Kuldeep Vats et al., 2012).

4-3 Open Shortest Path First (OSPF)

OSPF belongs to the category of link state routing protocols that generally require each router in the network to know about the complete network topology. Today, link state routing protocols. Traditionally, OSPF has been a routing protocol for wired networks with largely static topology (Goyal M. *et al.* , 2008). The IETF OSPF-MANET working group has been developing an OSPF MANET interface extensions. These extensions have been designed and implemented based upon an IPv6 routing protocol, namely OSPFv3. OSPFv3 is not directly applicable to IPv4 networks (Pei G. *et al.* , 2008). Accordingly, OSPF specifications for MANET are different from the wired networks. They have the following built-in principles: User data is always forwarded over optimal paths., User data is only forwarded over links between routers with explicitly synchronized link state data-base **(**Ning Du. et al., 2012**).**

4-3-1 Working of OSPFv3:

According to the principles and expectations referred above, the general functionalities are interpreted as follows:

A. Packet Format and Forwarding

An universal specification of the packet format and an optimized flooding mechanism serves as the transport mechanism for all control traffic.

B. Neighbor Discover

Optimized OSPF aims at being completely independent of the underlying link-layer being used. In optimized OSPF, a node emits HELLO-messages periodically. Changes in the neighborhood are detected from the information in these messages. A HELLO message contains the emitting node's own address and the list of neighbors known to the node, including the status of the link to each neighbor (e.g. symmetric or asymmetric). A node thereby informs its neighbors with which neighbors, and in what direction, communication has been confirmed. Upon receiving a HELLO-message, a node can thus gather information describing its neighborhood and two hop neighborhood, as well as detect the "quality" of the links in its neighborhood: the link from a node A to a neighbor B is symmetric if in the HELLO-message from B the node A sees its own address (with any link status), otherwise the link is asymmetric. Fig.3 shows the procedure of a typical neighbor discovery session using HELLO messages **(**Ning Du. et al., 2012**)**.

C. MPR Selection and MPR Signaling

The objective of MPR(Multi-Point Relay) selection is for a node to select a subnet of its neighbors such that a broadcast message, retransmitted by these selected neighbors, will be received by all nodes 2 hops away **(**Ning Du. et al., 2012**)**..

D. Topology Control Message Diffusion

Topology Control messages are diffused with the purpose of providing each node in the network with sufficient link-state information to allow route calculation **(**Ning Du. et al., 2012**)**..

E. Route calculation

Given the link state information acquired through periodic message exchange, as well as the interface configuration of the nodes, the routing table for each node can be computed **(**Ning Du. et al., 2012**).**

5- ROUTING PROTOCOL SIMULATION

Testing mobile wireless protocols in a real-world environment presents numerous difficulties. These difficulties include creating repeatable scenarios with tens, hundreds, or even thousands of mobile nodes. Creating multiple scenarios with only small variances is also quite challenging. Because of these difficulties, simulations of routing protocols have been created to test the protocol in a variety of repeatable scenarios. However, while simulating a protocol can aid in the basic design and testing of the protocol, certain assumptions and simplifications can be made in a simulation that are not valid in a real-world scenario. Hence, it is important to implement the protocol, once the simulation is complete (Mhala N. N. et al., 2010). In this paper, the study was done by simulating the modeled system using OPNET modeler. The OPNET Modeler environment includes tools for all phases of a study, including model design, simulation, data collection, and data analysis. OPNET Modeler is the industry's leading environment for network modeling and simulation to design and study communication networks, devices, protocols, and applications with unmatched flexibility and scalability (www.opnet.com).

6- SIMULATION PROCEDURE

The three protocols (AODV, GRP and OSPFv3) were taken in different scenarios. Each protocol was taken in three scenarios that consist of number of nodes connected to the server. The application used in each scenario was (FTP). The number of nodes was increased from: 10, 25 and 50 nodes to study the performance of each protocol when the number of nodes was increased in terms of many parameters. The data rate was the WLAN 802.11b standard (11Mbps).

6-1 Case 1: The protocol is AODV

Three scenarios with number of nodes 10, 25 and 50 nodes connected wirelessly to the server, the routing protocol was AODV as shown in Fig.4.

6-2 Case 2: The protocol is GRP

Three scenarios with number of nodes 10, 25 and 50 nodes connected wirelessly to the server, the routing protocol was GRP as shown in Fig.5.

6-3 Case 3: The protocol is OSPFv3

Three scenarios with number of nodes 10, 25 and 50 nodes connected wirelessly to the server, the routing protocol was OSPFv3 as shown in Fig.6.

7- RESULTS

The discrete event statistics for many parameters are taken for the 9 scenarios shown above to study the performance of the three protocols for (MANET). The simulation is run for 15 minutes and the results are taken in terms of many parameters as follows:

1- The following results show the performance of AODV routing protocol if the number of mobile nodes is increased.
   - Routing traffic received: Amount of routing traffic received in bits/sec in the entire network shown in Fig.7.
   - Route discovery time: The time to discover a route to a specific destination is the time when a route request was sent out to discover a route to that destination until the time a route reply is received with a route to that destination. This statistic represents

to discover a route to a specific destination by all nodes in the network shown in Fig.8.

2- The traffic received and sent of GRP routing protocol if the number of mobile nodes is increased shown in Fig.9 and Fig. 10.

3- Delay which represents the end to end delay of all the packets received by the wireless LAN MACs of all WLAN nodes in the network and forwarded to the higher layer. This delay includes medium access delay at the source MAC, reception of all the fragments individually, and transfer of the frames via AP, if access point functionality is enabled.

Delay can be represented mathematically as in eq.(1) (Naveen Bilandi et al., 2010)

$$d_{end\text{-}end} = N[d_{trans} + d_{prop} + d_{proc}] \quad (1)$$

Where:
$d_{end\text{-}end}$ = End to end delay
d_{trans} = Transmission delay
d_{prop} = Propagating delay
d_{proc} = Processing delay

Delay of OSPFv3 routing protocol if the number of mobile nodes was increased shown in Fig.11.

4- Throughput: Represents the total number of bits (in bits/sec) forwarded from wireless LAN layers to higher layers in all WLAN nodes of the network. Throughput can be represented mathematically as in eq.(2) (Naveen Bilandi, et al., 2010)

$$\text{Throughput} = \frac{\text{Number of delivered packet} * \text{Packet size} * 8}{\text{Total duration of simulation}} \quad (2)$$

Throughput of OSPFv3 routing protocol if the number of mobile nodes was increased. shown in Fig.12.

5- Fig. 13, Fig.14 and Fig. 15 showed the comparison between the three protocols in terms of delay, load and throughput with (50 mobile nodes).

6- Table 1 showed comparison between the three protocols in terms of number of characteristics (www.opnet.com).

8- DISCUSSION AND CONCLUSIONS:

1- Three protocols (AODV, GRP and OSPFv3) are taken with increased number of mobile nodes for each protocol to study the performance of reactive and proactive protocols.
2- For AODV, routing traffic received and route discovery time are increased when the number of mobile nodes are increased.
3- In GRP routing protocol, traffic received and traffic sent are increased gradually when number of mobile nodes are increased.
4- In OSPFv3 routing protocol, throughput is increased when the number of nodes are increased but the delay increased and decreased when the number of nodes are increased.
5- With fixed number of mobile nodes, (50 nodes), three protocols were compared in terms of delay, Network load and throughput. The results showed that OSPFv3 routing protocol had large delay (0.0087 at 14 minutes of simulation time) than AODV and GRP which reach 0.0012 and 0.00062 respectively while load in GRP was increased gradually to become larger than AODV and OSPFv3 routing protocols. Load in GRP reaches 42,138.56 bits/sec while it reaches (15,484.373 bits/sec and 2,677.01 bits/sec) in OSPFv3 and AODV respectively. AODV was better in delay and smaller load than GRP and OSPFv3.
6- Throughput (number of bits transmitted per second) was large in OSPFv3 than (AODV and GRP) and reaches 13,930.987 bits/sec while throughput reach (6,263.36 bits/sec and 3.959.61 bits/sec) in (GRP and AODV) respectively.
7- This performance study was studied in terms of some parameters for three protocols. Other MANET routing protocols such as (DSR, TORA, DSDV, OLSR,…etc) could be taken with other parameters for further studies such as (number of hops per route, packet dropped, route error sent, Acknowledgment and Acknowledgement request sent, retransmission attempts and buffer overflow).

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LIST OF ABBRIVIATIONS:

AODV: Ad-hoc On-demand distance vector
DBF: Distributed Bellman-Ford
DSDV: Destination-Sequenced Distance Vector
DSR: Dynamic Source Routing
EIL: Effective Outgoing Links
FTP: File Transfer Protocol
GRP: Geographic Routing Protocol
LAN: Local Area Network
MANET: Mobile Ad-hoc Network
MPR: Multi-point Relay
NIG: Network Information Gathering
OLSR: Optimized Link State Routing
OPNET: Optimized Network Engineering Tools
OSPFv3: Open Shortest Path First version3
PRP : Proactive routing protocol
RREP: Route Reply
RREQ: Route Request
RREQS: Reverse Request Query by Source
RRP: Reactive routing protocol
TORA: Temporally-Ordered Routing Algorithm
WAN: Wide Area Network
WLAN: Wireless Local Area Network
WRP: Wireless Routing Protocol
ZRP: Zone Routing Protocol

Table 1 Comparison of MANET Routing Protocols

Characteristics	AODV	OSPFv3	GRP
Routing Philosophy	Reactive	Proactive	Proactive
Type of Routing	Hop-by-hop routing	Hop-by-hop routing	Hop-by-hop routing
Frequency of Updates	As needed	Periodically	Periodically
Worst case	Full flooding	Full flooding	Pure link state
Multiple routes	No	No	Yes

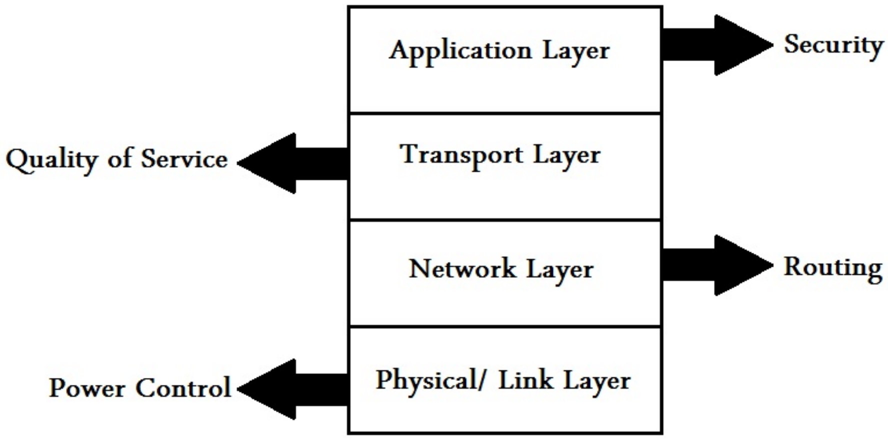


Fig.1 MANET challenges (Taneja S. *et al.*, 2010)

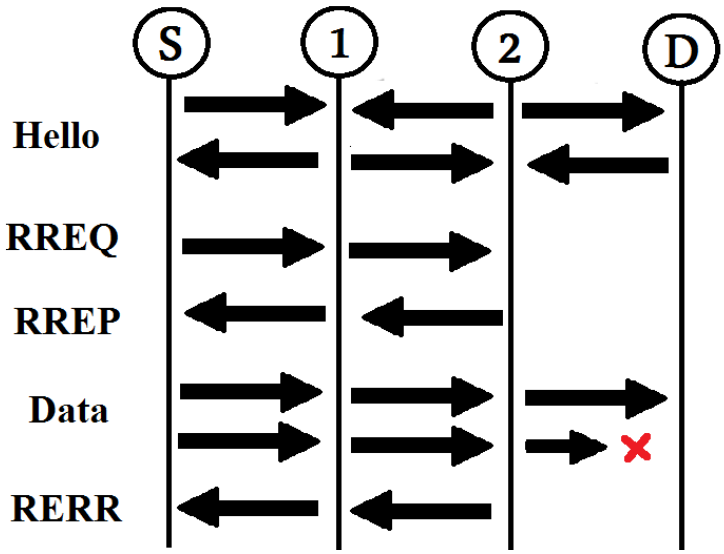


Fig.2 AODV Protocol Messaging (Nitiket N. et al., 2010)

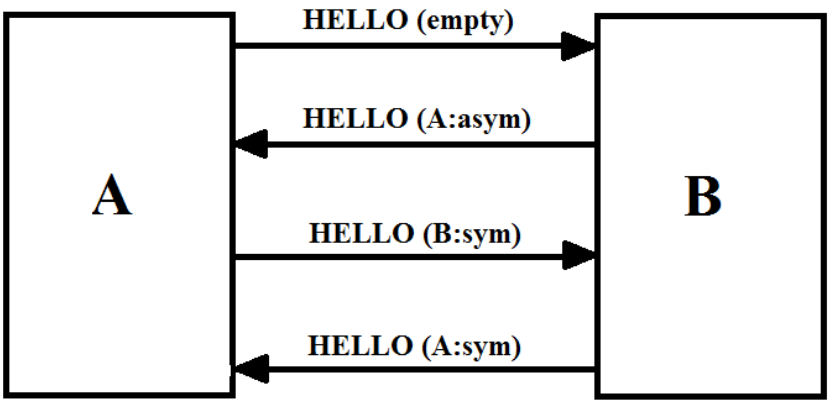
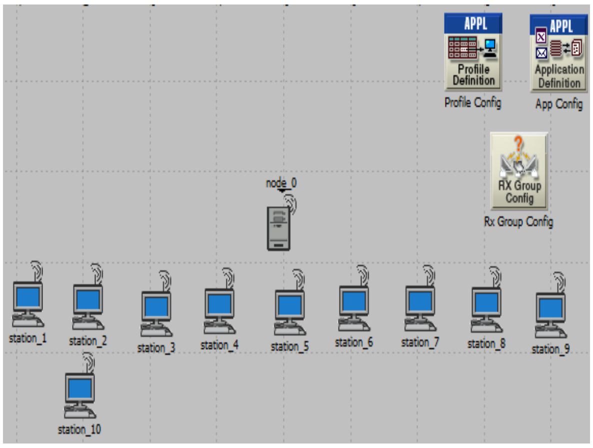
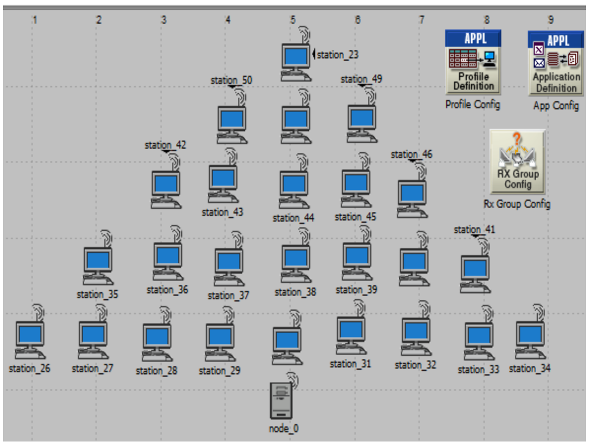


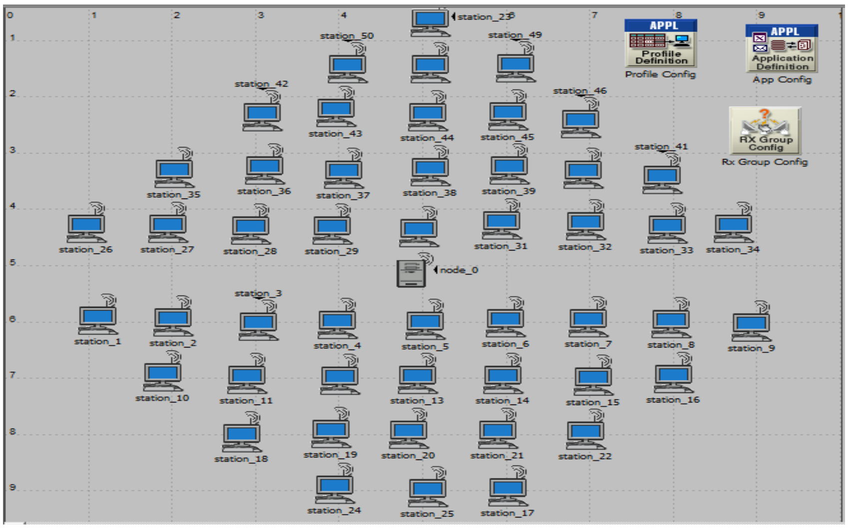
Fig.3 Typical neighbor discovery session using HELLO messages (Ning D. et al., 2012)



AODV_10 nodes

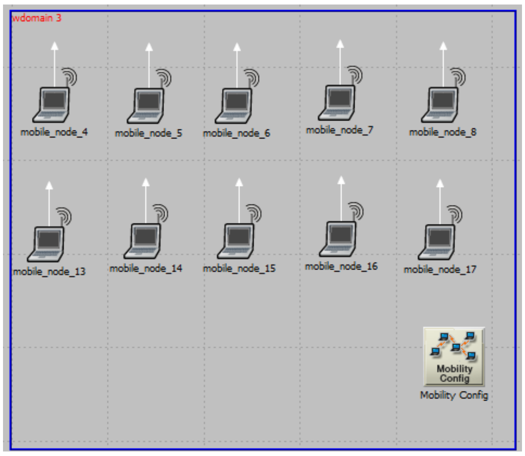


AODV_25 nodes

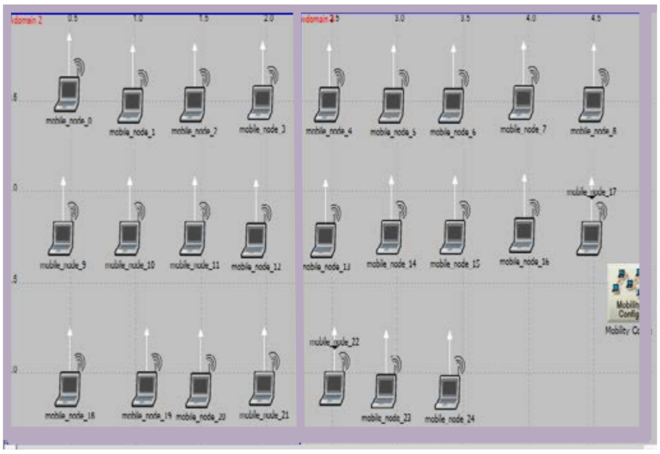


AODV_50 nodes

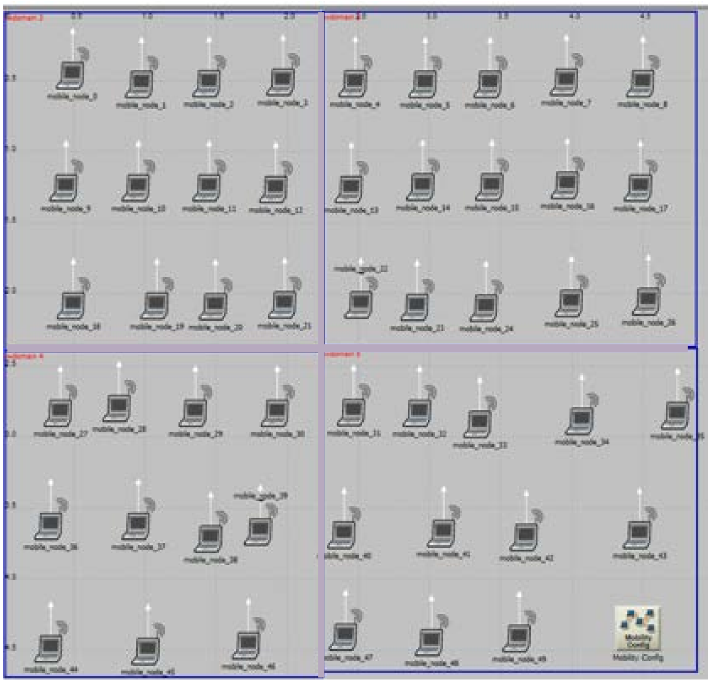
Fig.4 AODV Routing Protocol



GRP_10 nodes

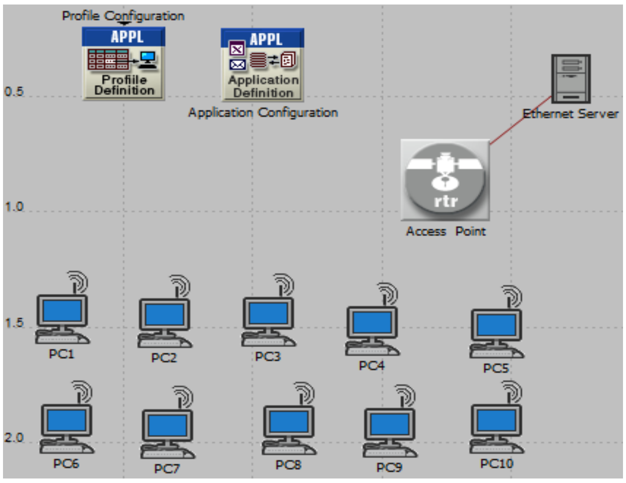


GRP_25 nodes

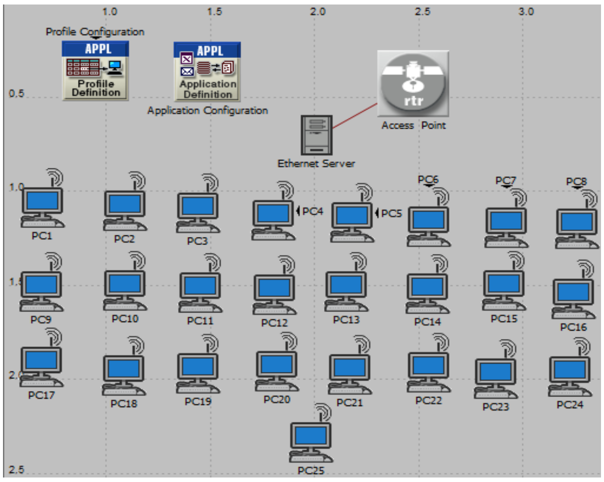


GRP_50 nodes

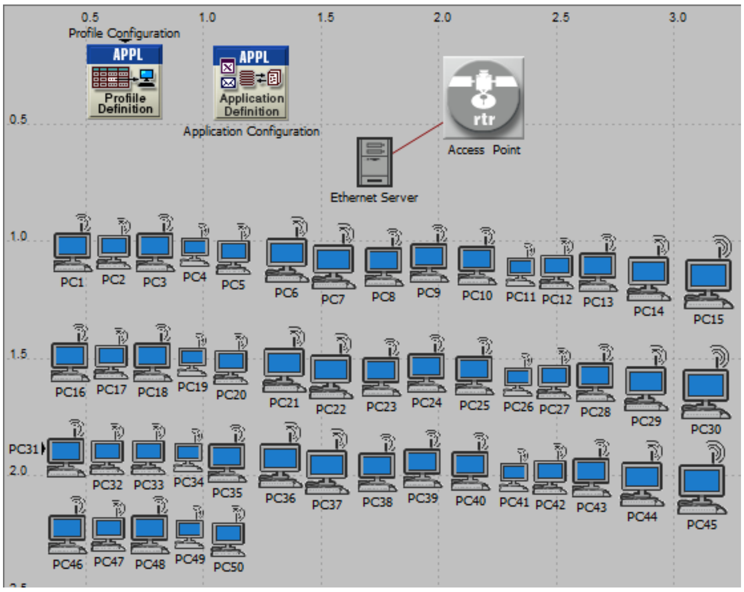
Fig.5 GRP Routing Protocol



OSPFv3_10 nodes



OSPFv3_25 nodes



OSPFv3_50 nodes

Fig.6 OSPFv3 Routing protocol

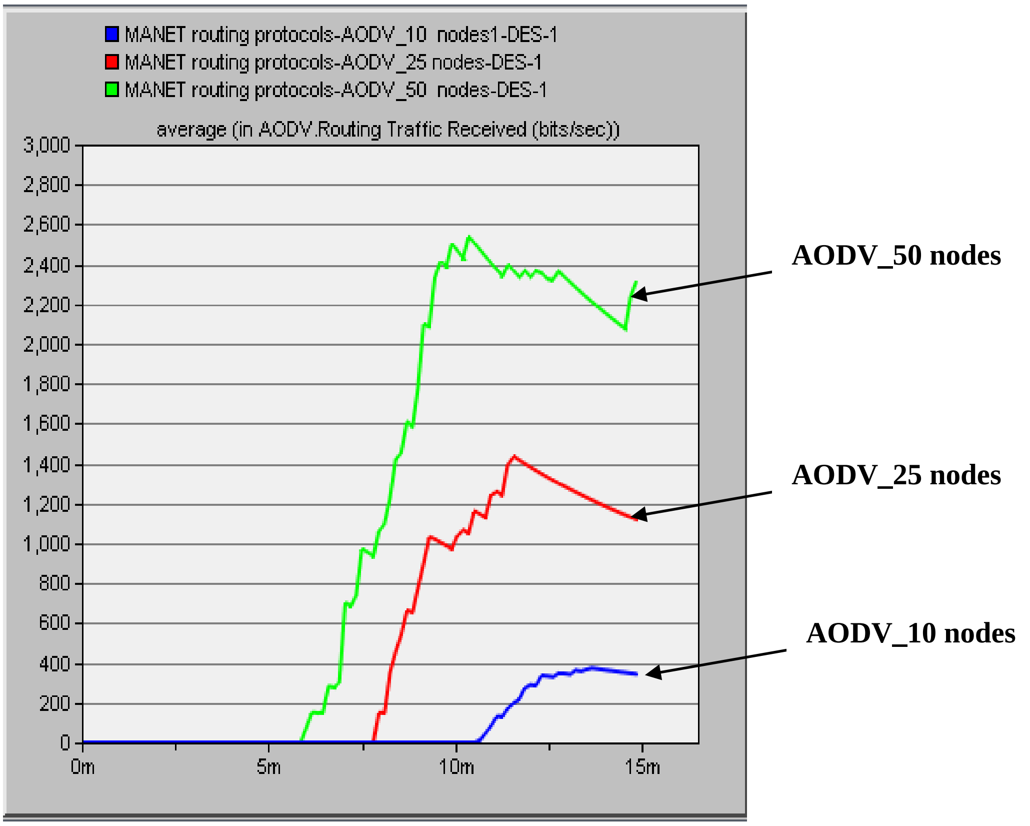


Fig.7 Routing Traffic Received for AODV Routing Protocol

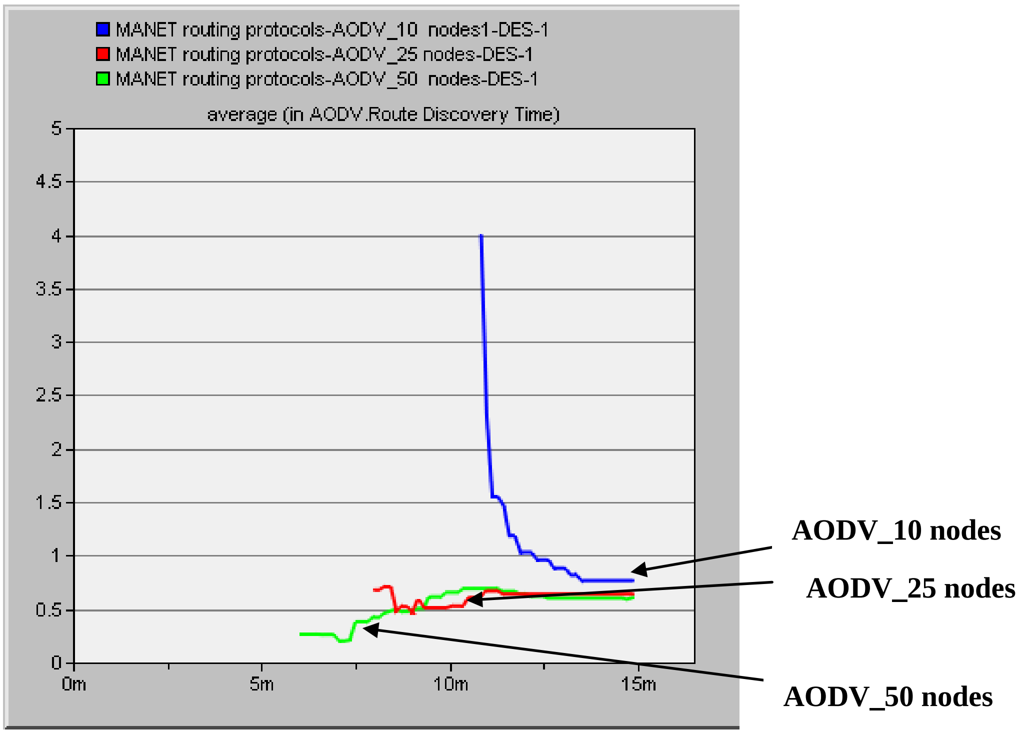


Fig.8 Route discovery time of AODV Routing Protocol

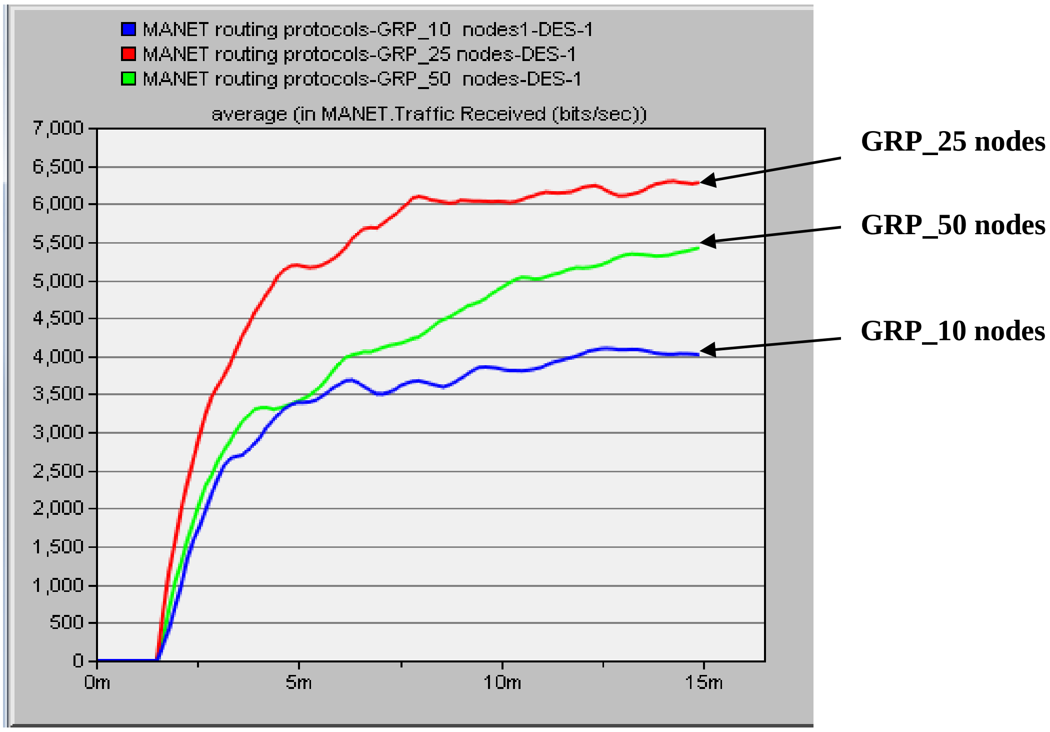


Fig.9 Traffic received for GRP Routing Protocol

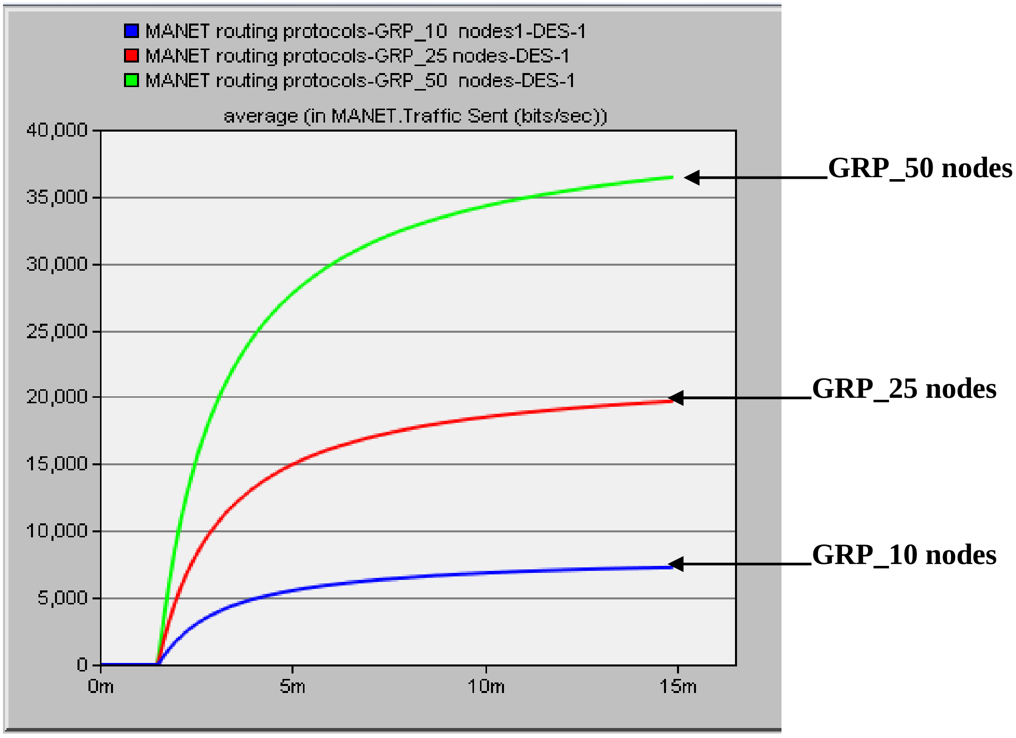


Fig.10 Traffic Sent for GRP Routing Protocol

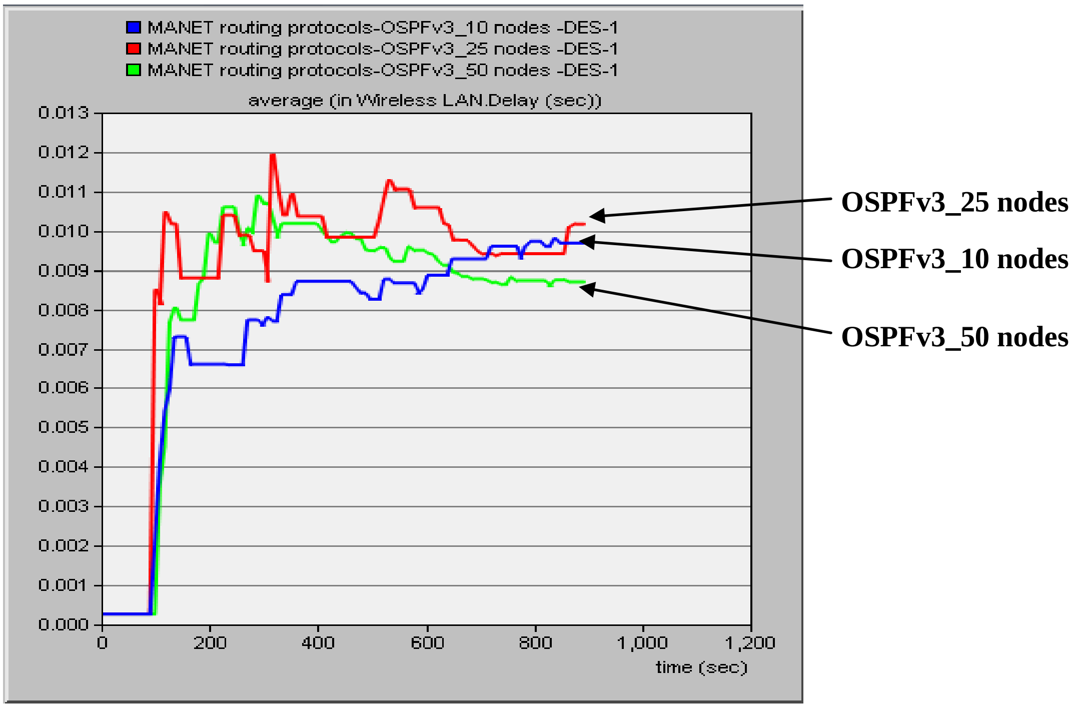


Fig.11 End - to – end delay for OSPFv3 Routing Protocol

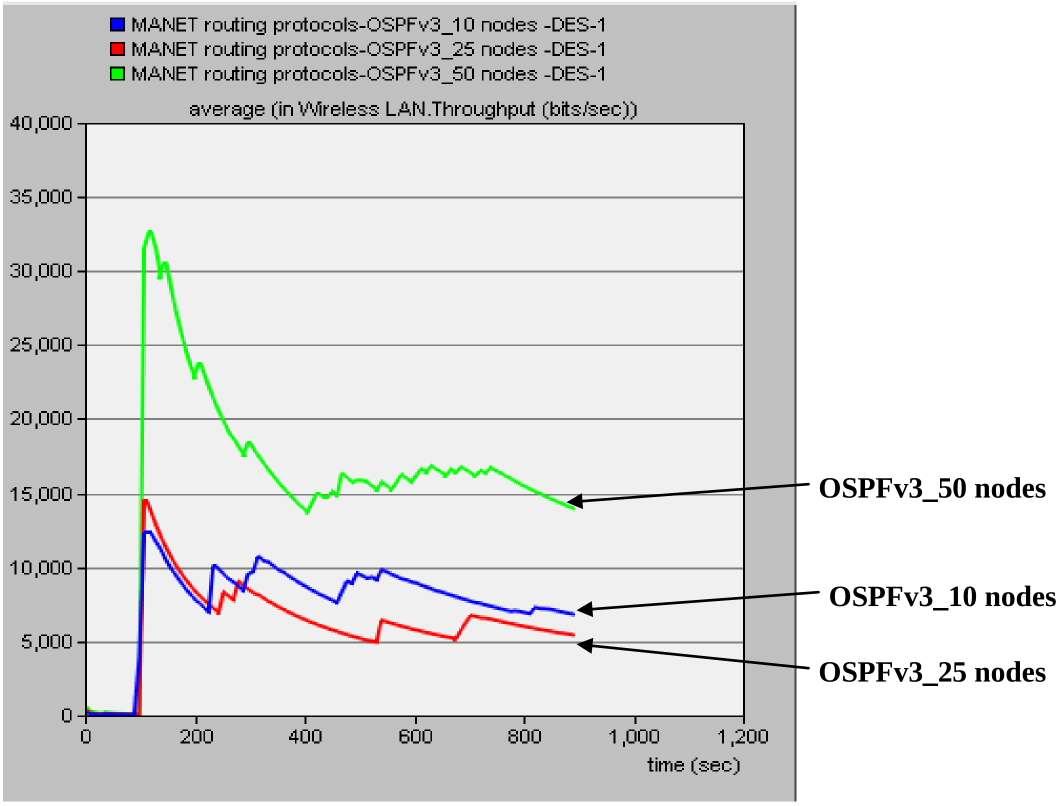


Fig.12 Throughput for OSPFv3 Routing Protocol

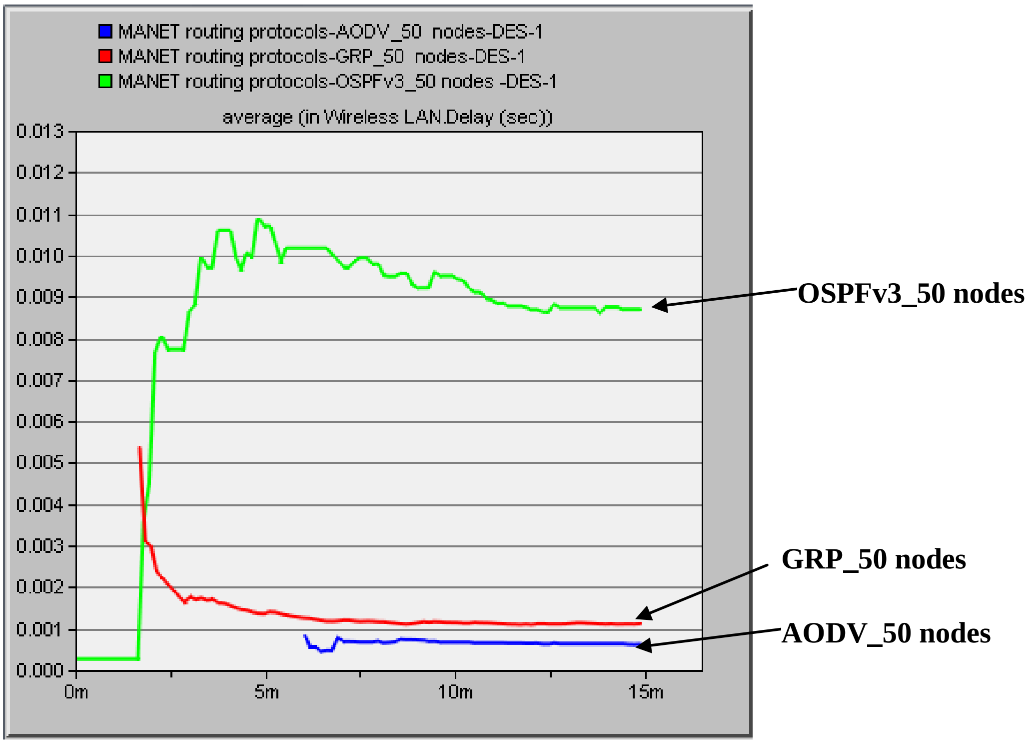


Fig.13 Delay for AODV, GRP and OSPFv3 Routing Protocols

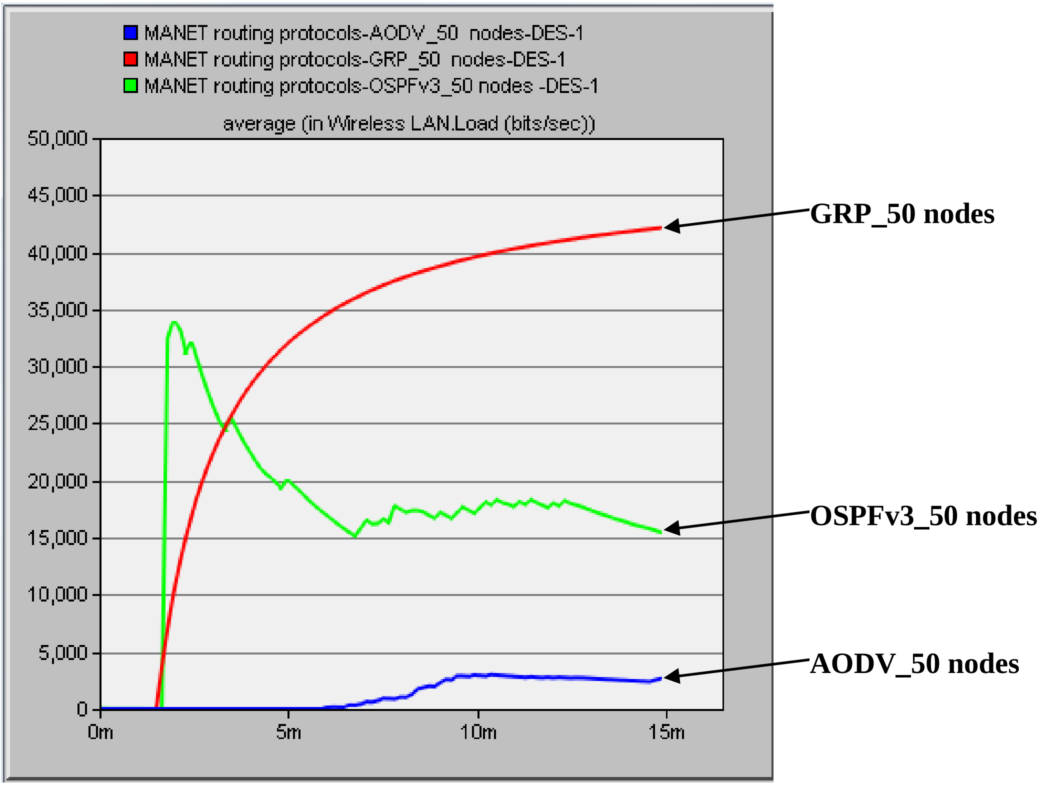


Fig.14 Load for AODV, GRP and OSPFv3 Routing Protocols

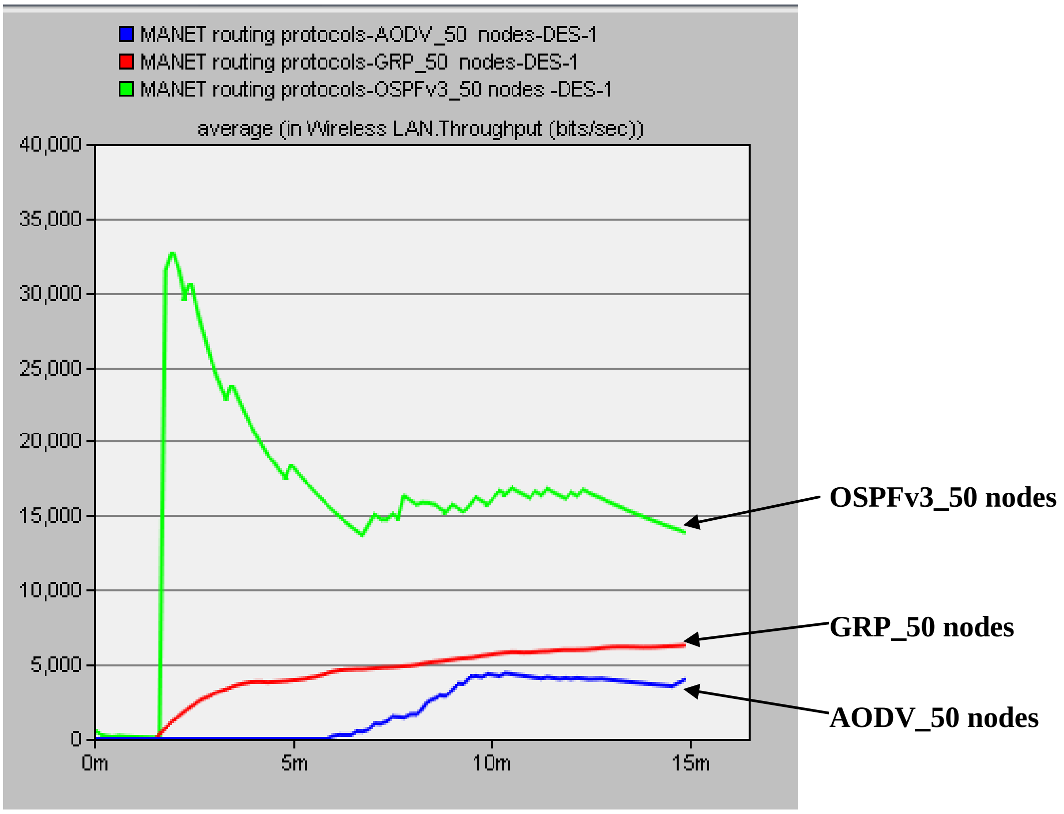


Fig.15 Throughput for AODV, GRP and OSPFv3 Routing Protocols