Throughput Performance Comparison of Reactive and Proactive Routing Protocols in Mobile Ad Hoc Networks using OPNET v14.5

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ABSTRACT
In wireless communication, using ad-hoc networking any user desiring to communicate with each other can form a temporary network, without any form of centralized administration. Each node participating in the network is mobile and can be connected dynamically in an arbitrary manner. All nodes of these networks behave as routers and take part in discovery and maintenance of routes to other nodes in the network. Because nodes are forwarding packets for each other, some sort of routing protocol is necessary to make the routing decisions. Routing in the MANETs is a challenging task and has received a tremendous amount of attention from researches. This has led to development of many different routing protocols for MANETs, and each author of each proposed protocol argues that the strategy proposed provides an improvement over a number of different strategies considered in the literature for a given network scenario. In the recent years, it has been quite difficult to determine which protocols may perform best under different network scenarios, such as change in node density and traffic applications. This paper begins with an overview of classification of routing protocols. We then provide a performance comparison of throughput for three mobile ad-hoc routing protocols AODV, DSR and OLSR to understand and analyze the behavior of these protocols under different parameters. All the experimental set up and simulations is done using OPNET v14.5 Simulator.

Keywords
Routing protocol, MANET, AODV, DSR, OLSR, OPNET, FTP traffic, Multimedia, video conferencing traffic.

1. INTRODUCTION
A network is a group of people or systems or organizations who tend to share their information collectively for their business purpose which can be done as wired or wireless. Wireless can be distinguished from wired as no physical connectivity between nodes is needed. Wireless mobile ad-hoc networks are characterized as networks without any physical connections. In these networks there is no fixed topology due to the mobility of nodes, interference, multipath propagation and path loss. Hence a dynamic routing protocol is needed for these networks to function properly. Ad-hoc networks are wireless networks where nodes communicate with each other. Ad-hoc networks form spontaneously without a need of an infrastructure or centralized controller. This type of peer-to-peer system infers that each node, or user, in the network can act as a data endpoint or intermediate repeater. Thus, all users work together to improve the reliability of network communications using multi-hop links.

Routing in ad-networks has been a challenging task ever since the wireless networks came into existence. The major reason for this is the constant change in network topology because of high degree of node mobility [1]. A number of protocols have been developed for accomplish this task. This paper concentrates on functionality of the three routing protocols: AODV, DSR and OLSR. The first two are reactive protocols and the third is proactive protocol. A comparison between the throughput performances of the referred routing protocols is done in order to prove its correctness and efficiency, under different traffic type and network load scenarios [2]. The entire network is implemented in OPNET simulator for these routing protocols.

2. CLASSIFICATION OF ROUTING PROTOCOLS IN MANET'S
Classification of routing protocols in MANET's can be done in many ways [3], but most of these are done depending on routing strategy and network structure. According to the routing strategy the routing protocols can be categorized as Table-driven and source initiated, while depending on the network structure these are classified as flat routing, hierarchical routing and geographic position assisted routing. Both the Table-driven and source initiated protocols come under the Flat routing [3]. Fig. 1 illustrates classification of routing protocols based on routing strategy.

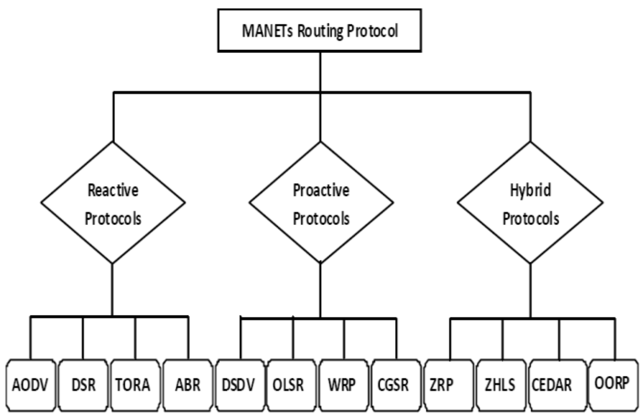


Fig 1: Classification of routing protocols based on routing strategy

2.1 Reactive routing protocols

These protocols are also called on demand protocols since they don't maintain routing information or routing activity at the network nodes if there is no communication. If a node wants to send a packet to another node then this protocol searches for the route in an on-demand manner and establishes the connection in order to transmit and receive the packet [4]. The route discovery usually occurs by flooding the route request packets throughout the network.

2.1.1 Ad hoc On Demand Distance Vector

AODV is a very simple, efficient, and effective routing protocol for Mobile Ad-hoc Networks which do not have fixed topology. Each mobile node operates as a specialized router and routes are obtained as needed i.e. on-demand with little on periodic advertisements. As it uses on-demand routing therefore it built route to transmit data packets when the source node desired and is trying to maintain established route as long as they are needed. Nodes of network periodically exchange information of distance table to their neighbors and ready for immediate updates. AODV protocol is responsible to select shortest and loop free route from table to transfer data packets. In case of errors or changes in selected route, it is able to create a new route for the rest of transmission of establishment and maintenance. AODV forms trees which connect multicast group members. The trees are composed of the group members and the nodes needed to connect the members. It uses sequence numbers to ensure the freshness of routes. It is loop-free, self-starting, and scales to large numbers of mobile nodes.

AODV routing protocol in ad hoc network communicate between mobile nodes through four types of different messages- Route Request, Route Reply, Route Error, and Hello Message. To establish a route between source and destination node Route Request (RREQ) and Route Reply (RREP) packet query cycle are used. Route Error (REER) and HELLO data packets are used for route maintenance. Because of its reactive nature, AODV can handle highly dynamic behavior of Vehicle Ad-hoc networks. Overhead on bandwidth will be occurred compared to DSR, when an RREQ travels from node to node in the process of discovering the route info on demand, it sets up the reverse path in itself with the addresses of all the nodes through which it is passing and it carries all this info all its way. AODV is a reactive routing protocol. This means that AODV does not discover a route until a flow is initiated. This route discovery latency result can be high in large-scale mesh networks [5].

2.1.2 Dynamic Source Routing

DSR also belongs to the class of reactive protocols and allows nodes to dynamically discover a route across multiple network hops to any destination. It is a source-routed on-demand routing protocol. Source routing means the sender (source or initiator) determines the whole path from the source to the destination and carries the complete ordered list of nodes through which the packet must pass. Intermediate nodes do not need to maintain up-to-date routing information in order to route the packets they forward [5].

Routing of data packets in DSR protocol between mobile nodes of ad hoc network is based on request/reply method. It controls the wastage of bandwidth by eliminating need of periodic table updating. It can establish a route to destination through source routing; therefore it does not require transmission of periodic hello message by a node to inform its neighbor about his presence. It has only two major phases which are Route Discovery and Route Maintenance. Route Reply would only be generated if the message has reached the intended destination node (route record which is initially contained in Route Request would be inserted into the Route Reply). To return the Route Reply, the destination node must have a route to the source node. If the route is in the Destination Node's route cache, the route would be used. Otherwise, the node will reverse the route based on the route record in the Route Reply message header [6].

2.2 Proactive routing protocols

These protocols are also called as table driven protocols since they maintain the routing information even before it is needed. Each and every node in the network maintains routing information to every other node in the network. Routes information is generally kept in the routing tables and is periodically updated as the network topology changes [7]. The proactive protocols are not suitable for larger networks, as they need to maintain node entries for each and every node in the routing table of every node. This causes more overhead in the routing table leading to consumption of more bandwidth.

2.2.1 Optimized Link State Routing

OLSR permanently stores and updates its routing table. It keeps track of routing table in order to provide a route if needed. OLSR can be implemented in any ad hoc network. Due to its nature it is called as proactive routing protocol. All the nodes in the network do not broadcast the route packets. Just Multipoint Relay (MPR) nodes broadcast route packets. These MPR nodes can be selected in the neighbor of source node. Each node in the network keeps a list of MPR nodes. This MPR selector is obtained from HELLO packets sending between in neighbor nodes. These routes are built before any source node intends to send a message to a specified destination. Each and every node in the network keeps a routing table. This is the reason the routing overhead for OLSR is minimum than other reactive routing protocols and it provide a shortest route to the destination in the network. There is no need to build the new routes, as the existing in use route does not increase enough routing overhead. It reduces the route discovery delay. Nodes in the network send HELLO messages to their neighbors. These messages are sent at a predetermined interval in OLSR to determine the link status.

3. SIMULATION FRAMEWORK

3.1 Simulation Tool

Simulation can be defined to show the eventual real behavior of the selected system model. It is used for performance optimization on the basis of creating a model of the system in order to gain insight into their functioning. We can predict the estimation and assumption of the real system by using simulation results. Since the availability of the IEEE 802.11 (Wi-Fi) standard, researchers investigate mobile ad hoc networks (MANETs). Since then, many simulators were proposed, and there was one more selection alternative of the simulators e.g., NS-2 [8], GloMoSim [9], QualNet [10], OPNET [11] and OMNeT++ [12]. In order to perform the simulation work we had to select the suitable simulator.

Only OPNET and NS-2 contains an extensive set of models, protocols and algorithms which would dramatically shorten our startup time, since we will have to worry only about the implementation of our algorithms and of possible modifications/extensions to existing modules. However, NS-2 lacks in the scalability of simulating up to thousand of nodes to carry out studies over a wide range of detail and scenarios. Further, in terms of ease to use/modify/extend, OPNET seems to be more than satisfactory. In this sense it is probably comparable to QualNet and OMNeT++. Here, also NS-2 scores poorly.

Thus, in the light of the review of the candidate network simulators, none of the reviewed simulators seem to really possess the whole set of characteristics required for good discrete-event simulation. However, OPNET appears as the best compromise in terms of number of pre-built components, modularity, scalability, and modifiability. Further it has a good level of acceptance from the scientific community, advanced graphical and mathematical tools for experiment building, monitoring and post-processing, along with good documentation, and possibility of parallel and/or distributed implementations [13]. In this sense, we see OPNET as an effective simulation framework on top of which can be used for performance analysis of mobile ad hoc networks. We plan to start to build our algorithms and simulation architecture by using OPNET v14.5 for our simulations.

3.2 Throughput

In communication of various types of networks, such as MANET, network throughput is the average rate of successful message delivery over a communication channel. The throughput is usually measured in bits per second (bit/s or bps) or in data packets per second or data packets per time slot. These data may be delivered over a physical or logical link, or pass through a certain network node. The system throughput or aggregate throughput is the sum of the data rates that are delivered to all terminals in a network [14]. Some factors affect the throughput as; if there are many topology changes in the network, unreliable communication between nodes, limited bandwidth available and limited energy. A high throughput is absolute choice in every network. Throughput can be represented mathematically as

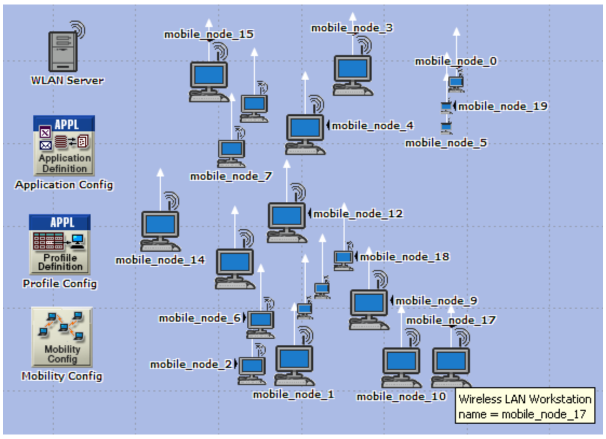
$$\text{Throughput} = \frac{\text{Number of delivered packet} * \text{Packet Size} * 8}{\text{Total duration of simulation}}$$

3.3 Simulation Model

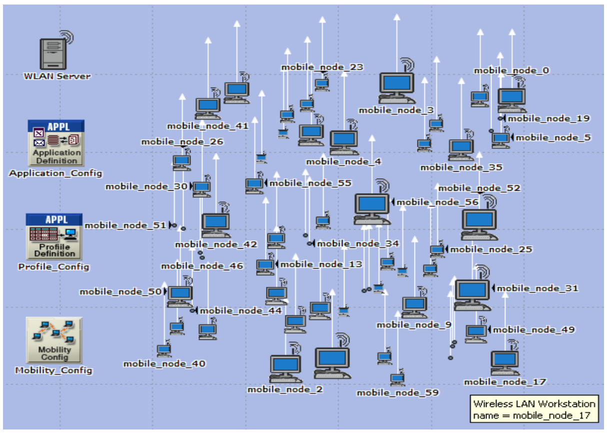
The simulation focused on the performance of routing protocols when node density (scalability) and traffic load (type) are changed. Therefore, two simulation groups, one consisting of little nodes i.e., 20 nodes initially and then in another increasing the nodes to large extent i.e. to 100 is considered. The nodes were randomly placed within certain gap from each other in 1000 x 1000 m in campus environment along with a fixed WLAN application server. IPv4 addressing was assigned to all the nodes.

The nodes were wireless LAN mobile nodes with data rate of 11 Mbps moving with a constant speed of 10 m/sec. MANET process model is used as default no changes are taken place. Each MANET node has a receiver and a transmitter to communicate on the network with other nodes. The transmitters and receivers parameter were configured with defining default RXGroup in the network where all receivers are considered as potential destinations. Every node in the network is configured to execute AODV, DSR and OLSR respectively.

Two network models as shown in Fig. 2 are designed and taken into consideration for evaluating the performance and robustness of AODV, DSR and OLSR routing protocols. Application configuration, Profile configuration, and Mobility configuration are configured to work the network according to the aim of the paper similar to related papers [5,15,16,17]. All the three referred protocols are tested against the throughput parameter in both the scenarios. The results obtained in the form of graphs, all the graphs are displayed as average. Evaluation and simulation results are collected for the below network.



(a) Network model with 20 nodes



(b) Network model with 60 nodes

Fig 2: MANET Scenarios with different node densities

3.4 Simulation Statistics

We used Global statistics to analyze the behavior of protocols from the entire network. To view the results of all the scenarios for performance evaluation we used DES [20]. We run the simulation for five min i.e. 300 sec and save the graphs for analysis. The DES execution manager window for the simulation of FTP scenarios is shown in Fig. 3, and Video Conferencing scenarios is shown in Fig. 4.

It is observed that for FTP traffic OLSR simulates the more number of events than the reactive protocols (AODV and DSR). On the other hand, for heavy load Video Conferencing traffic it requires simulation of comparatively less number of events for same density networks. Further it is apparent that for simulation of more number of events, more time is required for complete simulation.

4. ANALYZING SIMULATION

We used two kinds of scenarios with one consisting 20 nodes and other consisting 60 nodes, both with one fixed WLAN server which acts as application server. Now we discuss throughput performance of all the three routing protocols for each parameter explicitly. For all the protocols, the graphs shown are in time average form and show the throughput in bits/sec. Here also, the x-axis represents time in min and the y-axis data rate in bit/sec.

4.1.1 AODV performance
AODV protocol was simulated in both 20 and 60 mobile nodes scenarios. From the given results in Fig. 5, it is observed that the throughput increases when the number of nodes increases for simple FTP traffic. However, when the traffic is set to video conferencing, signifying heavy traffic, the throughput rises abruptly when node density increases.

4.1.2 DSR performance
DSR protocol was simulated in both 20 and 60 mobile nodes scenarios. From the given results in Fig. 6, it is observed that for simple FTP traffic the throughput increases when the number of nodes increases. When the traffic is set to video conferencing signifying heavy traffic, the throughput increases compared to FTP, but decreases when node density increases.

Both AODV and DSR show similar kind of behavior in FTP load because of the characteristics features of maintaining routing tables in proactive protocols. In Video Conferencing load the throughput of DSR decreases when the number of nodes is increased, signifying that DSR is only suitable for smaller low density networks.

4.1.3 OLSR performance
OLSR protocol was simulated in both 20 and 60 mobile nodes scenarios. From the given results in Fig. 7, it is observed that the throughput increases when the number of nodes is increased in both simple FTP and Video Conferencing load. Further, in OLSR it is observed there is no effect of traffic type in throughput. The throughput remains same for both kinds of traffic and only depends on the node density. Thus it is suitable for all kinds of traffic.

5. CONCLUSION
This paper mainly consists of two studies, one is analytical study and other is simulation study. From analytical study it is concluded that routing protocols in new modern arena of telecommunications, internet systems and in seamless communication play major role to develop better communication between end users. Different routing protocols have different attributes according to their environmental scenarios. The selection of suitable protocol according to the network definitely increases the reliability of that network.

From the simulation study, it is observed that increase in number of nodes causes increase in the throughput for several protocols. This is because when the numbers of mobile nodes are increased, the data which is needed to deliver to the specific destination have to pass from many mobile nodes which cause more delay and network load. However, reactive protocols act in different manner when node density is increased. Further, during large traffic, the rate of collision count increases which also affects the throughput of the system [15].

At the end we came to the point from our simulation and analytical study that the performance of routing protocols vary with network and selection of accurate routing protocols according to the network, ultimately influence the efficiency of that network in magnificent way[18].

The future scope suggested is the development of modified version of the referred routing protocols which can consider different aspects of routing protocols such as rate of higher route establishment with lesser route breakage. Effect of mobility on performance of routing protocols can also be analyzed for environments where topology of nodes changes frequently [21]. There is also a possibility to use either NS-2 or GloMoSim in the future, if we realize that the use of OPNET is in some sense limiting for our research. Practically, according to the previous discussions on the problems inherent to the use of simulation and simulators, we might consider the possibility to test our models and algorithms using different simulators in order to carry out analysis at different levels and to obtain stronger statistical validations.

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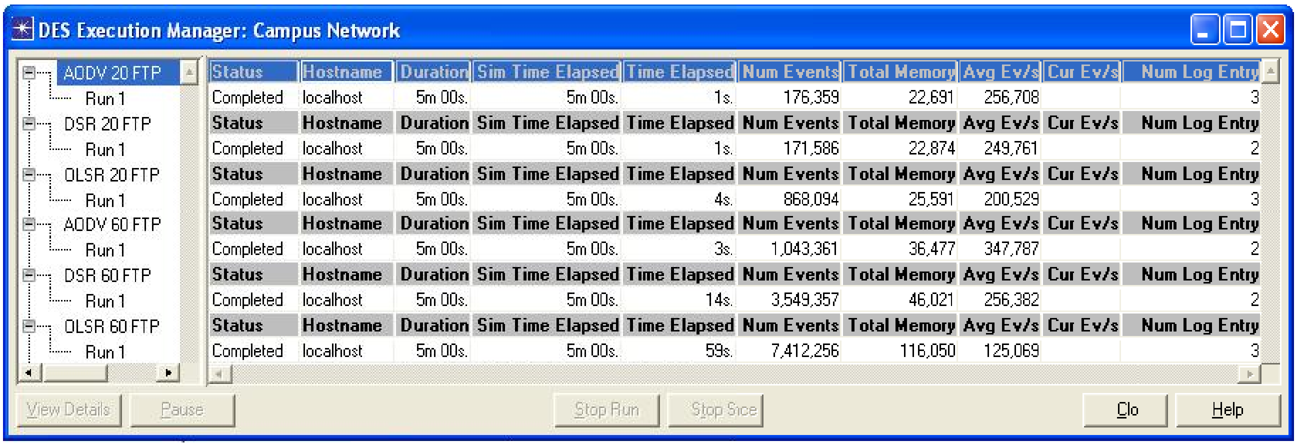


Fig. 3: DES Execution Window for FTP Scenarios

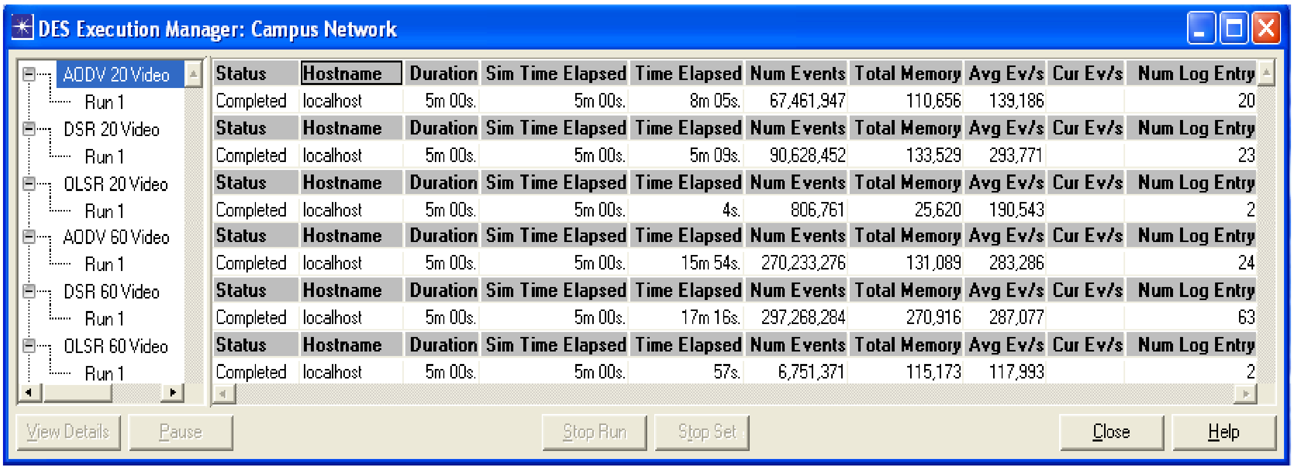
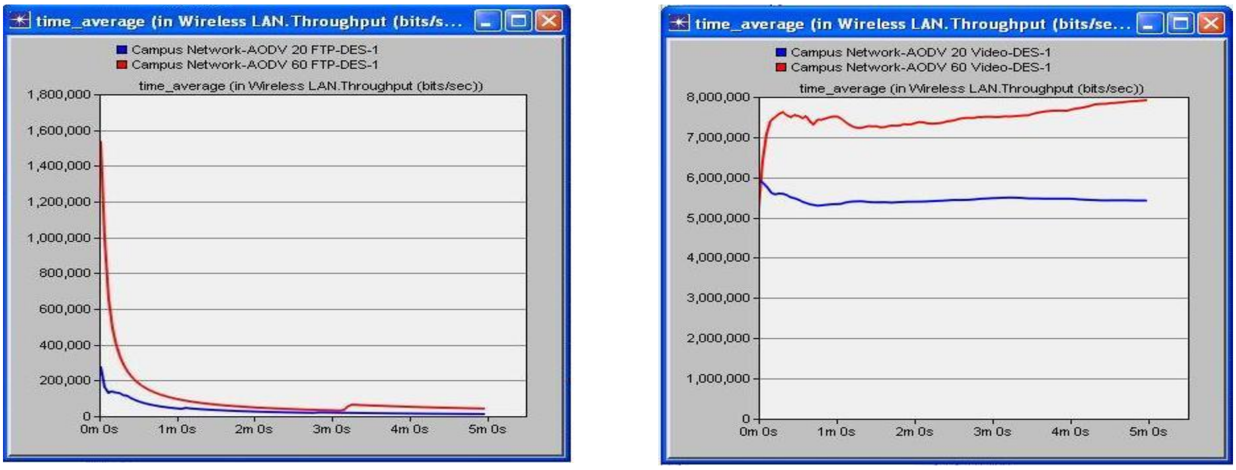
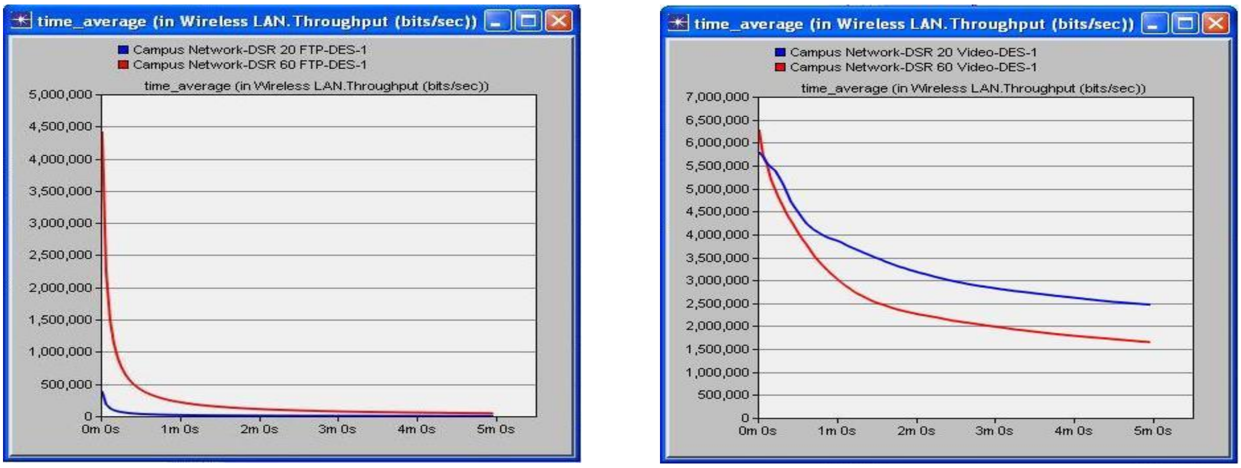


Fig. 4: DES Execution Window for Video Conferencing Scenarios



(a) Throughput in FTP traffic **(b) Throughput in Video Conferencing traffic**

Fig. 5: AODV performance in 20 and 60 nodes



(a) Throughput in FTP traffic **(b) Throughput in Video Conferencing traffic**

Fig. 6: DSR performance in 20 and 60 nodes

(a) Throughput in FTP traffic **(b) Throughput in Video Conferencing traffic**

Fig. 7: OLSR performance in 20 and 60 nodes