Performance Comparison of MANET Routing Protocols based on real-life scenarios

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Abstract—**In order to ensure a reliable and efficient end-to-end communication among the network nodes in a Mobile Ad Hoc Network (MANET), an appropriate routing protocol is needed. In this paper, we present an extensive simulation-based comparison of three well-known MANET routing protocols (AODV, DSDV and OLSR) evaluating their performance in three real-life scenarios. Considering various performance metrics (PDR, Delay, Average Delay, Throughput and Total Energy Consumption), we suggest the most appropriate routing protocol in every scenario.**

I. INTRODUCTION

Mobile Ad Hoc Networks (MANETs) represent complex distributed systems consisting of wireless mobile nodes that can freely and dynamically self-organize into arbitrary and temporary network topologies as the one depicted in Figure 1. Without doubt, mobile ad hoc networking research has received considerable attention in recent years. This is because this technology allows people and devices to seamlessly internetwork in areas with no pre-existing communication infrastructure [1]. The peculiar characteristics and complexities of MANETs, namely the multi-hop routing, the autonomous and infrastructureless design, the dynamic topology, the device heterogeneity, the energy constrained operations, the bandwidth constrained variable capacity of links, the limited physical security and the network scalability, impose many design challenges, especially for the networking protocols.

Several researchers have conducted qualitative and quantitative analysis of Ad Hoc Routing Protocols evaluating different performance metrics and utilizing different simulators. Most of these analyses focus on the main challenges of MANETs which are reliability, bandwidth and battery power. Although the use of simulation studies has increased, the confirmation and agreement among their results has decreased. This is because the simulation studies are not based on realistic (real-life) scenarios and their research field is rather general and based on random assumptions. As a result, the conclusions drawn cannot directly be used in Mobile Ad Hoc Network applications. Instead, further studies must be performed beforehand, in order for a network engineer or practitioner to choose the proper routing protocol for a given MANET application.

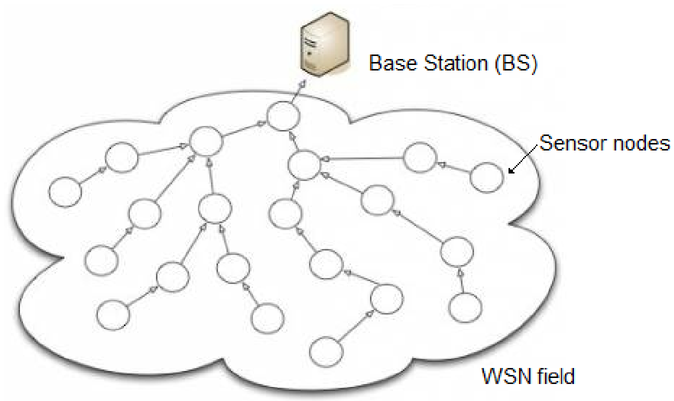

Figure 1 Multihop routing tree connecting sensor nodes and the base station

Based on the methodology used and the subject of their study, previous studies can be classified in energy-based performance comparisons [2], [3], mobility-based performance comparisons [4], multimedia-based performance comparisons [5], network based-performance comparisons [6] and security-based performance comparisons [7]. For example, in [8], the authors compare several MANET protocols utilizing various QoS metrics concluding that OLSR performs quite predictably, delivering virtually most data packets at node mobility and shows increase in throughput even when the routing load was increased. In [9] the performance comparisons are based on simulation scenarios with varying pause times. The authors showed that increase in the density of nodes yields to an increase in the mean end-to-end delay, increase in the pause time leads to a decrease in the mean end-to-end delay and that increase in the number of nodes will cause increase in the mean time for loop detection. In [10] the authors choose to evaluate the selected routing protocols algorithms with respect to the network traffic, the node speed, as well as the area and the antenna range in different simulation scenarios showing that MAODV performs better for high traffic and ODMRP performs better for large areas and high node speeds and poorer for small antenna ranges.

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In this paper, we focus on evaluating the performance of three routing protocols for MANETs in realistic environments. Our intention is to specify the best choice for each scenario and for certain parameters. Although lot of research has been done during the past years in MANETs, a large percentage of them evaluate the protocols under the same performance parameters and metrics and under non-realistic conditions: the transmitter and receiver devices are not modeled according to the commercial ones, but instead the default parameters of the simulator; are used. Also, some of the mobility models used do not describe the path a person or a car follows, etc. The overall goal of this paper is to develop realistic scenarios for everyday life MANET applications and through the simulation process of those scenarios, to compare the most significant MANET routing protocols for different performance parameters. Furthermore, we investigate the effect of the Direct Sequence Spread Spectrum (DSSS) Rate [11] that is a parameter not be examined by previous simulation studies.

The remainder of the paper is organized as follows: Section II provides an overview of routing in MANETs and classifies the MANET routing protocols. Section III analyzes the real-life simulation scenarios. The simulation environment, the performance metrics and the simulation-based results for every scenario are recorded in Section IV. Finally, Section V concludes the paper.

II. ROUTING IN MANETS

Routing is the act of selecting the route that information will follow from a source to a destination in a network. The routing concept basically involves two activities: firstly, determining optimal routing paths, and secondly, transferring the information groups (called packets) through the selected paths. Irrespective to other wireless networks (i.e. cellular networks where the base station can reach all mobile nodes), in MANETs there is no infrastructure support, and the destination node might be out of range of the source node. A routing procedure is thus always needed in order to find a path between the source and the destination and forward the packets appropriately. Additionally, in the case of ad-hoc networks, each node must be able to forward data for other nodes depleting its energy for the network's general viability and operability. This creates additional problems along with the problems of dynamic topology stemming from the mobility of the wireless nodes and which can lead to unpredictable connectivity changes.

Various protocols have been proposed by the researchers in order to address the routing issues in MANETs. These protocols can be classified in many ways, but most classifications are based on the routing strategy and/or the network structure. According to the routing strategy, the routing protocols can be categorized as *Pro-active* (table-driven) and *Reactive* (on-demand). Depending on the network structure, the protocols are classified as *flat routing*, *hierarchical routing* and *geographic position assisted routing* [12]. Both the Table-driven and On-demand protocols come under the Flat routing category.

The main difference between table-driven and on-demand routing protocols is regarding the routing information stored in the routing tables for every node. A network using an on-demand protocol will not maintain current routing information on all nodes for all times. Instead, such routing information is obtained on demand. If a node wants to transmit a message, and does not have enough routing information to route the message to the destination, the required information has to be obtained (unless the protocol is using directly a flooding approach to deliver the messages). The node needs to know at least the next hop (among its neighbors) for transmitting the packet. This is the case for the Ad hoc On-Demand Distance Vector (AODV) routing protocol [13]. AODV is one of the most significant reactive protocols and one of the three protocols studied in this paper. Proactive routing protocols will try to maintain correct routing information on all nodes in the network at all times. This can be achieved in different ways, and so there are two protocol subclasses: event driven and time-driven or regularly updated protocols. Event driven protocols will send routing update packets only when a change in topology occurs. Protocols that are updated in regular intervals will always send their topology information to other nodes at regular intervals. The Destination-Sequenced Distance Vector routing protocol (DSDV) [14] is an event driven proactive routing protocol and the Optimized Link State Routing Protocol (OLSR) [15] is a regular updated protocol. DSDV and OLSR are both studied in the present paper. The different strategy they follow to update their routing tables incurs more routing overhead but is advantageous because there is always current routing information.

III. THE REAL LIFE SIMULATION SCENARIOS

As already revealed, the main focus of this paper is to evaluate the performance of the AODV, DSDV and OLSR routing protocols for MANETs in realistic scenarios and specify the best choice for each scenario and performance metric. Next, we present the three realistic scenarios.

A. *School Field Trip Scenario*

The first scenario describes a field trip to Parnitha Mountain performed by a school class in order to provide the students with environmental experiences outside the school. The students should be able to record their activities while moving and be able to communicate with their teacher in every region of the mountain. The use of cell phones won't be the best option because there might be certain areas (e.g. canyons) where the reception will be poor to non-existent, and also sending videos might not be fully supported by all network providers of the devices. For these reasons, in this scenario both temporary and localized communication is demanded necessitating the use of MANET networking.

TABLE I. SIMULATION PARAMETERS OF THE SCOOL FIELD TRIP SCENARIO

Simulation Parameters	Values
Number of Nodes	21 (20 students and a teacher)
Nodes' Speed	2 m×sec-1
Senders	20 (the students)
Receivers	1 (the teacher)
Movement	Gauss-Markov Mobility Model
Area	1000m × 500 m
Protocols	AODV or DSDV or OLSR

Simulation Parameters	Values
DSSS Rate	1Mbps or 2Mbps or 5.5Mbps or 11Mbps
Packet Size	256 or 512 or 1024 or 2048 or 4096 bytes
Number of Packets	250
Interval	0 - 0,05 - 0,1 - 0,15 - 0,2 - 0,25 - 0,3 - 0,35 - 0,4 - 0,45 - 0,5 sec
Simulation Time	180 sec

In this scenario, we assume that there is a group of 20 students and a teacher (21 nodes). Each one of them is equipped with a hand-held device. All of them are walking in a certain direction (Gauss-Markov Mobility Model [16]) with a constant speed of 2 m/s. The traffic is Constant Bit Rate (CBR), which means that packets are send continuously with the same rate. Table I summarizes the simulation parameters of this first scenario.

B. Rescue Operation Scenario

The rescue operation scenario takes place on Olympus Mountain. After a snow slide, the traces of a group of mountaineers are lost. A rescue procedure starts immediately to find survivors. Rescue and emergency operations are characterized by very hectic and dynamic environments, where time is a critical factor. There is a lot of movement and activity on the site as personnel may arrive and leave the site at different times, e.g., in cases where personnel or other resources (ambulances, helicopters) are called out to other incidents in the area. Several organizations are involved in the operation, e.g., paramedics, fire fighters and police, in addition to a number of other organizations, some of which are voluntary. Wired networks do not exist in this environment and so a MANET is again essential to support communication among the rescue members.

TABLE II. SIMULATION PARAMETERS OF THE RESCUE OPERATION SCENARIO

Simulation Parameters	Values
Number of Nodes	10 – 20 – 30 – 40 – 50 – 60 – 70 – 80 – 90 - 100
Nodes' Speed	5 – 10 – 15 – 20 – 25 – 30 – 35 – 40 – 45 – 50 – 55 m×sec-1
Senders	the team members
Receivers	1 (the OSC)
Movement	Random Direction Mobility Model
Area	500m × 500 m
Protocols	AODV or DSDV or OLSR
DSSS Rate	11Mbps
Packet Size	2048 bytes
Number of Packets	150
Interval	0,1 sec
Data Rate	164 Kbps
Simulation Time	180 sec

The on-scene coordinator/commander (OSC) is the person who has the main role and responsibility of the team. Every member of the team informs the OSC about evidence and other important information s/he finds by sending him/her files or voice messages. In this way, the OSC has the full overview of all members of the team at all times. In this scenario, we examine how the number of the team members and their speed affect the communication. We assume that the operation is at an early stage and that the team has no information about the missing persons, but only about their location the last time they communicated with their base. For this reason, the team will have to blind search the location following the random Direction Mobility Model [17]. The next search area will be determined by the evidence they will collect from the present area. While searching, the team members will also inform the OSC by sending him/her files, text or voice messages and so the data rate is defined at 164 Kbps. The team members might search the area on foot or use vehicles specifically designed for mountains, and thus the speed the team members might have ranges from 5m/s (which corresponds to the average human walking) to 55m/s (which corresponds to the speed of a vehicle). In the following table the simulation parameters for this scenario are presented in detail.

C. Archaeological Site Scenario

The third scenario describes a visit to an archaeological site. In many museums visitors are given a handheld device, and after 15 minutes of training from Explainers (high school students, volunteers etc.) the visitor could see the exhibits, find particular online resources and even get information about the exhibit as s/he comes close to it. Most of the information is acoustic, so headsets are important. Because of the advantages this practice offers with respect to a classical visit to a museum, isolation phenomena are observed to most of the users. No interaction and no collaborations between the visitors are observed and the use of headset makes the handheld device the primary exhibit. In this scenario, we assume that there is a group of tourists who want to make an organized tour to the archeological site of Vergina. In hills around Vergina, there are burial sites of the kings of Macedon, including the tomb of Philip II, father of Alexander the Great. In this environment wired networks and Wi-Fi spots do not exist. Furthermore, cellular networks cannot meet the requirements of the present scenario since the mobile phone reception is very poor to non-existent in the conditions described. With the use of handheld devices (PDAs, smart phones, and any device with a wireless connectivity) and headsets every group of tourists can form a MANET and the tour guide will be able to send multimedia packets to the tourists describing the exhibitions. In this way the tours can easily become private and so many tours could be organized at the same time without interfering with each other.

TABLE III. SIMULATION PARAMETERS OF THE ARCHEOLOGICAL SITE SCENARIO

Simulation Parameters	Values
Number of Nodes	5 – 10 – 15 – 20 – 25 – 30
Nodes' Speed	2 m×sec-1
Sender	the tour guide
Receivers	The tourists
Movement	Gauss – Markov Mobility Model
Area	1000 × 1000 m
Protocols	AODV or DSDV or OLSR
DSSS Rate	1Mbps
Packet Size	4096 bytes

Simulation Parameters	Values
Number of Packets	50 – 100 – 150 – 200 – 250 – 300 – 350 – 400 – 450 – 500
Interval	0,015 sec
Data Rate	2200 Kbps
Simulation Time	180 sec

In this scenario we examine how the number of the team members and the number of packets being sent affect the communication. From their nature, tours follow a certain pattern of mobility. The tourists follow the tour guide to a certain direction with a constant speed of 2m/s, which is the average walking speed. The tour guide sends high quality videos and voice messages to the tourists and so the data rate is defined at 2200 Kbps. Table III depicts in detail the simulation parameters for this scenario.

IV. PERFORMANCE COMPARISON

For our simulation analysis, we have used NS-3 as our network simulator (version ns-3.13) and the scripts for the scenarios studied in this paper were written in C++. The performance metrics for the evaluation of the three routing protocols (AODV, OLSR and DSDV) are the following: a) packet delivery ratio (PDR), b) throughput, c) average delay and d) total energy consumption. In the next sections, for each scenario, we investigate and compare the behavior of the routing protocols. Due to space limitations we do not present numerical results such as graphs, but instead qualitative results that show in every case which protocols achieve the best performance. The cells in the tables of the following Figures contain the routing protocol with the best performance in that case.

A. *School Field Trip Scenario*

1) *Packet Delivery Ratio*

As expected, the smaller packet sizes and the higher interval values are, the better the PDR is for every routing protocol. Also, as the DSSS Rate is increasing, the PDR is increasing too with the protocols performing better in more demanding traffic levels. So, for higher DSSS Rates and bigger packet sizes, smaller interval values can be used. DSDV and OLSR always outperform AODV. OLSR achieves the best PDR in most cases (84.1%), while DSDV achieves the best PDR in the rest (15.9%) (Fig. 2). Therefore, the best choice with respect to (wrt) PDR for this scenario is the OLSR.

a)

Dsss Rate 1Mbps		Packet Size				
		256	512	1024	2048	4096
interval	0s	DSDV	DSDV	DSDV	OLSR	OLSR
	0,05s	DSDV	DSDV	DSDV	DSDV	OLSR
	0,1s	OLSR	OLSR	DSDV	DSDV	DSDV
	0,15s	OLSR	OLSR	OLSR	OLSR	DSDV
	0,2s	OLSR	OLSR	OLSR	DSDV	DSDV
	0,25s	OLSR	OLSR	OLSR	DSDV	DSDV
	0,3s	OLSR	OLSR	OLSR	DSDV	DSDV
	0,35s	OLSR	OLSR	OLSR	OLSR	DSDV
	0,4s	OLSR	OLSR	OLSR	OLSR	DSDV
	0,45s	OLSR	OLSR	OLSR	OLSR	DSDV
	0,5s	OLSR	OLSR	OLSR	OLSR	DSDV

b)

Dsss Rate 2 Mbps		Packet Size				
		256	512	1024	2048	4096
interval	0s	DSDV	DSDV	DSDV	DSDV	OLSR
	0,05s	OLSR	OLSR	OLSR	OLSR	DSDV
	0,1s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,15s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,2s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,25s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,3s	OLSR	OLSR	OLSR	DSDV	OLSR
	0,35s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,4s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,45s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,5s	OLSR	OLSR	OLSR	OLSR	OLSR

c)

Dsss Rate 5.5 Mbps		Packet Size				
		256	512	1024	2048	4096
interval	0s	DSDV	DSDV	DSDV	DSDV	DSDV
	0,05s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,1s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,15s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,2s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,25s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,3s	OLSR	OLSR	OLSR	OLSR	DSDV
	0,35s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,4s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,45s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,5s	OLSR	OLSR	OLSR	OLSR	OLSR

d)

Dsss Rate 11 Mbps		Packet Size				
		256	512	1024	2048	4096
interval	0s	DSDV	DSDV	DSDV	DSDV	DSDV
	0,05s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,1s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,15s	OLSR	DSDV	OLSR	OLSR	OLSR
	0,2s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,25s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,3s	OLSR	OLSR	OLSR	OLSR	DSDV
	0,35s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,4s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,45s	OLSR	OLSR	OLSR	OLSR	DSDV
	0,5s	OLSR	OLSR	OLSR	OLSR	OLSR

Figure 2 Best protocol wrt PDR (a) DSSS Rate = 1Mbps, (b) DSSS Rate = 2Mbps, (c) DSSS Rate = 5.5Mbps, (d) DSSS Rate = 11Mbps

2) *Average Delay*

The delay is highly affected by the packets size (the bigger the packet size, the higher is the delay). We also found that the delay is more balanced when the interval is 0.05 seconds. This means that the difference between the lowest and the highest delay is getting smaller as the interval is being reduced. The delay is also affected by the DSSS Rate. For higher DSSS Rate values the delay is gradually decreased. In Fig. 3, AODV achieves the lowest delay only in one case. OLSR and DSDV achieve quite the same performance, with OLSR being slightly better in most cases (59.9%). For lower DSSS Rates, DSDV achieves better average delay than OLSR. As the DSSS Rates increase, OLSR outperforms DSDV.

a)

Dsss Rate 1 Mbps		Packet Size				
		256	512	1024	2048	4096
interval	0s	DSDV	DSDV	DSDV	DSDV	AODV
	0,05s	DSDV	DSDV	DSDV	DSDV	DSDV
	0,1s	OLSR	DSDV	DSDV	DSDV	DSDV
	0,15s	OLSR	OLSR	DSDV	DSDV	DSDV
	0,2s	OLSR	OLSR	OLSR	DSDV	DSDV
	0,25s	OLSR	OLSR	OLSR	DSDV	DSDV
	0,3s	OLSR	OLSR	OLSR	DSDV	DSDV
	0,35s	OLSR	OLSR	OLSR	DSDV	DSDV
	0,4s	OLSR	DSDV	DSDV	OLSR	DSDV
	0,45s	OLSR	OLSR	DSDV	OLSR	DSDV
	0,5s	DSDV	DSDV	DSDV	DSDV	DSDV

b)

Dsss Rate 2 Mbps		Packet Size				
		256	512	1024	2048	4096
interval	0s	DSDV	DSDV	DSDV	DSDV	DSDV
	0,05s	OLSR	DSDV	DSDV	DSDV	DSDV
	0,1s	OLSR	OLSR	OLSR	DSDV	DSDV
	0,15s	OLSR	OLSR	OLSR	DSDV	DSDV
	0,2s	OLSR	OLSR	OLSR	OLSR	DSDV
	0,25s	DSDV	DSDV	DSDV	OLSR	DSDV
	0,3s	OLSR	OLSR	OLSR	OLSR	DSDV
	0,35s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,4s	OLSR	DSDV	DSDV	DSDV	OLSR
	0,45s	OLSR	OLSR	OLSR	DSDV	OLSR
	0,5s	DSDV	DSDV	DSDV	DSDV	OLSR

c)

Dsss Rate 5.5 Mbps		Packet Size				
		256	512	1024	2048	4096
interval	0s	DSDV	DSDV	DSDV	DSDV	DSDV
	0,05s	OLSR	OLSR	OLSR	DSDV	DSDV
	0,1s	OLSR	OLSR	OLSR	OLSR	DSDV
	0,15s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,2s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,25s	OLSR	OLSR	OLSR	OLSR	DSDV
	0,3s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,35s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,4s	DSDV	DSDV	DSDV	DSDV	DSDV
	0,45s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,5s	OLSR	OLSR	OLSR	OLSR	DSDV

d)

Dsss Rate 11 Mbps		Packet Size				
		256	512	1024	2048	4096
interval	0s	DSDV	DSDV	DSDV	DSDV	DSDV
	0,05s	OLSR	OLSR	OLSR	OLSR	DSDV
	0,1s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,15s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,2s	OLSR	OLSR	OLSR	OLSR	DSDV
	0,25s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,3s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,35s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,4s	DSDV	DSDV	DSDV	DSDV	DSDV
	0,45s	OLSR	OLSR	OLSR	OLSR	OLSR
	0,5s	OLSR	OLSR	OLSR	OLSR	OLSR

Figure 3 Best protocol wrt Average Delay (a) DSSS Rate = 1Mbps, (b) DSSS Rate = 2Mbps, (c) DSSS Rate = 5.5Mbps, (d) DSSS Rate = 11Mbps

3) *Throughput*

As the interval and the packet size increases, the throughput increases too. Also, higher DSSS Rate values achieve higher throughput. An interesting point is that AODV's best results regardless of the DSSS Rate are when the packet size is 2048 bytes and not 4096 bytes as it is expected. Also, in most cases for DSDV and OLSR, as the DSSS Rate increases, the throughput tends to coincide regardless of the packet size and the interval. DSDV and OLSR always outperform AODV. In most cases (83.2%) OLSR achieves the highest throughput (Fig. 4). Only in few cases (16.8%) DSDV achieves the highest throughput. Therefore, the best choice with respect to throughput for this scenario should be OLSR.

a)

Dsss Rate 1 Mbps	Packet Size				
interval	256	512	1024	2048	4096
0s	DSDV	DSDV	DSDV	OLSR	OLSR
0,05s	DSDV	DSDV	DSDV	DSDV	OLSR
0,1s	OLSR	OLSR	DSDV	DSDV	DSDV
0,15s	OLSR	OLSR	OLSR	OLSR	DSDV
0,2s	OLSR	OLSR	OLSR	DSDV	DSDV
0,25s	OLSR	OLSR	OLSR	DSDV	DSDV
0,3s	OLSR	OLSR	OLSR	DSDV	DSDV
0,35s	OLSR	OLSR	OLSR	OLSR	DSDV
0,4s	OLSR	OLSR	OLSR	OLSR	DSDV
0,45s	OLSR	OLSR	OLSR	OLSR	DSDV
0,5s	OLSR	OLSR	OLSR	OLSR	DSDV

b)

Dsss Rate 2 Mbps	Packet Size				
interval	256	512	1024	2048	4096
0s	DSDV	DSDV	DSDV	DSDV	OLSR
0,05s	OLSR	OLSR	OLSR	OLSR	DSDV
0,1s	OLSR	OLSR	OLSR	OLSR	OLSR
0,15s	OLSR	OLSR	OLSR	OLSR	OLSR
0,2s	OLSR	OLSR	OLSR	OLSR	OLSR
0,25s	OLSR	OLSR	OLSR	OLSR	OLSR
0,3s	OLSR	OLSR	OLSR	DSDV	OLSR
0,35s	OLSR	OLSR	OLSR	OLSR	OLSR
0,4s	OLSR	OLSR	OLSR	OLSR	OLSR
0,45s	OLSR	OLSR	OLSR	OLSR	OLSR
0,5s	OLSR	OLSR	OLSR	OLSR	OLSR

c)

Dsss Rate 5.5 Mbps	Packet Size				
interval	256	512	1024	2048	4096
0s	DSDV	DSDV	DSDV	DSDV	DSDV
0,05s	OLSR	OLSR	OLSR	OLSR	OLSR
0,1s	OLSR	OLSR	OLSR	OLSR	OLSR
0,15s	OLSR	OLSR	OLSR	OLSR	OLSR
0,2s	OLSR	OLSR	OLSR	OLSR	OLSR
0,25s	OLSR	OLSR	OLSR	OLSR	OLSR
0,3s	OLSR	OLSR	OLSR	OLSR	DSDV
0,35s	OLSR	OLSR	OLSR	OLSR	OLSR
0,4s	OLSR	OLSR	OLSR	OLSR	OLSR
0,45s	OLSR	OLSR	OLSR	OLSR	OLSR
0,5s	OLSR	OLSR	OLSR	OLSR	OLSR

d)

Dsss Rate 11 Mbps	Packet Size				
interval	256	512	1024	2048	4096
0s	DSDV	DSDV	DSDV	DSDV	DSDV
0,05s	OLSR	OLSR	OLSR	OLSR	OLSR
0,1s	OLSR	OLSR	OLSR	OLSR	OLSR
0,15s	OLSR	DSDV	OLSR	OLSR	OLSR
0,2s	OLSR	OLSR	OLSR	OLSR	OLSR
0,25s	OLSR	OLSR	OLSR	OLSR	OLSR
0,3s	OLSR	OLSR	OLSR	OLSR	DSDV
0,35s	OLSR	OLSR	OLSR	OLSR	OLSR
0,4s	OLSR	OLSR	OLSR	OLSR	OLSR
0,45s	OLSR	OLSR	OLSR	OLSR	DSDV
0,5s	OLSR	OLSR	OLSR	OLSR	OLSR

Figure 4 Best protocol wrt Throughput (a) DSSS Rate = 1Mbps, (b) DSSS Rate = 2Mbps, (c) DSSS Rate = 5.5Mbps, (d) DSSS Rate = 11Mbps

4) Total Energy Consumption

In most cases the bigger the packet size and the interval, the higher the total energy consumption is. Furthermore, for higher DSSS Rates, the total energy consumption is lower. Interestingly, for AODV, when the DSSS Rate= 1Mbps, the energy consumption is not affected by the packet size but only by the interval. Also, for DSDV and OLSR, as the DSSS Rate increases, the energy consumption tends to coincide regardless of the packet size and the interval. Because of the associated increased routing overhead, AODV always achieves the highest energy consumption. DSDV on the other hand, has the lowest total energy consumption when the DSSS Rate is 1, 2 or 5.5Mbps (Fig. 5). When the DSSS Rate is 11Mbps, OLSR, with few exceptions, has the lowest total energy consumption. Therefore, the best choice for this scenario from the energy consumption perspective should be based on the DSSS Rate that will be chosen.

a)

Dsss Rate 1 Mbps	Packet Size				
interval	256	512	1024	2048	4096
0s	DSDV	DSDV	DSDV	DSDV	DSDV
0,05s	DSDV	DSDV	DSDV	DSDV	DSDV
0,1s	DSDV	DSDV	DSDV	DSDV	DSDV
0,15s	DSDV	DSDV	DSDV	DSDV	DSDV
0,2s	DSDV	DSDV	DSDV	DSDV	DSDV
0,25s	DSDV	DSDV	DSDV	DSDV	DSDV
0,3s	DSDV	DSDV	DSDV	DSDV	DSDV
0,35s	DSDV	DSDV	DSDV	DSDV	DSDV
0,4s	DSDV	DSDV	DSDV	DSDV	DSDV
0,45s	DSDV	DSDV	DSDV	DSDV	DSDV
0,5s	DSDV	DSDV	DSDV	DSDV	DSDV

b)

Dsss Rate 2 Mbps	Packet Size				
interval	256	512	1024	2048	4096
0s	DSDV	DSDV	DSDV	DSDV	DSDV
0,05s	DSDV	DSDV	DSDV	DSDV	DSDV
0,1s	DSDV	DSDV	DSDV	DSDV	DSDV
0,15s	DSDV	DSDV	DSDV	DSDV	DSDV
0,2s	DSDV	DSDV	DSDV	DSDV	DSDV
0,25s	DSDV	DSDV	DSDV	DSDV	DSDV
0,3s	DSDV	DSDV	DSDV	DSDV	DSDV
0,35s	DSDV	DSDV	DSDV	DSDV	DSDV
0,4s	DSDV	DSDV	DSDV	DSDV	DSDV
0,45s	DSDV	DSDV	DSDV	DSDV	DSDV
0,5s	DSDV	DSDV	DSDV	DSDV	DSDV

c)

Dsss Rate 5.5 Mbps	Packet Size				
interval	256	512	1024	2048	4096
0s	DSDV	DSDV	DSDV	DSDV	DSDV
0,05s	DSDV	DSDV	DSDV	DSDV	DSDV
0,1s	DSDV	DSDV	DSDV	DSDV	DSDV
0,15s	DSDV	DSDV	DSDV	DSDV	DSDV
0,2s	DSDV	DSDV	DSDV	DSDV	DSDV
0,25s	DSDV	DSDV	DSDV	DSDV	DSDV
0,3s	DSDV	DSDV	DSDV	DSDV	DSDV
0,35s	DSDV	DSDV	DSDV	DSDV	DSDV
0,4s	DSDV	DSDV	DSDV	DSDV	DSDV
0,45s	DSDV	DSDV	DSDV	DSDV	DSDV
0,5s	DSDV	DSDV	DSDV	DSDV	DSDV

d)

Dsss Rate 11 Mbps	Packet Size				
interval	256	512	1024	2048	4096
0s	OLSR	OLSR	OLSR	OLSR	OLSR
0,05s	OLSR	OLSR	OLSR	OLSR	OLSR
0,1s	DSDV	OLSR	OLSR	OLSR	OLSR
0,15s	OLSR	OLSR	OLSR	OLSR	OLSR
0,2s	OLSR	OLSR	OLSR	OLSR	DSDV
0,25s	OLSR	OLSR	OLSR	OLSR	DSDV
0,3s	OLSR	OLSR	OLSR	OLSR	OLSR
0,35s	OLSR	OLSR	OLSR	OLSR	OLSR
0,4s	OLSR	OLSR	OLSR	OLSR	OLSR
0,45s	OLSR	OLSR	OLSR	OLSR	OLSR
0,5s	OLSR	OLSR	OLSR	OLSR	DSDV

Figure 5 Best protocol wrt Total Energy Consumption (a) DSSS Rate = 1Mbps, (b) DSSS Rate = 2Mbps, (c) DSSS Rate = 5.5Mbps, (d) DSSS Rate = 11Mbps

B. Rescue Operation Scenario

1) Packet Delivery Ratio

From the simulation results, we observe that the PDR is not affected by the nodes' speed, but by the number of nodes. As the number of nodes increases, the PDR decreases. Only in some cases and not in a certain pattern, the speed slightly affects the PDR of AODV. DSDV and OLSR always outperform AODV. In almost every case (99%) OLSR achieves the best PDR (Fig. 6). In only one case, DSDV achieves the best PDR. Therefore, the best choice with respect to PDR for this scenario should be OLSR.

	Speed										
Number of Nodes	5	10	15	20	25	30	35	40	45	50	55
10	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	DSDV	OLSR	OLSR	OLSR	OLSR
20	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
30	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
40	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
50	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
60	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
70	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
80	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
90	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
100	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR

Figure 6 Best protocol wrt PDR

2) Average Delay

As with PDR, the delay is also not affected by the nodes' speed, but by the number of nodes. As the number of nodes increases, the delay increases too. It is interesting to see that for DSDV and OLSR, when the number of nodes is less than 50 the delay is almost 0 seconds. For higher number of nodes the delay is more than 0.5 seconds. AODV always achieves the highest delay. Moreover, from Fig. 7, we observe that OLSR outperforms DSDV in most cases (89.09%) and therefore, it is the best choice if we are interested for delay-critical application scenarios as is the case of the rescue operation scenario.

	Speed										
Number of Nodes	5	10	15	20	25	30	35	40	45	50	55
10	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
20	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
30	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
40	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
50	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
60	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV
70	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	DSDV	OLSR
80	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
90	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
100	OLSR	DSDV	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR

Figure 7 Best protocol wrt Average Delay

3) Throughput

Concerning the throughput, the results are totally different for the two routing strategies (table driven and on-demand). Regarding AODV, the throughput decreases as the number of nodes is getting bigger. This is because AODV achieves smaller PDR for larger groups (bigger number of nodes).

Furthermore, the speed affects slightly the throughput performance of the AODV. Unlike AODV, the throughput in DSDV and OLSR increases as the number of nodes increases. This happens because, despite the fact that the PDR of DSDV and OLSR is being decreased as the number of nodes increases, the percentage of the successfully delivered packets is still at a satisfactory level (the PDR is almost 50% for 100 nodes). Speed does not affect the performance of DSDV and OLSR. In almost every case (99.09%) OLSR achieves the best throughput (Fig. 8). Therefore, the best choice with respect to throughput for this scenario should be OLSR.

Number of Nodes	Speed 5	10	15	20	25	30	35	40	45	50	55
10	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	DSDV	OLSR	OLSR	OLSR	OLSR
20	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
30	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
40	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
50	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
60	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
70	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
80	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
90	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
100	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR

Figure 8 Best protocol wrt Throughput

4) *Total Energy Consumption*

Based on the simulation results, the total energy consumption is also not affected by the nodes' speed. Instead, the number of nodes affects the total energy consumption. As such, as the number of nodes increases, the total energy consumption increases too. Similar to the previous metrics, DSDV and OLSR outperform AODV in all cases. In most cases (88.18%), OLSR achieves the lowest energy dissipation (Fig. 9). DSDV is the best choice only when the number of nodes is 10. Accordingly, when the total energy consumption concerns us the most in this scenario, OLSR is the best choice.

Number of Nodes	Speed 5	10	15	20	25	30	35	40	45	50	55
10	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV
20	OLSR	OLSR	OLSR	OLSR	OLSR	DSDV	DSDV	DSDV	OLSR	OLSR	OLSR
30	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
40	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
50	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
60	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
70	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
80	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
90	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
100	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR

Figure 9 Best protocol wrt Total Energy Consumption

C. *Archaeological Site Scenario*

1) *Packet Delivery Ratio*

Based on the simulation results, the PDR is affected by the number of nodes and by the number of packets being sent. As expected, the heavier the traffic, the lower the PDR is. Also, as the number of nodes increases, the PDR decreases. Regarding AODV, even for light traffic (5 nodes and 50 packets) the PDR does not surpass the 60% and therefore has never the best PDR. In most cases, OLSR exhibits the best PDR (Fig. 10). It succeeds in delivering packets at 98.5% regardless of the simulation parameters in use. DSDV on the other hand achieves better results for small number of nodes or for small number of packets. A certain pattern is observed; when the number of packets is 50 or 100, the PDR is 100%. Exceeding 100 packets, there is a decrease which seems to reach its peak when there are 200 packets. After that the PDR increases without reaching though 100%. Therefore, in this scenario, the best choice when the PDR matters the most, is OLSR when the number of packets is high and DSDV when the number of packets is small or the network size is small.

Number of Nodes	Number of Packets 50	100	150	200	250	300	350	400	450	500
5	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV
10	DSDV	DSDV	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
15	DSDV	DSDV	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
20	DSDV	DSDV	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
25	DSDV	DSDV	DSDV	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
30	DSDV	DSDV	DSDV	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR

Figure 10 Best protocol wrt PDR

2) *Average Delay*

When evaluating the performance of the routing protocols in terms of average delay we observe that this metric is greatly affected by the number of packets (the higher the number of packets, the higher the average delay is). In case of AODV, the delay is also affected by the number of nodes. Until the number of nodes becomes 20, the delay increases with a higher rate compared to the cases where the number of nodes are higher than 20 (this is also more intense for small number of packets). In case of OLSR and DSDV, the average delay is not dramatically affected by the number of nodes. AODV always achieves the highest delay in delivering packets. DSDV outperforms OLSR in every case (Fig. 11). Therefore, in this scenario, the best choice when the average delay concerns us the most is DSDV.

Number of Nodes	Number of Packets 50	100	150	200	250	300	350	400	450	500
5	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV
10	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV
15	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV
20	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV
25	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV
30	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV

Figure 11 Best protocol wrt Average Delay

3) *Throughput*

As expected, the higher the number of packets and nodes, the higher the throughput is. In the case of AODV, the throughput does not reach high levels due to the low percentages of the PDR. Concerning DSDV and OLSR, the throughput increases linearly as the number of nodes is increasing (Fig. 12 and 13). Overall, AODV achieves the lowest throughput. OLSR achieves the best throughput in most cases (63.4%). In the rest cases (36.6%), DSDV outperforms OLSR. Therefore, in this scenario, the best choice based on the throughput is OLSR when the number of packets being transmitted is high. DSDV is the best choice when the number of packets being transmitted or the number of nodes is small (Fig. 14).

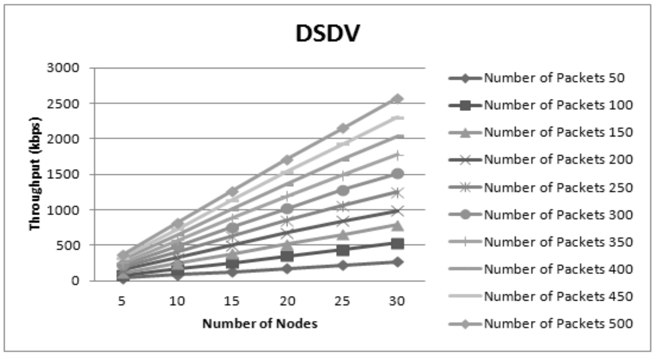

Figure 12 Throughput vs. Number of Nodes, DSDV Routing Protocol

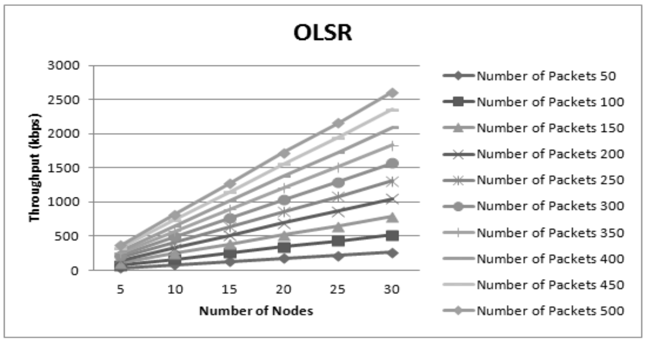

Figure 13 Throughput vs. Number of Nodes, OLSR Routing Protocol

		Number of Packets									
		50	100	150	200	250	300	350	400	450	500
Number of Nodes	5	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV
	10	DSDV	DSDV	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
	15	DSDV	DSDV	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
	20	DSDV	DSDV	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
	25	DSDV	DSDV	DSDV	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR
	30	DSDV	DSDV	DSDV	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR	OLSR

Figure 14 Best protocol wrt Throughput

4) *Total Energy Consumption*

As expected, for all three protocols and especially for DSDV and OLSR, the total energy consumption is linearly affected by the number of packets being sent and by the number of nodes participating in the network (Fig. 15 and 16). DSDV outperforms all protocols in every case, while AODV is the worst (Fig. 17). Therefore, the best choice for this scenario based on the total energy consumption is DSDV.

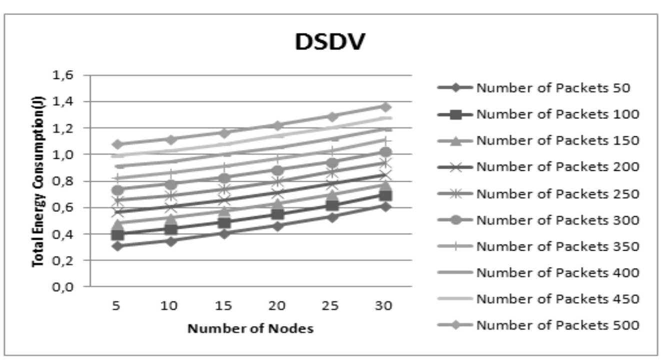

Figure 15 Total Energy Consumption vs. Number of Nodes, DSDV Routing Protocol

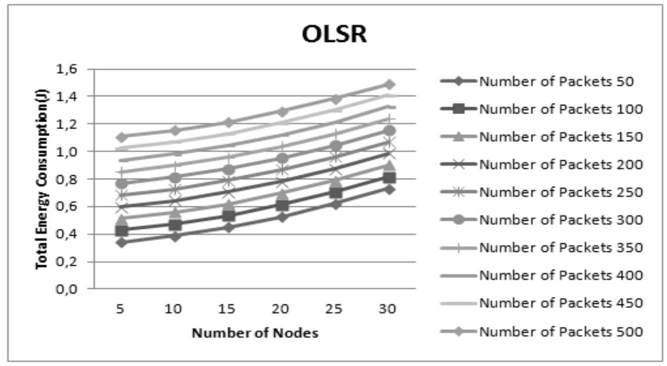

Figure 16 Total Energy Consumption vs. Number of Nodes, OLSR Routing Protocol

		Number of Packets									
		50	100	150	200	250	300	350	400	450	500
Number of Nodes	5	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV
	10	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV
	15	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV
	20	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV
	25	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV
	30	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV	DSDV

Figure 17 Best protocol wrt Total Energy Consumption

V. CONCLUSIONS

In this paper, we have examined the performance of the AODV, DSDV and OLSR routing protocols in three real-life scenarios by varying the simulation parameters in each scenario and by measuring four performance metrics (Packet Delivery Ratio (PDR), Average Delay, Throughput, and Total Energy Consumption).

Considering the aforementioned simulation-based results, we can conclude that considering PDR and regardless of the size of the network, OLSR performs better. Also, DSDV achieves better results for bigger packets sizes and for lower DSSS Rates. Considering the average delay, DSDV performs better for lower DSSS Rates. For small networks, OLSR achieves better results and as the size of the network increases, DSDV performs better. Average delay exhibits large variability in AODV (recall that it is a reactive protocol), but remains almost constant (with extremely small changes) as the number of nodes and the speed changes in OLSR and DSDV (Proactive Protocols). Considering the throughput, regardless of the size of the network, OLSR performs better. DSDV achieves better results for bigger packets sizes and for lower DSSS Rates. For the total energy consumption, DSDV performs better for bigger packets sizes and OLSR achieves better results for higher DSSS Rates, when the size of the network is small (less than 40 nodes).

Overall, it is clear that DSDV and OLSR always outperform AODV. In most cases, DSDV and OLSR achieve similar results due to their similar nature (they both are proactive routing protocols). However, the selection of the proper routing protocol depends highly on the application in use. Finally, we observed that the speed of the mobile nodes or the mobility pattern does not affect the performance of the protocols on small and average size networks.

REFERENCES

[1] I. Chlamtac, M. Conti and J. Liu "Mobile ad hoc networking: imperatives and challenges" Ad Hoc Networks 1 , pp. 13-64, 2003.

[2] L.C. Cano and P. Manzoni, "A Performance Comparison of Energy Consumption for Mobile Ad Hoc Networks Routing Protocols", MASCOTS '00 Proceedings of the 8th International Symposium on Modeling, Analysis and Simulation of Computer and Telecommunication Systems, 2000.

[3] E. Ahvar and M. Fathy, "Performance Evaluation of Routing Protocols For High Density Ad Hoc Networks based on Energy Consumption by GlomoSim Simulator", World Academy of Science, Engineering and Technology, 2007.

[4] Y.K. Hassan, M.H. Abd El-Aziz and A.S. Abd El-Radi, "Performance Evaluation of Mobility Speed over MANET Routing Protocols", International Journal of Network Security, pp. 128-138, November 2010.

[5] G. Adam, C. Bouras, A. Gkamas, V. Kapoulas, G. Kioumourtzis, and N. Tavoularis, "Performance Evaluation of Routing Protocols for multimedia transmission over Mobile Ad hoc Networks", 4th Joint IFIP Wireless and Mobile Networks Conference, Toulouse, France, October 26-28, 2011.

[6] D. O. Jörg, "Performance Comparison Of MANET Routing Protocols In Different Network Sizes", Institute of Computer Science and Applied Mathematics Computer Networks and Distributed Systems, 2003.

[7] K. Sadasivam, V. Changrani and T.A. Yang, "Scenario Based Performance Evaluation of Secure Routing in MANETs", in Proceedings of ICWN, 2005.

[8] N. Qasim, F. Said and H. Aghvami, "Mobile Ad Hoc Networks Simulations Using Routing Protocols for Performance Comparisons" Proceedings of the World Congress on Engineering 2008, London, U.K., Vol I, WCE 2008, July 2 - 4, 2008.

[9] A.K. Gupta, H. Sadawarti and A.K. Verma, "Performance analysis of AODV, DSR & TORA Routing Protocols" IACSIT International Journal of Engineering and Technology, Vol.2, No.2, April 2010.

[10] A. Vasiliou and A.A. Economides, "Evaluation of Multicasting Algorithms in Manets" Proceedings 3rd World Enformatika Conference (WEC' 05) - International Conference on Telecommunications and Electronic Commerce (TEC 2005), 2005.

[11] Y. Liu, P. Ning, H. Dai and A. Liu "Randomized Differential DSSS: Jamming-Resistant Wireless Broadcast Communication" IEEE INFOCOM 2010 proceedings, 2010.

[12] X. Hong, K. Xu and M. Gerla, "Scalable routing protocols for mobile ad hoc networks", University of California, Los Angeles, CA 90095, 2002.

[13] C.E. Perkins, E. Belding-Royer and S. Das, "Ad hoc On-Demand Distance Vector (AODV) Routing". IETF NetworkWorking Group, July 2003.

[14] C.E. Perkins and P. Bhagwat, "Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for Mobile Computers" London England UK: SIGCOMM 94-8/94, 1994.

[15] T. Clausen and P. Jacquet, "Optimized Link State Routing Protocol (OLSR)" RFC 3626. IETF Network Working Group, October 2003.

[16] B. Liang and Z.J. Haas, "Predictive Distance-Based Mobility Management for PCS Networks" Proceedings of IEEE Information Communications Conference (INFOCOM 1999), April 1999.

[17] F. Bai and A. Helmy, "A Survey of Mobility Models in Wireless Adhoc Networks", University of Southern California, U.S.A., 2006.