COMPARATIVE ANALYSIS OF ROUTING PROTOCOLS IN MOBILE AD HOC NETWORKS

Mohamed Elboukhari[1], Mostafa Azizi[1] and Abdelmalek Azizi[2,3]

[1]Department of Applied Engineering, ESTO, Oujda, Morocco
[2]Departement Mathematics & Computer Science, FSO, Oujda, Morocco
[3]Academy Hassan II of Sciences & Technology, Rabat, Morocco

ABSTRACT

A Mobile Ad Hoc Network (MANET) is a collection of mobile nodes that want to communicate without any pre-determined infrastructure and fixed organization of available links. Each node in MANET operates as a router, forwarding information packets for other mobile nodes. There are many routing protocols that possess different performance levels in different scenarios. The main task is to evaluate the existing routing protocols and finding by comparing them the best one. In this article we compare AODV, DSR, DSDV, OLSR and DYMO routing protocols in mobile ad hoc networks (MANETs) to specify the best operational conditions for each MANETs protocol. We study these five MANETs routing protocols by different simulations in NS-2 simulator. We describe that pause time parameter affect their performance. This performance analysis is measured in terms of Packet Delivery Ratio, Average End-to-End Delay, Normalized Routing Load and Average Throughput.

KEYWORDS

Mobile Ad Hoc Network (MANET), Performance Parameters, AODV, DSR, DSDV, OLSR, DYMO.

1. Introduction

Wireless networks are organized in two basic types that are infrastructure based wireless networks and ad hoc based wireless networks. In the infrastructure based wireless network, nodes are mobile, base stations are fixed. As a consequence of this, nodes can leave the range of the base stations and comes in range of other base stations. In ad hoc based wireless networks, nodes are kept mobile but the base stations are not kept fixed and the entire nodes operate as routers.
Researchers have done huge work to develop routing protocols in different kinds of ad hoc networks like MANETs (Mobile Ad Hoc Networks), WSNs (Wireless Sensor Networks), WMNs (Wireless Mesh Networks), and VANETS (Vehicular Ad-Hoc Networks) etc. [1]. The main objective of MANETs is to elaborate routing functionality at each of the mobile node is. For designing MANETs routing protocols aspect approach, the information-theoretic approach, game-theoretic approach or dynamic control approach has been applied [2].

In mobile ad hoc networks, a mobile node can communicate with other mobile stations whether they lie within the same radio transmission range or not. Therefore, four important functions are to be implemented by the routing protocols: maintaining network connectivity, network topology, packet routing, scheduling and channel assignment. Routing protocols are designed in MANETs with some basic goals that are minimum control overhead, minimum processing overhead, multi-hop routing, dynamic topology maintenance and loop prevention [3].

The remainder of the paper is organized as follows. After describing the related works in section 2, MANETs routing protocols are presented in section 3. Section 4 describes simulation environment. The results of our simulations are analysed in section 5. Finally, section 6 concludes the paper.

2. Related Works

Many works have been elaborated related to the performance comparison of different routing protocols in MANET. We focus on those works performed by network simulator NS-2.

Table 1. Performance analysis of MANET routing protocols.

Ref. no	Protocols used	Performance metrics	Variable Parameters
[4]	AODV, DSR, DSDV	End to End Delay, Packet Delivery Ratio, Normalized routing load, Throughput	Mobility
[5]	AODV, DSR, DSDV	End to End Delay, Packet Delivery Ratio, Throughput	Number of nodes
[6]	AODV, DSR, DSDV	Packet Delivery Ratio, End to End Delay, Normalized Routing Load	Pause time, Mobility and Sending rate
[7]	AODV, DSR, DSDV	Average End to End Delay, Normalized Routing Load, Packet Delivery Ratio,	Number of Nodes, Speed, Pause time, Transmission Power
[8]	DSDV, AODV, DSR, TORA	Throughput, Routing Overhead, Path Optimality, Packet Loss, Average delay	Traffic Load, Movement patterns
[9]	AODV, DSR, DSDV	Packet Delivery Ratio, Average End to End Delay, Routing Overhead	Pause time
[10]	AODV, DSR, DSDV	Packet Delivery Ratio, Average End to End Delay, Normalized Routing Load	Pause time, Number of nodes and mobility
[11]	DSDV, AODV, DSR, TORA	Average Delay,Jitter, Routing Load, Loss Ratio, Throughput and Connectivity	Network size
[12]	DSDV, AODV	Packet Delivery Fraction, Average End to End Delay, Throughput	Number on nodes, Speed, Time
[13]	AODV, DSDV	Packet Delivery Ratio, Average End to End Delay	Mobility of nodes

Table 1 illustrate that comparative performance evaluation for all the parameters namely Packet Delivery Ratio, Throughput, Average End to End Delay, Jitter, Routing Load, and Routing Frequency among the routing protocols have not been elaborate in a single paper.

In our article, we will compare five MANET protocols (AODV, DSR, DSDV, OLSR, and DYMO). In our knowledge, there is no work in the literature until now which compares these five protocols under varying pause time parameter.

3. Routing Protocls in MANET

The MANETs routing protocols are divided into three categories depending on their functionality: Reactive (On-demand) routing protocols, Proactive (Table-driven) routing protocols and Hybrid routing protocols [14].

Proactive Routing Protocols: The routing data in these routing protocols is stored in the organization of tables managed by each mobile node. The tables must be updated due to continuous change in the network topology. These protocols are employed where the route requirements are frequent. FSR, STAR, GSR, DSDV, OLSR, CGSR and WRP are the examples.
Reactive Routing Protocols: These routing protocols discover routes to other mobile nodes only when they are needed. A route discovery process is invoked when a node wants to exchange a few messages with another node for which it does not possess a route table access. AODV, DSR, LAR, TORA, CBRP and ARA are the examples.

Hybrid Routing Protocols: These protocols combine intrinsic worth of both the proactive and reactive approaches. For illustration, proactive protocols could be employed between networks and reactive protocols inside the networks. DST, ZRP, DDR, ZHLS are the examples.

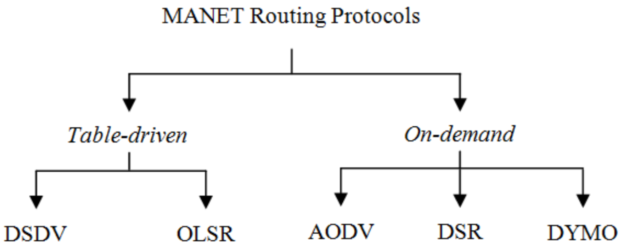

Figure 1. Classification of MANET Routing Protocols

3.1. Ad-hoc On-Demand distance Vector routing protocol (AODV)

AODV [15, 16] is a reactive routing protocol which employs an on-demand approach for finding routes, so a route is elaborated only when it is requisite by a source node for sending information packets. AODV uses sequence numbers to make certain freshness of routes. It employs route request (RREQ) messages flooded through the network to discover the paths needed by a source node. AODV aids nodes to locate out routes very fast for new destinations, and does not require nodes to manage routes to destinations that are not in dynamic communication. AODV helps nodes to operate in response to link breakages and changes in network topology in a timely manner and the operation of AODV is loop-free [17]. If a route to a new destination is demanded, the source node broadcasts a RREQ message to find a route to the requisite destination. An intermediate node that receives a RREQ replies to it employing route reply message only if it possess a route to the destination whose analogous destination sequence number is greater or equal to the one used in the RREQ. Another important point to mention is that the RREQ also contains the most recent sequence number for the destination of which the source node is responsive. When a node receives the RREQ it may send a route reply (RREP) if it is either the destination node or if it possesses a route to the destination with equivalent sequence number greater than or equal to that included in the RREQ message. In this last case, it unicast a RREP reverse message to the source node. Otherwise, it rebroadcasts the RREQ message. Nodes store track of the RREQ's source IP address and broadcast ID.

3.2. Dynamic Source Routing (DSR)

Dynamic Source Routing (DSR) [18] is a routing protocol for wireless mesh networks and is elaborated according to the technique known as “source routing”. DSR makes the network completely self-organizing and self-configuring, devoid of the need for any pre-existing network infrastructure.

The Dynamic Source Routing protocol possesses two main mechanisms route discovery and route maintenance. In the route discovery process a source node wishing to drive a packet to a destination node, as certain a source route to the destination. In route maintenance mechanism a node wishing to transmit a packet to a destination is able to perceive, while using a source route to the destination, if the network topology has altered such that it can no longer make use of its route to destination because a link along the route no longer works. And in case when Route Maintenance indicates a source route is broken, source can try to bring into play any other route, it happens to know to destination, or it can invoke route discovery again to find a new route for subsequent packets to destination.

3.3. Dynamic MANET On-Demand Routing Protocol (DYMO)

DYMO [19] manages a large variety of mobility patterns by dynamically discovering routes on-demand. It also manages a wide selection of traffic patterns. The fundamental functionalities of DYMO are route discovery and route maintenance.

During route discovery process, a DYMO router lunches a flooding of a Route Request message (RREQ) throughout the MANET to come across a route to a particular destination node. During the hop-by-hop flooding process, each intermediate DYMO router receiving the RREQ message stores a route to the originator node. When the target’s DYMO router receives the RREQ message, it stores a route to the originator and responds with a Route Reply (RREP), unicasting hop-by-hop through originating DYMO router. Each intermediate DYMO router that receives the RREP message creates a route to the target, and then the RREP is unicasted hop-by-hop on the way to the originator. When the originator’s DYMO router receives the RREP message, routes have been elaborated between the originating DYMO router and the target DYMO router in both directions.

Route maintenance is composed of two operations. To conserve routes in use, DYMO routers expand route lifetimes upon successfully forwarding a packet. To act in response to changes in the network topology, DYMO routers keep an eye on traffic being forwarded. If a data packet is received to be forwarded and a route for the destination is not known (or the destination route is broken down), then the DYMO router of the source node of the data packet is notified. A Route Error (RERR) is sent to point out the route to one or more affected destination addresses is broken or misplaced. When the source’s DYMO router receives the RERR message, it marks the route as broken. Before the DYMO router can forward a data packet to the same destination, it has to lunch the route discovery mechanism again for that destination.

3.4. Destination Sequenced Distance Vector (DSDV) Protocol

DSDV [20] is one of the examples of proactive protocol. The protocol adds a new attribute, sequence number, to each route table entry at each node. Each node maintains a routing table at its own and which aids in packet transmission.

For the transmission of packets each node stores routing table. The routing contains the information for the connectivity to different stations in the network. These stations give all the available destinations and the number of stations (hops) required to reach each destination in the routing table. The routing entry is tagged with a sequence number which is originated by the destination node. Each station sends and updates its routing table periodically. The packets being broadcasted between nodes indicate a list of accessible stations and number of nodes required to reach that particular station. Routing information is broadcast periodically by broadcasting or multicasting the packets. In DSDV protocol each mobile node in the network must constantly advertise its routing table to each of its neighboring stations. As the information in the table may change frequently, the advertisement should be done on the continuous basis so that every station can locate its neighbors in the network. It ensures the shortest number of nodes (hops) required from source station to a destination station.

The data broadcasted by each mobile node will include its new sequence number and the following data for each new route: the number of hops required to reach the destination, the destination address and the new sequence number (originally stamped by the destination).

3.5. Opitmized Link State Routing (OLSR) Protocol

OLSR [21] is an optimization of a pure link state protocol. Whenever there is any modification in the topology then information is flooded to all nodes. This causes overheads and such overheads are decreased by Multipoint relays (MPR). Two types of control messages are employed in OLSR; they are topology control and hello messages. There is also Multiple Interface Declaration (MID) messages which are employed for announcing other host that the announcing host can possess multiple OLSR interface addresses [22]. The MID message is broadcasted throughout the network only by MPRs. Also there is a “Host and Network Association” (HNA) message which gives the external routing information by giving the possibility for routing to the external addresses.

4. Simulation Environment

4.1. Mobility Model

A model that describes the movement of mobile nodes, and changes in their velocity and acceleration over time is called Mobility model. Basic parameters related to node movement are mobility speed, number of nodes, sending rate, pause time, number of connections, simulation duration. Mobility models can be categorized in to two types group and entity models. the motion of mobile nodes in entity models are independent from each other, while in group models the movements of mobile nodes are dependent on each other [23].

In our article we chose the Random Waypoint Mobility, generated by the software BonnMotion [24]. It is an entity model, in which a node can choose any random destination and any random velocity. The node starts moving towards the selected destination node. After reaching the destination node, the node stops for a small duration defined by the “Pause Time” parameter and it repeats the complete process again until the simulation process ends.

4.2. Simulation Parameters

We elaborate the experiments for the evaluation of the performance of Ad Hoc routing protocol AODV, DSR, DSDV, OLSR and DYMO with varying the Pause Time parameter. We have elaborated 30 simulation run in total out of which 30 trace files has been derived for Random Waypoint Mobility each. We tested all performance metrics in our experiment under varying

Pause Time of node (0 to 50sec) and while other parameters are constant. Table 1 presents the simulation parameters used in this evaluation.

Table 2. Simulations parapmeters

Parameters	*Value*
Simulator	NS-2.34
Data packet size	512 byte
Simulation duration	50 sec
Environnement size	500m × 500m
Number of Nodes	20
Pause Time	0 to 50 sec
MAC Layer Protocol	IEEE 802.11
Traffic Type	CBR
Number of connections	15
Maximum Mobility	20 m/s
Mobility Model	Random Waypoint
Protocols	AODV, DSR, DSDV, OLSR, DYMO

4.3. NS-2 simulator

The network simulations have been performed using network simulator NS-2 [25]. The NS-2 simulator is discrete event simulation software used for network simulations. It simulates events such as sending, receiving, dropping and forwarding packets. The ns-allinone-2.34 [25] supports simulation for some MANET routing protocols as AODV, DSR and DSDV. The simulation of protocols OLSR and DYMO are based on the work presented in [26]. NS-2 is implemented in C++ programming language with Object Tool Common Language.

Although NS-2. 34 can be implemented on different platforms, for this article, we choose a Linux platform i.e. Ubuntu LTS 12.04, as Linux offers a number of programming development tools as [27] that can be used with the simulations process. To run a NS-2.34 simulation, the user must write the OTCL simulation script. Also NS-2 provides a visual representation of the simulated network by tracing nodes events and movements and writing them in a file named as Network Animator or NAM file [25]. The performance parameters are graphically visualized in MATLAB [28].

4.4. Performance Metrics

RFC2501 [29] illustrates a number of quantitative metrics that can be used for evaluating the performance of MANET routing protocols. To analyze routing protocols (AODV, DSR, DSDV, OLSR and DYMO), we have focused on four performance metrics for evaluation which are Packet Delivery Fraction, Average End-to-End Delay, Normalized, Routing Load and Average Throughput.

4.4.1. Packet Delivery Fraction

The Packet Delivery Fraction is defined as the ratio of number of received packets successfully at the destinations nodes over the number of packets sent by the sources nodes. Packet Loss Fraction is defined as 1- Packet Delivery Fraction.

4.4.2. Average End to End Delay

The Average End to end delay is the average time from the transmission of a data packet at a source node until data packet delivery to a destination node which contains all possible delays generated by queuing at the interface queue, buffering during route discovery process, propagation and transfer times of data packets and retransmission delays.

4.4.3. Normalized Routing Load

The Normalized Routing Load is described as the ratio of all control packets sent by all source nodes to number of received data packets at the destination nodes.

4.4.4. Average Throughput

The Average Throughput is the average number of packets successfully delivered per unit time. It can be calculated as the number of bits delivered per second.

5. Simulation Results and Analysis

The results after simulation are viewed in five figures. The performance of MANETs routing protocols based on the varying the Pause Time is elaborated on parameters like Packet Delivery Fraction, Average End-to-End Delay, Normalized Routing Load and Average Throughput.

5.1. Packet Delivery Fraction (PDF)

Figure 2 shows that the PDR of AODV and DSR is greater than other protocols DYMO, OLSR and DSDV. At the height mobility (Pause Time is equal to 0), the protocol DSR has a better PDF when compared to other protocol. The protocol DSDV exhibits the lowest PDF in all scenarios. With the decreasing of mobility (increase of Pause Time), the protocols AODV, DSR and DYMO have a better value of PDF than the protocols OLSR and DSDV. It seems that on-demand protocols perform well than table-driven protocols. Because table-driven approach of managing routing information, it is not as adequate to the route changes which occur during high mobility. The lazy approach in contrast used by the on-demand protocols to maitain the routing information as and when they are created make them more adequate and result in better performance (high PDF).

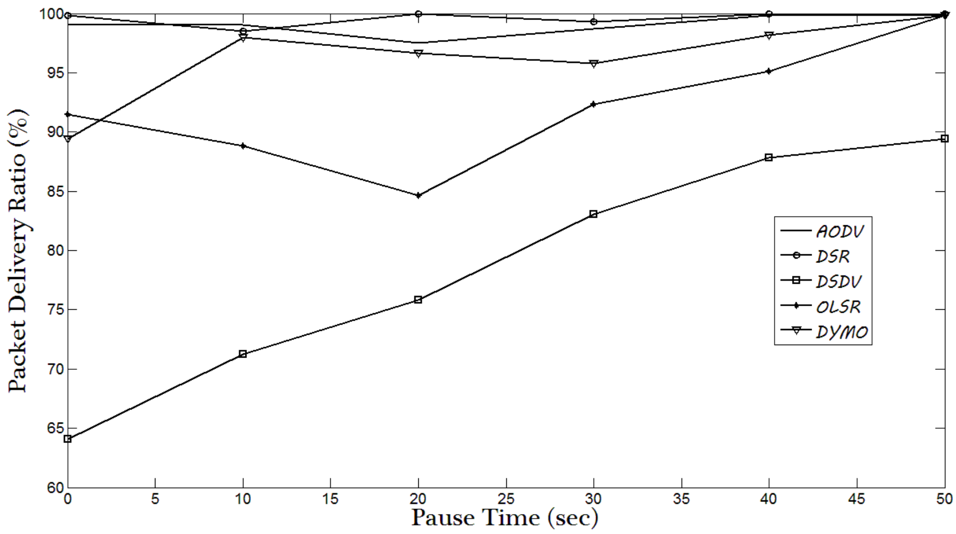

Figure 2: Packet Delivery Fraction versus Pause Time

5.2. Average End to End Delay (E2E)

From Figure 3, it can be observed that OLSR exhibits the lowest average E2E except on one scenario when Pause Time equal to 10s. In this scenario, the other protocol of table-driven protocol DSDV has the lowest E2E. With height mobility (Pause Time equal to 0s) and low mobility (Pause Time equal to 50s), OLSR and DSDV have the lowest average E2E. OLSR and DSDV as table-driven protocols have routing tables and they do not need to discover the route for the same destination.

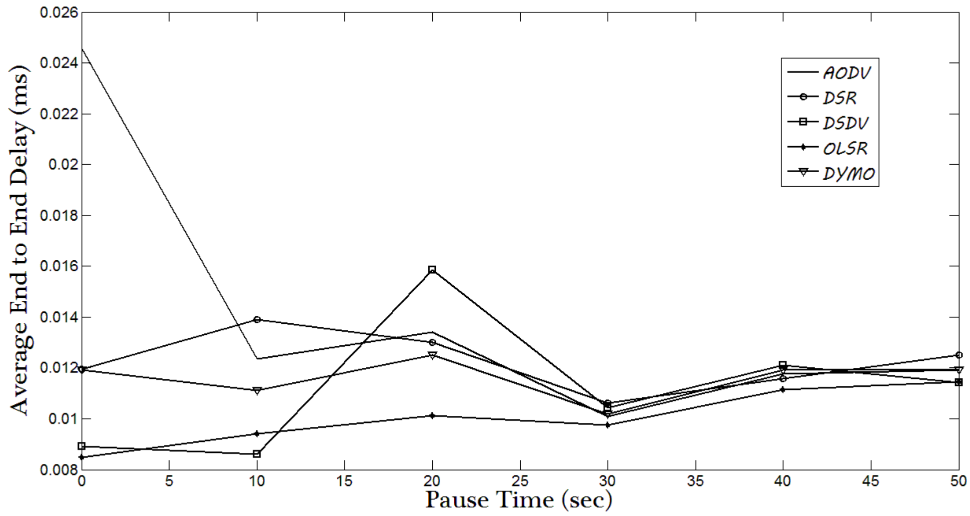

Figure 3: Average End to End Delay versus Pause Time

5.3. Routing Load

From Figure 4, we remark that DSR demonstrates the lowest and OLSR shows highest Normalized Routing Load. In on-demand protocols (AODV, DSR and DYMO), the routes are maintained only between the nodes which want to communicate as well as a single route discovery may yield many routes to the destination, therefore, the routing overhead is less. In comparing the two table-driven protocols (DSDV and OLSR), OLSR has more Normalized Routing Load than DSDV.

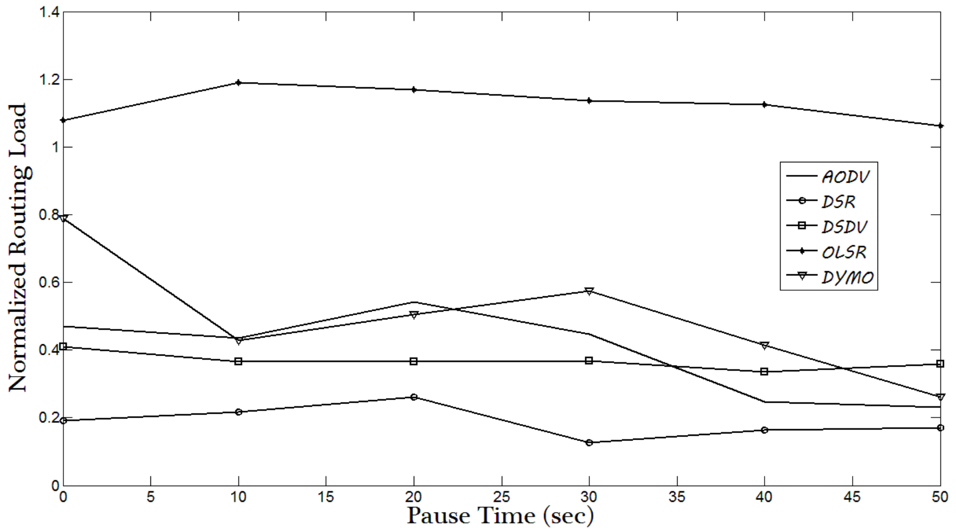

Figure 4: Normalized Routing Load versus Pause Time

5.4. Average Throughput

The Figure 5 shows that the DSDV gives the lowest Average Throughput. We note also that the DSDV Throughput increases with the increasing of Pause Time. The three protocols AODV, DSR and DYMO have better Average Throughput when compared to two protocols OLSR and DSDV. It seems as on-demand protocols outperform table-driven protocols in almost all the scenarios we have taken into account.

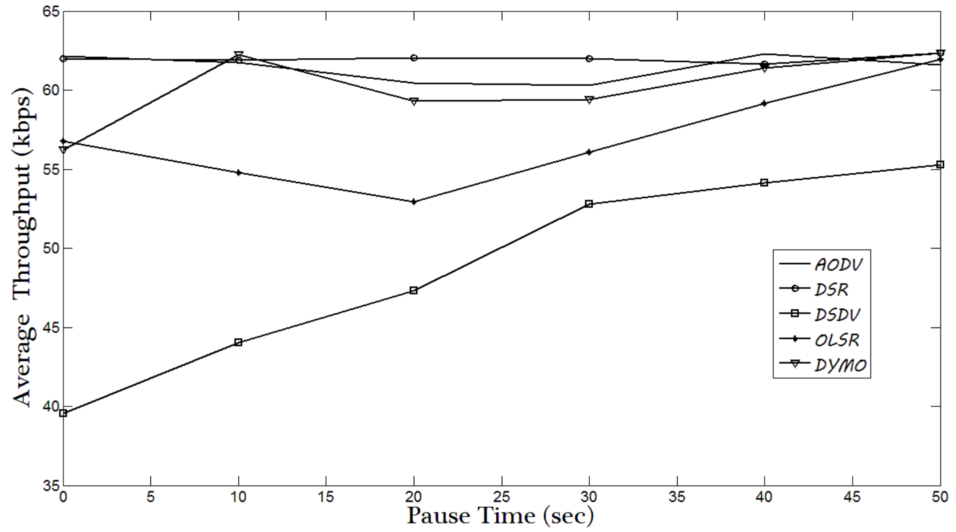

Figure 5: Average Throughput versus Pause Time

6. Conclusions

In this article different MANETs routing protocols such as AODV, DSR, DSDV, OLSR and DYMO is evaluated. With the help of NS-2 simulation we compared these protocols under different network conditions. We measure the Packet Delivery Ratio, Average End to End, Routing Load, and Average Throughput as performance matrices.

In terms of Packet Delivery Packet, AODV and DSR are better than other protocols (DSDV, OLSR and DYMO). OLSR shows the lowest Average End to End Delay (good performance) compared to other protocols. DSR demonstrates the lowest Normalized Routing Load than other protocols. AODV, DSR and DYMO outperform other protocols (OLSR, DSDV) in terms of Average Throughput.

In our future work, we will focus on extending the set of the experiments by taking into consideration other simulations parameters (propagation models, MAC protocols, etc). Our future simulations will be implemented in NS-3[30]

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Authors

Mohamed elboukhari received the DESA (diploma of high study) degree in numerical analysis, computer science and treatment of signal in 2005 from the University of Science, Oujda, Morocco. He is currently an assistant professor, department of Applied Engineering, ESTO, university Mohamed First, Oujda, Morocco. His research interests include cryptography, quantum cryptography and wireless network security, Mobile Ad Hoc Networks (MANETS).

Mostafa azizi received the diploma of engineer in automatic and computer industry in 1993 from school Mohammadia of engineers, Rabat, Morocco and he received the Ph. D in computer science in 2001 from the university Montreal, Canada. He is currently professor at university of Mohamed first, Oujda, Morocco. His main interests include aspect of real time, embedded system, security and communication and management of the computer systems in relation with process industry.

Abdelmalek azizi received the Ph. D in theory of numbers in 1993 from university Laval, Canada. He is professor at department of mathematics in university Mohamed First, Oujda, Morocco. He is interesting in history of mathematics in Morocco and in the application of the theory of number in cryptography.