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Evaluating the Power Consumption of Routing Protocols for Wireless Sensor Networks under different Metric Parameters

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Abstract*: Due to their self-organizing, rapid deployment and low-cost features, mobile ad hoc network (MANET) are proving to be a promising architecture for communicating between wireless links between mobile nodes. Despite the many advantages of wireless sensor networks in many areas, they have many problems such as managing the power consumption of mobile devices, selecting the routing protocol, limiting bandwidth and the shortest path. In order to achieve a good service quality, to ensure the routing of the information and to extend the lifetime of the entire network, the analysis of the protocol's performance is the main step to make before the selection of protocol. Therefore, the selected protocol should have the best results in terms of delivery and data integrity. This article presents a performance analysis of some routing protocols namely, DSDV, OLSR, DSR, and AODV, which are evaluated and simulated using the NS2 simulator. The results of the simulation give the better performance of routing study protocols based on the average end-to-end delay, throughput, and packet delivery.

***Keywords:* Wireless sensor networks, mobile ad hoc networks, routing, energy consumption, DSDV, OLSR, DSR, AODV, network simulator 2, performance metric.**

I. INTRODUCTION

Mobile Ad hoc Networks (MANET) are defined as the wireless networks that can organize without a pre-defined infrastructure or centralized administration. Indeed, a wireless sensor network is mainly based on a large number of sensor nodes capable of capturing and transmitting environmental data in an autonomous manner, it is a data transmission system designed to operate for a long time period [1]. The main problem for this transmission system is to optimize the energy consumption of sensor nodes and to ensure the routing of the nominal traffic in order to guarantee a good service quality.

In general, ad hoc mobile networks will need to support efficient and robust operations by providing routing functionality, packet delivery reporting, throughput, and security. These networks will have dynamic random topologies, sometimes very changing, which will be composed of wireless links with limited bandwidth. Routing protocols for Ad-hoc mobile networks used to efficiently route data can be classified in different ways and according to several criteria [2]. Any routing strategy is based on techniques that can be divided into three major classes namely: proactive routing protocols, reactive routing protocols and hybrid routing protocols.

- Proactive Routing Protocol: Protocol for setting up routing tables and knowing the topology of the network. In general, proactive routing protocols try to keep the best subsisting paths to all possible targets at each node of the network. To do this, they use the regular exchange of control messages to update the routing tables to any destination that can be reached from there [3]. The routing tables are modified each time the network topology changes. Two main methods are used for this category: the Link state method and the Distance Vector method. The two proactive routing protocols we are going to study for this class are: DSDV and OLSR.
- Reactive Routing Protocol: Protocol having the ability that perform a routing table when a sensor node decides to transmit data, which invokes a path discovery mechanism to the destination. The created path is always valid as long as the final sensor node is accessible or until the route is no longer used. He has no data on the network. Not knowing the topology of this one nor the available energy. Generally, these are protocols whose control of the routes is done on demand, which is to say when a source have to transmit data packets to a target [4]. In this framework several mechanisms can be adopted, the most important are: Backward Learning Technique and Source Routing technique. The two reactive routing protocols studied in our work are: DSR and AODV.
- Hybrid Routing Protocol: This routing protocol combines the best mechanisms and features of proactive and reactive protocols. In this approach, hybrid protocols use proactive methods (periodic control messages) to discover routes in a predefined neighborhood.

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Flooding techniques of reactive protocols are used to obtain routes to distant nodes. This class of protocols is suitable to large networks, however, it also combines the disadvantages of proactive and reactive protocols at once.

This article aims to present a performance analysis of two types of routing protocols for wireless sensor networks (Proactive/Reactive) in order to define an ideal routing algorithm for our future works, namely DSDV, OLSR, DSR and AODV. This document consisted of V sections as follows. In Section II, a study of four routing approaches has been described. In section III, the evaluation of metrics for network performance was explained. The results of our simulation will be analyzed and discussed in section IV. At the end, we draw the conclusion and our perspectives in the last section.

II. DESCRIPTION OF ROUTING PROTOCOLS

It is very necessary during a data transmission fact to call a routing protocol that will perfectly convey the packet sent by the best route. Indeed, many protocols are proposed at the ad hoc level. In our article, we focused on DSDV and OLSR as proactive protocols and DSR and AODV as responsive protocols.

In this part of work, we will present the four routing protocols of MANET networks, starting with a detailed study of the routing protocol, its way of acting, and its operating principle.

The following figure illustrates the type of each routing protocol:

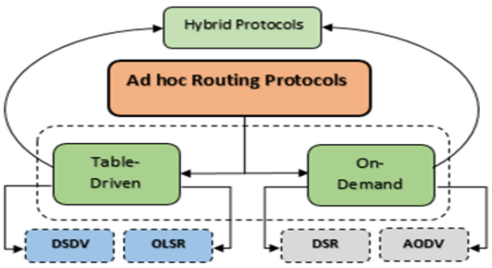

Fig. 1.Class of routing protocols

A. Destination Sequenced Distance Vector Routing Protocol (DSDV)

DSDV is designed specifically for mobile networks [5]. It is rely on the improved form of Bellman-Ford's distributed algorithm. Any sensor node belonging to the network has a routing table containing all neighboring nodes and also the number of hops to all possible destinations. The DSDV protocol [6] uses a sequence number to avoid looping to distinguish new routes from old ones and to update new routes that are available to reach target nodes.

Periodically, broadcasts are made to update the routing table. These updates are either incremental or complete. In DSDV, the sequence number originates and is interlinked to a target node. During an update, the received data is compared with that already available and the route with the largest sequence number will be retained. In the case where two roads have an identical sequence number, then the road with a minimum jump and with a better metric is selected.

For this algorithm each update packet contains a new incremented sequence number, the sending node [7]. In addition, for each new route it has the address of the target, the number of hops separating the node from the destination and the sequence number assigned by the target node. The sequence number starts with the sending node and is incremented for each new route found. When the node finds an update to a given destination, it updates the number of hops to that target and increments its sequence number.

The change in the topology of the network makes appearing loops of roads, it is then that the use of the sequence numbers is useful because it makes the routing protocol DSDV applicable for a dynamic topology of the network. The use of updated sequence numbers when the topology changes allows the DSDV protocol to be adapted to mobile ad-hoc networks [8]. Also taking into account that the updates transmission are postponed, so to have a leveraging effect when the topology changes rapidly.

- Advantages of DSDV:
  - DSDV assures free loop paths.
  - All hop number and sequence number information is in the routing table.
  - Extra traffic can be avoided with incremental updates.
- Disadvantages of DSDV:
  - It does not support multi-route routing.
  - It is hard to preserve a routing table for a larger network, and to determine the delay for declaring paths.
  - DSDV involves a steady update of its routing tables that depletes battery power.

B. Optimized Link State Routing Protocol (OLSR)

OLSR is an optimized proactive link state routing protocol, which applies routing rules in an Ad-hoc context [9]. It uses a technique that allows each node to perfectly know a global vision on the topology of the network. Using this topological map, a source node can choose the shortest path to a target.

This routing protocol decreases the size of the control messages and declares a subdivision of links with its neighbors that are the noted multipoint relays (MPRs). It also minimizes the cost of flooding control traffic by using only multipoint relay nodes to broadcast its messages [10]. Only MPRs broadcast messages.

The Multi-Protocol Router method significantly decreases the number of redundant retransmissions during broadcast. OLSR nodes periodically exchange control messages and preserve routes to reach any OLSR node of the network [11]. The advantage of this technique is to significantly reduce the traffic for the distribution of the control messages in the network, but also to reduce the size of the subset of the links distributed to the whole network because the routes are created based on multipoint relay [10]. The idea of this technique is to decrease the flood of control traffic in a network by decreasing the same retransmissions in the similar region. Any sensor in the network chooses a set of nodes in its surroundings for which the messages will be transmitted. A node chooses its MPRs in its neighborhood so that it is at a jump with a symmetric link. By this choice, the coverage area will be two jumps.

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The nodes considered as MPR make it known in its vicinity by the control messages sent, they have the utility of setting up road to all possible targets of the network. By choosing the route using MPRs, the problems of packet transmission for unidirectional links are eliminated [12]. All nodes in the network keep information about their neighbors who have been chosen as MPRs.

In this type of routing protocol the sensors exchange information periodically to obtain the information necessary for the choice of multipoint relays and also necessary for the calculation of the routing table [13]. Nodes also send "HELLO" messages periodically to get information about their close neighborhood. This allows each node to choose its multipoint relay set. There is another type of message that the OLSR protocol uses, the TC (Topology Control) message. With this message, multipoint relays are periodically declared in the network. They are broadcast using multipoint relays and this gives a controlled and optimized diffusion [9, 11]. The information disseminated gives a map of the network containing all the nodes of it but also a partial set of links.

- Advantages of OLSR:
  - It is better for very dense network due to MPR.
  - Since the routing table is periodically updated, dynamic convergence is high in the OLSR routing protocol.
  - It doesn't need a centralized administrative structure to manage the routing process.
- Disadvantages of OLSR:
  - OLSR does not have enough backup space to hold all of its data.
  - The computation generated by each topology change or the neighborhood of a node causes performance degradation of the OLSR.

C. Dynamic Source Routing Protocol (DSR)

The DSR routing protocol is rely on the use of the source routing technique. This method consists of the data source determining the complete sequence of sensors through which the data packets will be sent to achieve the target [14]. The headers of the data packets have the sequence of the nodes through which they must pass, where each intermediate node that is between the source and the target during the routing of the information, removes its address from the packet before retransmitting it. Indeed, this routing requires knowledge of the route to use from the source of the data. This knowledge of the roads is obtained by a routing table maintained in each node.

To establish the routes, each sensor node can initiate a dynamic route discovery [14]. Indeed, the route request in the DSR protocol is based on the transmission of Route Request packets, this packet contains the list of nodes to cross to reach it. In addition to the address of the data source, the packet also covers a list of all nodes so far visited, so each node that receives the packet can draw from it a routing table that it may subsequently use. Each route request packet contains a unique identifier to detect duplications of that packet [15]. When a node has read the packet, it starts searching for a path containing the requested destination in its caching road (or all known roads are stored). In cases where no road is found, the node transmits the Route Request packet to the next node while adding its address to the node sequence stocked in the Route Request packet. And so on, the packet is shipped from node to node in the network until arriving at the destination node where then to a node having in its road cache the knowledge of the destination path [16]. If a path is found, a Route Reply packet with the sequence of nodes to reach the target node is returned to the source node.

To return the packet, the destination uses a path it already knows, if it does not have a path to join the source it can use the path that is in the packet it has received. DSR maintains a route and uses it until a path node detects a transmission error [17]. When this occurs, the sensor node that discovered the transmission error transmits a message to the source indicating that the path is no longer valid after it. Thus the source can adapt its routing table and must restart a new route discovery request.

- Advantages of DSR:
  - DSR is able to handle the asymmetry of links in the network.
  - The storage of routes in the packets which ensures the absence of a routing loop.
- Disadvantages of DSR:
  - The addition in data packets that increases the overhead and consumes more bandwidth and energy.
  - Determining the delay before starting the transmission of packets caused by the route discovery procedure.

D. Ad-hoc On Demande Vector Protocol (AODV)

AODV reduces the number of broadcast messages by making on-demand routes [18]. Indeed, it requires a data routing route only when it needs it. This technique consists of no longer maintaining all the roads but only the one we need. The AODV protocol, however, retains the principles of sequence numbers and routing node by node. It allows nodes to use the coolest routes following their sequence numbers.

AODV [19] aims to differentiate local connection management and general topology management, and to share changes information in local connections to neighboring mobile nodes that need this information.

The AODV protocol operates a road discovery mechanism that is rely on dynamic route establishment by the intermediate nodes. This system is effective for networks with a huge number of nodes.

At the level of this discovery of the roads, AODV keeps information on the discovery route on each transit node. In fact, the routing tables essentially contain the target address, the address of the next node, the number distance of nodes to cross to achieve the target, the target sequence number and the expiry time of every table entry [20].

When a node that needs to transmit data to a target, and whose entry in the routing table is expired, it sends a route request message to its neighborhood called Route Request message (RREQ). During its routing in the network, the RREQ message makes temporary inputs in the routing tables for the reverse road of the nodes through which it passes.

When the destination is found, the route is ready accessible by a message called RREP (Route Reply) responding to the RREQ of the source node. This message comes back to the temporary path left by RREQ. During its reverse path to the source, the RREP creates inputs for the destination in the routing tables of the intermediate nodes. These routing entries have a fixed duration after which they expire.

The neighborhood of a node is detected by means of periodic "HELLO" messages [20]. When a node uses one of these neighbors to send the data, and the node does not receive the HELLO message, then the link is considered broken and a failure information is sent to the active neighbors. The source having knowledge of the broken link may choose to stop transmitting the data or to request a new route to convey this information, by transmitting again a message RREQ [21]. This algorithm ensures responsiveness to topology changes and provides efficient use of bandwidth while optimizing the amount of control information on the network.

- Advantages of AODV:
  - Using sequence number in messages, avoid infinite loop problems and are essential to the process of updating the routing table.
  - The callback of the IP address of the origin node in each message which makes it possible to lose the trace of the node at the origin of the sending of message during the different relays.
- Disadvantages of AODV:
  - There is no generic message format, each message has its own format: RREQ, RREP, and RERR.
  - It is difficult to measure the expiration time of the route if no data is transferred.

III. SIMULATION METHODOLOGY AND PERFORMANCE METRICS

For MANET networks, each routing protocol has the obligation to be efficient from an energy point of view and lifetime, and to choose the best route to transmit the packets from the source to the destination [22]. Indeed, it must take into consideration all the possible events encountered during a radio communication and which may be sources of additional consumption.

A. Simulation Methods and Parameters

Our simulation was performed on (Network Simulator 2) NS2 [23], in order to assess the performance results of a range of routing protocols, namely DSDV, OLSR, DSR and AODV, in terms of path optimality and overloading routing, in terms of average end-to-end delay rate, throughput and packet delivery rates. Indeed, the purpose of our studies is to survey and quantify the effects of various factors and their interactions on the overall performance of ad hoc networks.

Our simulation network was composed of a number of nodes counted from 10 to 70 nodes deployed over an area of 800m*100m, we assumed that all mobile network nodes are equipped with IEEE 802.11 communication interfaces. We have also chosen to model the communication between nodes using CBR traffic, each source generates packets of 512 bytes.

The various parameters used according to the assumed simulation context are represented on the following table:

Table- I: Simulation Parameters

Parameters	Value
Simulator	NS2
Protocols	DSDV, OLSR, DSR, AODV
Channel type	Channel/Wireless channel
Radio-Propagation model	Propagation/TwoRayGround
Link layer type	LL
Antenna model	Antenna/OmniAntenna
MAC type	Mac /802.11
Mobility model	Random Waypoint
Interface queue type	Queue/DropTail/PriQueue CMUPriQueue
Network interface type	Phy/WirelessPhy
Number of nodes	10, 30, 50, 70
Area of the network	800m*1000m
Transmission range	350 m
Simulation time	200 s
Node speed	20 m/s
Packet size	512 Mbit

B. Performance Metrics

In this article, the focus is on the performance capability of each routing protocol measured quantitatively. In this context, the following metrics [24] have been taken into account in order to assess the performance of MANET routing protocols: DSDV, OLSR, DSR and AODV.

1) Average End-to-End Delay (EED): It is the time taken by the data packets from the source node to the target node. This delay also includes queues during retransmissions of information packets, and the time of discovery of information routing paths. This parameter is the ratio of the difference (from the time each packet sending from the source node to the time when receiving the same packet by the destination node) to the whole number of packets received by the destination node. The performance of the routing protocol is better when the value of this metric is low.
2) Average Throughput: This parameter can be defined as the whole data packets number successfully received from the source node to the destination node over the full time of the simulation. It is represented in bits / bytes per second. This metric is proof that the network manages to send the information constantly to the collection point. This is an important parameter for analyzing network protocols.
3) Average Packet Delivery Fraction (PDF): This report represents the number of all information packets successfully received by the destination node over the full data packets number sent by all nodes in the network.

IV. PERFORMANCE ANALYSIS AND DISCUSION

In the MANET network, numerous quantitative and qualitative measures of network performance make it possible to compare ad hoc routing protocols [25].

In this paper, our routing protocols performance analysis was performed on the basis of three metric parameters: EED, Throughput, and PDF.

The following figures show successively the average end-to-end delay, the throughput and the packet delivery rate for the four routing protocols: DSDV, OLSR, DSR and AODV.

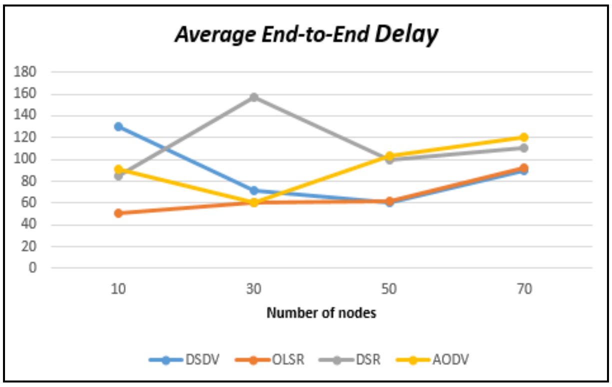

Fig. 2.Average End-to-End Delay

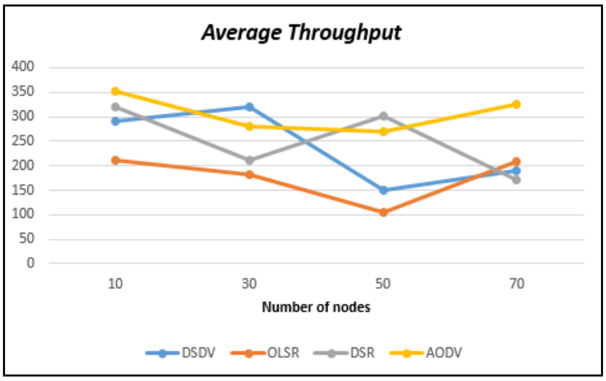

Fig. 3.Average Throughput

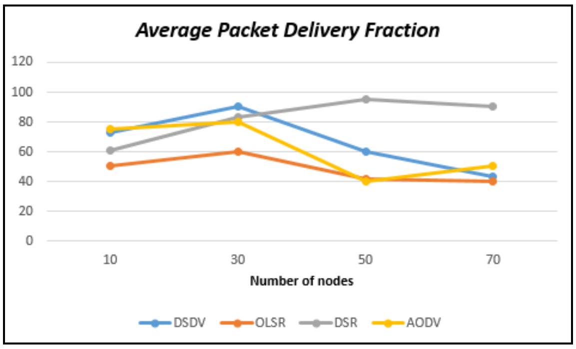

Fig. 4.Average Packet Delivery Fraction

A. Average End-to-End Delay (EED) Result

From Fig. 2, we note that the average end-to-end delay is impacted by the high amount of CBR packets when a link break occurs. The DSR and AODV performance is almost uniform, except when the network size is 30 knots, DSR increases while AODV decreases.

However, the DSDV and OLSR performance is degraded due to the increased number of nodes. The EED of DSDV decreases quad the network size is between 10 and 50 nodes, per center that of the OSR increases up to 70 nodes. In fact, the exchange load of the routing tables is becoming higher and the frequency of exchanges is also increasing because of the mobility of the nodes. The average end-to-end time of the OLSR protocol is very low, whereas DSR has a moderate average delay.

B. Average Throughput Result

Fig. 3 illustrates that the whole number of received data packets increases for the three AODV, DSDV, and OLSR routing protocols as the number of nodes increases from 50 to 70 nodes. However, the Throughput of the DSR protocol is decreasing.

From the results of the simulation obtained, we see that the Throughput of the AODV protocol is much higher than all other routing protocols, because it uses well-defined route information and available in the routing table, this allows quickly route the data capture to the destination node. The average rate of the OLSR protocol is very low because of its self-organized nature. The performance of the two DSDV and DSR routing protocols varies according to the number of nodes, they have an average throughput. A different number of sensor nodes and the transmission range as a system parameter primarily impacts the overall power consumption and performance of the WSN.

C. Average Packet Delivery Fraction (PDF) Result

Fig. 4 shows the ratio between the packets number generated by the sources of the application layer and the received packets number by the final destination's receivers of the four routing protocols.

Note that the PDR performance of the DSR protocol is better with a higher number of nodes than the other three protocols. It increases positively when the number of nodes growths from 10 to 70 knots. The DSDV protocol works well when the network size is less than the load. However, its performance decreases as the number of nodes growths due to increased network traffic.

Still in terms of package delivery ratio, the performance of the OVD is uniformly uniform. There is a slight increase depending on the number of nodes, when the network size is between 30 and 50 nodes, the PDF decreases. However, the optimized OLSR routing protocol has the lowest average packet delivery ratio of all other protocols.

In reactive mode, mainly for DSR and AODV routing protocols, routes are only discovered when they are really needed. Indeed, a node wishing to send a data packet to another sensor node, these search the route on an on-demand basis and establish a connection to transmit and receive the packet. In addition, road discovery typically involves flooding query messages across the network. On the other hand, in proactive routing, and for the DSDV and OLSR routing protocols, each sensor node permanently maintains the route between two nodes. Therefore, the creation and maintenance of the route is accomplished through a clustering of periodic and event-triggered routing updates derived from the remote vector method or the link state.

V. CONCLUSION

In our paper, we evaluated a realistic analysis of MANET ad-hoc routing protocols based on the three metric metrics, namely the average end-to-end delay, throughput, and delivery rate of packets with a number different from nodes and a different network size.

Based on our obtained results, we concluded that the AODV reactive routing protocol is the greater in terms of average throughput and improved in the case of packet delivery rates. DSR also offers a better packet delivery report and works with as little delay as possible on the network, making it suitable for utmost random mobile networks. For network size analysis and high node mobility conditions, DSDV is more energy efficient and efficient in dense networks. The OLSR routing protocol performs route selection in acyclic paths to work better in case of average delivery report of packets. Overall, reactive routing protocols have been shown to work well in the case of average delay and throughput with proactive routing protocols. In this context, the simulation results obtained for our scenario approve better performance of the routing techniques examined in terms of quality of service, reliability and optimization of energy consumption.

Considering these performances, we will be able to design a routing protocol that can appropriately provide the integrity and delivery of data in a highly random mobility network. For future work, our goal is to provide a better and more secure protocol by combining better properties with other protocols.

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