Evaluation of AODV, DSR and DSDV Routing Protocols for Static WSNs: A Simulation Study

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ABSTRACT: *Wireless Sensor Networks (WSNs) have been regarded as distinguished Ad Hoc networks that can be used for specific applications. Since a WSN consists of potentially hundreds of low cost, small size and battery powered sensor nodes, it has more potentials than other Ad Hoc networks to be deployed in many emerging applications. The WSNs raised many new challenges such as: the design of embedded sensors and wireless networking technologies, in other words the routing protocols.*

Scalability of routing protocols used in WSNs is a critical issue due to the extremely high node numbers and relatively high node density. A good routing protocol has to be scalable and adaptive to the changes in the network topology. Thus protocols must perform well as the network grows larger or as the workload increases.

Many Ad Hoc routing protocols such as Ad Hoc On demand Distance Vector (AODV), Dynamic Source Routing (DSR), and Destination Sequenced Distance Vector (DSDV), have been proved to perform well on the Mobile Ad Hoc networks (MANETs). In this paper, a performance study is carried out, using some simulation network models, to investigate how well AODV, DSR, and DSDV routing protocols work on WSNs, in static environments, using NS-2 simulator. The performance study focuses on the impact of the network size, network density (up to 500 nodes), number of sources (data connections), and the type of generated traffic model. The performance metrics to be used in this work are average end-to-end delay, packet delivery fraction (PDF), routing overheads (ROH), and average energy consumption per received packet.

1. Introduction

The WSN is typically consists of small nodes with sensing, computation, and wireless communications capabilities [1]. The sensors measure ambient conditions in the surrounding environment and then transfer measurements into signals that can be processed to reveal some characteristics about phenomena located in the area around sensors [2]. The WSN may also have

some interesting features including self-organization, dynamic network topology, and multi-hop routing, which are important for many real world applications. The applications cover many areas such as: disaster management, border protection, combat field surveillance, and any place where humans cannot easily access or there is danger to human life [3].

Although sensor networks and mobile Ad Hoc networks are similar to some extent, they are radically distinct in many aspects, both MANETs and WSNs belong to Ad Hoc networks and built on top of wireless communication channels; nodes communicate with each other through multi-hop links; each node serves as a router to forward packets for others; and nodes are resource-constrained and usually powered by batteries. Sensor nodes are usually densely deployed in a field of interest and their number can be several orders of magnitude higher than that in a MANET; severe energy, computation, and storage constraints; sensor networks are application specific, and usually designed and deployed for a specific application; network topology changes frequently due to node failure, damage, energy depletion, or movement; and in most sensor network applications, the data sensed by sensor nodes flow from multiple source sensor nodes to a particular sink, exhibiting a many -to- one traffic pattern [1, 2, 3, 4].

Information routing is a very challenging task in distributed Ad Hoc networks, especially in WSNs due to the inherent characteristics that distinguish these networks from other Ad Hoc networks. Another important design issue in sensor networks is that sensor networks are application specific. Hence the application scenario demands affect the protocol design in a sensor network. The proposed routing protocol for sensor networks should consider all the above issues for it to be very efficient.

There are many routing protocols that had been proposed for Ad Hoc networks. Many of them such as AODV, DSR, DSDV, Temporary Ordered Routing Algorithm (TORA) and Optimized Link State Routing Protocol (OLSR) had been investigated on the MANETs in the past few years [5, 6, 7]. The performance investigations of these protocols, on MANETs, have produced many useful results. We have seen very limited findings on how these Ad Hoc routing protocols perform in wireless sensor networks [3, 8, 9, 10, 11].

The objective of this paper is to carry out a systematic performance study on three well known routing protocols, namely AODV, DSDV, and DSR, which had been extensively investigated on MANETs, i.e., to investigate their capabilities on WSNs, and to study the scalability of these protocols, (which is defined as the ability to maintain the performance characteristics without considering the size or workload of the network), by through studying the effect of specific parameters, such as: network size, network density (up to 500 nodes), number of sources (data connections), and the type of generated traffic model on the performance of these protocols. There has been no substantial work reported in evaluating the effect of these parameters on the performance of these protocols for static WSNs.

The rest of the paper is organized as follows: A brief description of the related works is presented in section II. The protocol description is described in section III. In section IV, the simulation environment is explained. Section V presents the simulation results. In section VI the simulation results are discussed and compared with previous related works. The paper is concluded in section VII.

2. Related Works

[3] investigated how well Ad Hoc routing protocols work on WSNs with a different number of sources. Average end-to-end delay, PDF and ROH were examined for 50 nodes in (1500×300) m^2 network for five routing protocols namely: AODV, DSR, DSDV, TORA and OLSR. They conclude that for each of these routing protocols, there are some merits and drawbacks. They found that AODV always performs better using single or multiple sources. DSDV comes next to the AODV despite the fact that DSDV has a relatively low packet delivery fraction.

[8] evaluated the capability of AODV on how far it can react to network topology change in Mobile WSN. They investigated the performance of this protocol using packet loss and energy consumption performance metrics for the mobile nodes, for various speeds, densities and route update intervals (RUI). The evaluation was carried out using 9 nodes in an area of (100×100) m^2 network. The results show a high percentage of packet loss as well as a reduction in the total network energy consumption of mobile nodes, whenever the RUI is getting longer.

[9] evaluated and compared MANET routing protocols for WSN. They made a performance comparison between AODV and TORA protocols using a single source for a network size of (1000 ×1000) m^2. The presented results show that AODV outperforms

TORA in the throughput, however AODV was found to have higher delay than TORA.

[10] carried out a performance comparison study between the Energy and Activity-aware Routing (EAR) protocol and other four existing protocols, namely Gradient Broadcast (GRAB), Gradient Based Routing (GBR), DSR, and AODV, in terms of packet latency, PDF and average energy consumption per delivered packet. The simulation experiment was done using 400 nodes with 10% and 50% active source nodes. The simulation results demonstrated that a routing protocol, for which its design is based on a combination of routing parameters, shows a better performance than a protocol based on just hop-count and energy consumption or those using flooding.

[13] analyzed the effect of traffic patterns with Reference Point Group Mobility (RPGM) model on MANET routing protocols for WSN. They have chosen the Normalized Routing Load (NRL), PDF and throughput as their figures of merit to compare DSR and AODV protocols with 30, 40 and 50 nodes moving in an area of 1000×1000. They found high NRL for both Exponential and Pareto types of traffic models compared to Constant Bit Rate (CBR) traffic in both DSR and AODV. The PDF is comparable in all types of traffic patterns and routing protocols. Throughput is high for AODV routing protocol across all traffic models.

3. Routing Protocols Description

In this section, a brief review for the simulated Ad Hoc routing protocols is given. Ad Hoc Routing protocols can be categorized into two classes: proactive and reactive. The routing protocols are *proactive* in that they maintain routes to all nodes, including nodes to which no packets are sent. They are based on either link-state or distance vector principles, where they require periodic control messages to maintain routes to every node in the network. An alternative approach is *reactive* route establishment, where routes between nodes are determined only when they are explicitly needed to route packets [5]. Three routing protocols are studied in this work, namely DSDV, DSR, and AODV. These protocols have been developed particularly for MANETs. This selection was made as they are the most attractive protocols according to the studies that compared DSDV, TORA, DSR, AODV and OLSR protocols on MANETs.

3.1 Destination-Sequenced Distance-Vector routing (DSDV)
The DSDV routing protocol is built on top of Bellman-Ford routing algorithm [14]. The main achievement of this algorithm is to solve the routing loop problem. In DSDV algorithm, every mobile station has to maintain a routing table, which lists all available destinations, the number of hops to reach the destination, and the sequence number assigned by the destination node. The sequence number is used to distinguish old routes from new ones and thus avoid the formation of loops. The stations periodically transmit its routing table to its immediate neighbors.

3.2 Dynamic Source Routing (DSR)
The distinguishing feature of the DSR protocol is its low network overhead [14]. The protocol is composed of the two main mechanisms of Route Discovery and Route Maintenance. The route discovery mechanism, floods the network with route request (RREQ) packets. The RREQ packets, received by the neighbors, are checked for the availability of a route to destination. If the route is not available in the node cache, then it rebroadcasts it, otherwise the node replies to the originator with a route reply (RREP) packet. Since RREQ and RREP packets both are source routed, original source can obtain the route and adds to its route cache. In case a link on a source route is occasionally broken; then the source node is notified with a route error (RERR) packet. Once the RERR is received, the source removes the route from its cache and route discovery process is reinitiated. DSR being a reactive routing protocol has no need to periodically flood the network for updating the routing tables like table-driven routing protocols do. Intermediate nodes are able to utilize the route cache information efficiently to reduce the control overhead.

3.3 Ad Hoc On demand Distance Vector Routing (AODV)
AODV offers quick adaptation to dynamic link conditions, low resource constrain and low network utilization [5]. The protocol adapts a similar route discovery mechanism to that used by DSR. However, route maintenance in AODV adapts table driven mechanism, as it keeps only a single route for each node, irrespective of multiple routes in route cache maintained in DSR protocol. AODV relies on sequence number based mechanism to keep track of the freshness of the route entry and to avoid route loops. All the routing packets carry these sequence numbers. Also AODV maintains timer-based state information of various states in each node. Whenever a route entry is not used for long time, it has to be erased from the route table. Nodes keep monitoring the link status of next hope of all the active routes. In case of any link break is identified, RERR packets are sent to notify the other nodes. In contrast to DSR, route error packets in AODV are intended to inform all sources in the subnet using the link when a failure occurs.

4. Simulation Environment & Setup

4.1 Simulation Model

The simulation experiments were conducted using NS-2, (version 2.32), a discrete event simulator widely used in the networking research community for simulating WSNs [16]. NS-2 simulator was validated for wireless networks in [12], and later verified in a number of publications, e.g. [6]. The application's scenario of this study is Environmental Data Collection, which is one of the WSN applications [1]. In this application, large numbers of sensors are deployed in the field to measure different parameters such as temperature, speed, humidity and direction. In data collection applications the sensor nodes remain sleep most of the time and report measurements frequently to the base station (sink). The deployment of large scale of sensors in such applications usually static and they may be equipped with effective power scavenging methods, such as solar cells [1]. In our simulation experiments, source nodes (The source nodes are the sensor nodes that have detected phenomena and need to transmit the sensed data to the sink node), generate data packets that are routed to the sink located in the center of the WSN, as shown in figure 1.

The default setups for DSR, DSDV, and AODV routing protocols are adopted and used here, in order to make a performance comparison with the results presented in [3, 6, 8, 9], we use 512 byte data packets of CBR traffic. To investigate the impact of network density, we simulate populations of 100, 200, 300, 400, and 500 nodes in area of $2125m \times 2125$ m with 10 CBR sources. To investigate the impact of network size, the simulation experiments are carried out for populations of 100, 200, 300, 400, and 500 nodes in areas of $2121m \times 425$ m, $3000m \times 600$ m, $3675m \times 735$ m, $4250m \times 850$ m, and $5000m \times 1000m$ respectively, for 200s of simulation time using 10 CBR sources. The above combination of areas and number of nodes are made to give identical node densities for these areas. The density of nodes is kept high enough to allow a meaningful comparison of the tested protocols; a markedly lower density may cause the network to be frequently disconnected, which makes the performance investigation to measure the efficiency of different routing protocols more complicated. In addition to the above, the simulation experiments are extended to cover the following percentages of active nodes: 10%, 20%, 30%, 40%, and 50% CBR traffic sources for $2121m \times 425$ m network size populated by 100 nodes.

The traffic pattern changes with the nature of applications. Traditional data applications generate constant bit rate traffic, which is the traffic model of choice of most of the researchers for a long time in the area of WSN. Recently some applications have a radically different traffic patterns. For instance the data rate in multimedia application increases till it reaches its peak. This pattern for traffic generation can be captured by a Poisson model. Hence, the simulation experiments are carried out for these three routing protocols, taking into consideration two types of generated traffic models, namely CBR and Poisson models with the following parameters:

4.1.1 CBR model
With this model, the packets are generated at a deterministic rate. Packet size is set to 64 bytes and is generated at a constant rate of 2 kb/s.

4.1.2 Poisson model
The Poisson traffic model is an ON/OFF model with inter-arrival times modeled by an exponential distribution. During ON period, the traffic is generated at 2kb/s. Average ON; OFF periods are 315ms and 325ms respectively. Packet size is set to 64 bytes and the holding time follows an exponential distribution with a mean of 100s.
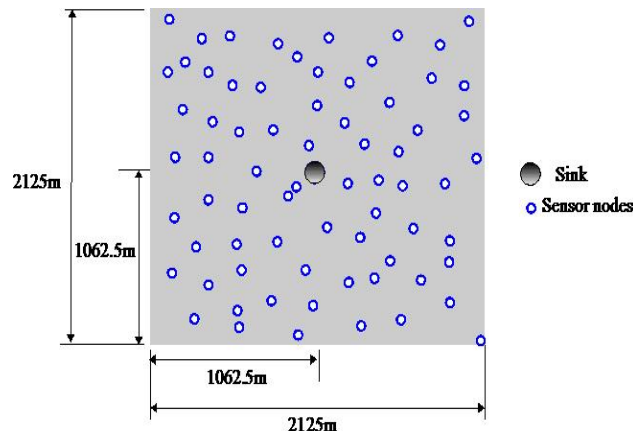

Figure 1. Architecture of the Simulated WSN

These setups are in accordance with previous studies which carried out to evaluate Ad Hoc routing protocols under similar traffic models [14, 15].

All source-to-sink connections are started at times uniformly distributed between 0 and 100s. The chosen sending rate is 4packets/s, except for the effect of the generated traffic model. Each data point presented in this paper is an average of five runs, each lasting for about 200s of simulation time. The IEEE 802.11 Distributed Coordination Function (DCF) is used as the Medium Access Control Protocol with the suggested parameters to model 914MHz Lucent Wave LAN DSSS radio interface at a 2 Mb/s data rate. The adjusted parameters in the simulation are given in Table.1.

4.2 Performance Metrics
While comparing the three protocols, we focused on four performance metrics such as Packet Delivery Fraction (PDF), Average End-to-End Delay, Routing Overheads (ROH), and Average Energy Consumption per delivered packet.

a) Packet Delivery Fraction (PDF): measures the percentage of data packets generated by nodes that are successfully delivered to the sink, expressed as:
(*Total number of data packets successfully delivered*) / (*Total number of data packets sent*) ×100%.

b) Average End-to-End Delay: measures the average time it takes to route a data packet from the source node to the sink. It is expressed as:
(Σ *Individual data packet latency*) / (Σ *Total number of data packets delivered*).

c) Routing Overheads (ROH): The average number of control packets produced per sensor node. The control packets include route requests, replies and error messages.

d) Average Energy Consumption per Delivered Packet: This measures the energy expended per delivered data packet. It is expressed as:
(Σ *Energy expended by each node*)/ (*Total number of delivered data packets*).

Parameter	Value
Max. number of nodes (N)	500 nodes
MAC type	IEEE 802.11/ DCF
Propagation model	Two ray ground
Traffic type	Constant bit rate
Agent	UDP
Queue length	50 packets
Connection Rate	4 pkts/sec
Tx power	0.2818 W
Transmission range	200 m
Initial energy	200J
Simulation time	200 seconds

Table 1. Parameters Used in the Simulation

5. Simulation Results

5.1 Influence of the number of nodes
The density of nodes is expected to have a significant influence on the performance of the routing protocols. Low density may cause the network to be frequently disconnected, while high density increases the contention. Figure 2 depicts the PDF, average end-to-end delay, ROH, and average energy consumed per delivered packet measured to 100, 200, 300, 400, and 500 nodes. In terms of PDF, AODV performs well when the number of nodes is less than 200, as shown in figure 2-(a), it is noticed that the AODV starts to fall off markedly beyond 200 nodes. This decline in the performance indicates that the AODV cannot cope with the excess traffic in the network which caused by the routing packets exchange.
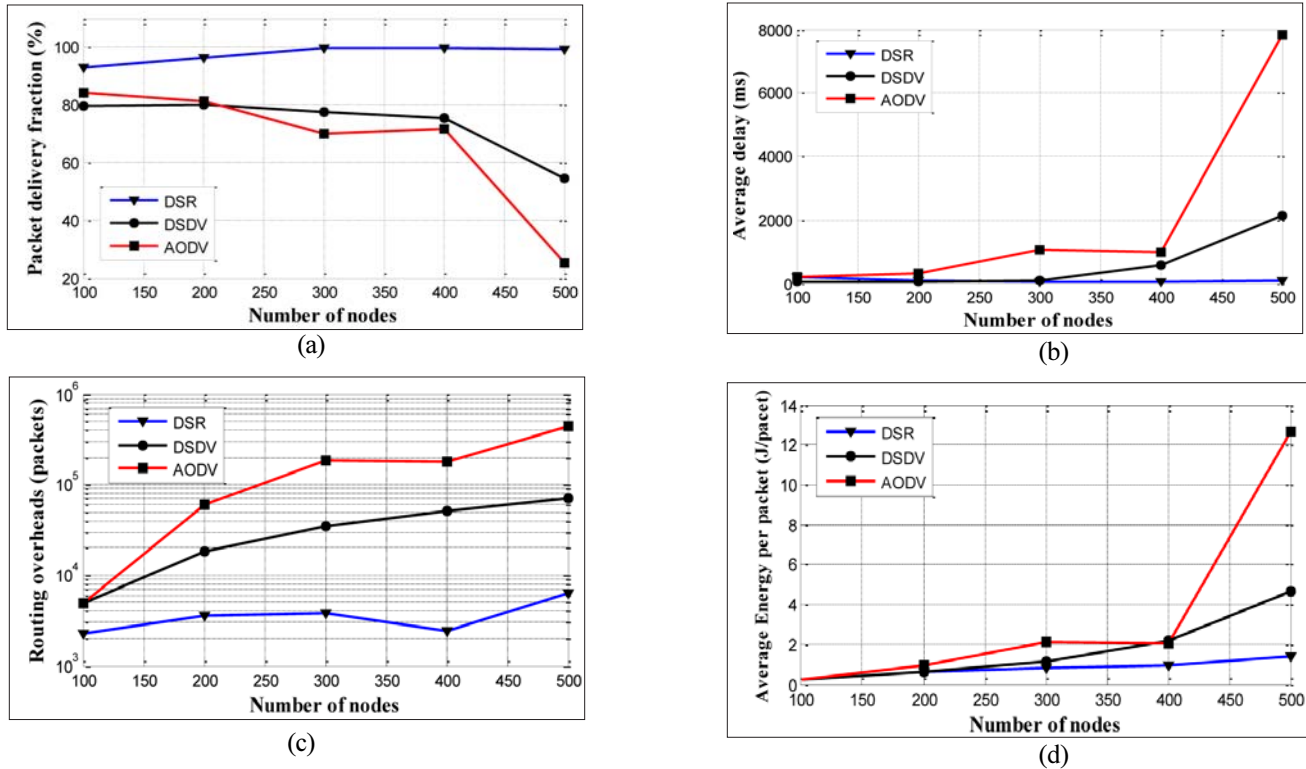
Figure 2. Influence of the number of nodes

For DSR, the effect of disconnected network due to low node density is evident from the presented results for 100 nodes per area, as shown in figure 2-(a), there is a gradual improvement in PDF, from around 91% to greater than 98%, as the nodes density is increased. However, the DSR routing protocol is found to perform better with the increase in the number of nodes. As the DSR routing protocol caches all known routes; it is very likely that during route discovery for some destination such as node D, a route for another node A is found, recorded, and later used from the cache, this strategy will ultimately save the network bandwidth, which leads to improve the performance of DSR protocol, especially when the number of nodes increases. For DSDV, it can clearly be noticed that a proactive approach is not acceptable at all when the network population increases. The received packets fraction drastically goes down to 55 %. The reason for this is that packets are sent before the routing tables have had enough time to converge and the packets are dropped.

From figure 2-(b), one can notice that the best average end-to-end delay is exhibited by DSR and DSDV protocols; it is almost less than 0.1s and 2s respectively. However, the two protocols react differently, where the average end-to-end delay increases for the DSDV and it is almost consistent for the DSR as the number of nodes increases. The average end-to-delay for AODV is found to be increasing with the increase in the number of nodes. In this experiment, the increase in the number of nodes means also an increase in the path length; this behavior is easy to explain: longer routes take longer time to discover and to travel along them. They also have a higher probability to break than shorter ones; as a consequence more route repairs are needed for DSDV and AODV protocols, which in turn results in a higher latency of the data packets. On the other hand, the DSR protocol uses a route cache to store alternative routes which ultimately reduces the overall latency.

In terms of ROH, as shown in figure 2-(c), it is noticed that the performance of AODV protocol exhibits similarly as DSDV protocol. Both generate a high routing load, showing more dependence on the number of nodes. Although the DSR outperforms, however, it demonstrates regular change on ROH in its response to the change in the number of nodes, with less overall values. Generally, with more nodes within the network, routing overheads will increase.

Route discovery in AODV is energy intensive, this is clearly noticed in larger networks (beyond 200 nodes), as shown in figure 2-(d). With an operating environment that is plagued with node failures, in static WSN node failure is due to energy depletion, it may be very difficult to establish a full route from source to the destination at a given point in time. The source will keep sending the route discovery packet but will not receive a definite route response from the destination. Route discovery packets

will accordingly flood the network consuming more energy. As an improvement over AODV, DSR uses a route cache to reduce route discovery cost. DSDV shows less energy consumption than AODV, but higher than DSR.

5.2 Influence of the network size

When talking about the size of a network, it is not only the number of nodes in the network that is of interest. The area that the nodes are spread out over is also interesting. This basically decides the connectivity of the network. In this experiment we study the performance of AODV, DSDV, and DSR protocols for areas of $2121m \times 425m$, $3000m \times 600m$, $3675m \times 735m$, $4250m \times 850m$, and $5000m \times 1000m$ populated by 100, 200, 300, 400, and 500 static nodes, respectively. These combinations of areas and number of nodes are made to give identical node densities for these areas. The term "*number of nodes*" here, indicates indirectly to the corresponding area size.

Figure 3 shows the simulation results for this experiment. The PDF performance for DSR and AODV are very similar with small size network (less than 200 nodes), as illustrated in figure 3-(a). As the network size increases, DSR outperforms AODV by about 60 percent (at about 500 nodes). For a large size network, however, DSR has a better delivery fraction than AODV. It is noticed that AODV managed to deliver more than 90% of its packets in small size network (less than 200 nodes). However, as the network size increases, the performance falls off markedly to deliver about 35% of data packets at 500 nodes. The same picture is observed for DSDV protocol, which delivers more than 85% in small size networks (less than 300 nodes). As the network size grows, the PDF falls quickly, and at 500 nodes only 60% of data packets find their way to the sink node. DSDV protocol has shown the worst PDF when the network size is small, however, as the network size increases (beyond 300 nodes), this protocol shows some kind of improvement in its performance in comparison to the AODV protocol. Generally, for both AODV and DSDV protocols, it is noticed that as the number of nodes grows beyond 200 nodes (network size increased), the PDF starts to decline quickly. As mentioned before, the DSR caches all known routes; this strategy brings to DSR protocol some improvements in its performance, as presented in figure 3-(a). This is also attributed to the quick route discovery process, which allows the routing algorithm to quickly adapt to route changes in DSR. The AODV protocol turns out to be unable to effectively deliver data in large size network, which is populated by a large number of nodes. The reason behind this degradation in performance is due to the high routing overhead required by this protocol, as depicted in figure 3-(c). AODV uses route expiry, (route expires when it is not used by the node for long time or there is no RREP received from this route), dropping some packets when a route expires and a new route has to be found. To keep the routes active and routing information fresh, the DSDV periodically broadcasts its routing tables, which does not provide much help in large networks.
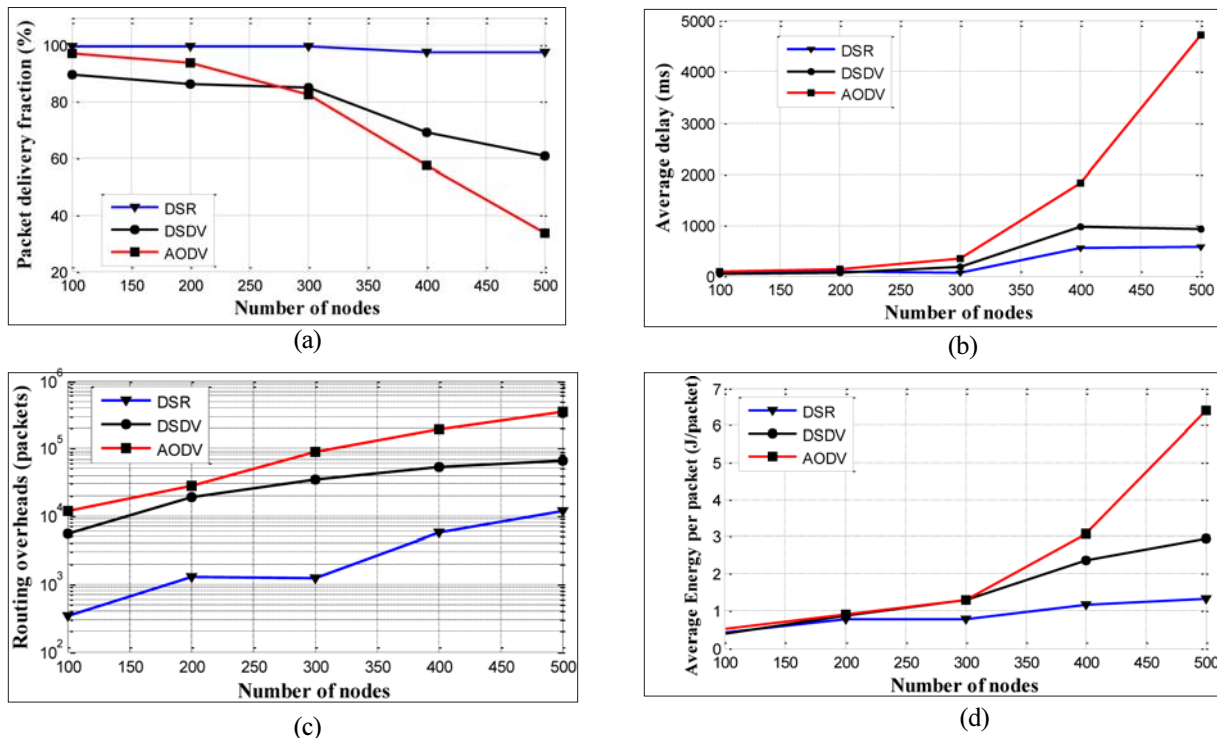

Figure 3. Influence of the network size

In terms of average end-to-end delay, as shown in figure 3-(b), the three protocols exhibit in a similar fashion for small sized networks. However, as the network size grows, beyond 300 nodes, there will be a noticeable degradation in the delay performance for the AODV protocol, in comparison to the performance of the other protocols. In this respect when the number of nodes reaches 500, the DSR protocol supersedes the AODV protocol by about a factor of 8. AODV has the worst delay characteristic because of the loss of distance information as a result of route breakages. Also in AODV route construction may not occur quickly. This leads to potential lengthy delays while waiting for new routes to be determined. In DSR, the Route Discovery is fast; therefore it shows a better delay performance than that of the other two protocols, for all proposed network sizes.

The DSR protocol has demonstrated significant lower routing overheads, in comparison to that of DSDV and AODV protocols, as shown in figure 3-(c). For a large sized network, the AODV protocol has shown higher ROHs, this can be clearly noticed when the number of nodes becomes 500, where the difference between its ROHs and DSR's ROHs performance reaches to about 10 times in favor to the DSR protocol. For all protocols the overheads increase as the network size increases and the DSDV protocol shows lower overheads in comparison to that of the AODV protocol.

According to the results presented in figure 3-(d), for the average consumed energy per delivered packet, the energy consumption increases as the network size increases for all protocols. The increase in average energy consumption per packet as a function of network size is close to linear for DSR and DSDV. In case of AODV, the increase in consumption is drastic, this is can be clearly noticed when the network size has increased from 300 nodes to up to 500 nodes. This is due to the large drop in packet delivery with the increased network size combined with AODV protocol overheads. The resulting collisions and retransmission attempts cause additional energy waste.

5.3 Influence of the number of sources

The offered load simulation experiment is done by varying the offered load to the network. There are mainly three parameters that can be used to adjust the offered load: Packet size, Number of CBR sources flows and Rate of flow at which traffic is sent. The network population and network size simulation experiments are conducted using a packet size of 512 bytes and a rate of flow of 4packets/s for 10 CBR sources. This is a fairly moderate offered load, so for the offered load simulations, we want to investigate how the protocols behave when the load is increased. Either the packet size or the packet transmission rate can be increased, but the parameter that best describes the load is the number of CBR flows. The packet size was held constant at 512 bytes and the rate of flows at 4packets/s. Each source generates 620 packets, in average during the simulation time.

Figure 4 depicts the effects of network loading on the performance of the three protocols with respect to the increase in the number of data connections, (number of sources), from 10% to 50%. Figure 4-(a) shows that, in respect to the PDF performance, there is a declining trend in the performance of the three protocols as the number of data connections increases. As the generated packets within the network are high, each broken link resulted in more dropped packets and the probability of collision is increased, this which explains why there is degradation in PDF performance starting from 10 CBR sources onward. Both DSR and DSDV protocols reacted consistently to the network loading condition. As shown in the figure, the PDF of DSR protocol has dropped from 99% to 36% when the number of connection sources is increased from 10 to 50, the DSDV protocol performance has dropped from 89% to 36%, while that of AODV protocol has dropped from 97% to 10%. The PDFs for all protocols have dropped more gradually with the increase in the number of connections. Both DSR and DSDV protocols have managed to maintain the PDF performance to be more than 36%.

The Average end-to-end delay performance of these three routing protocols is shown in figure 4-(b). The AODV has experienced the worst sharp increase from 28ms to 6.5s, whereas the latency of DSR and DSDV protocols has increased from 25ms to 4.1s and from 17ms to 4.6s respectively. The increase in the network average latency performance, for the tested protocols, is noticed to be in agreement to that experienced in the PDF performance test.

The results presented in figure 4-(c), show that the DSR protocol has demonstrated a lowest ROH, if compared to that of DSDV and AODV protocols. This counts for about 10 times in favor to the DSR protocol at 10 sources, whereas The DSDV protocol performance is almost moderate. The amount of control information required by the DSDV protocol is not affected to a great extent by the change in the number of active sources; it looks like that the number of control packets remains almost constant irrespective of the number of sources. The number of control packets is actually increased a little bit as the number of sources does increase from 10 to 50 sources. The amount of difference is counted for about 715 control packets. The reason behind this difference is that when there is an increase in data sources there will be more collisions, which means that some of the update messages are dropped. The loss of these update messages makes this protocol unable to trigger the nodes by these new updates.
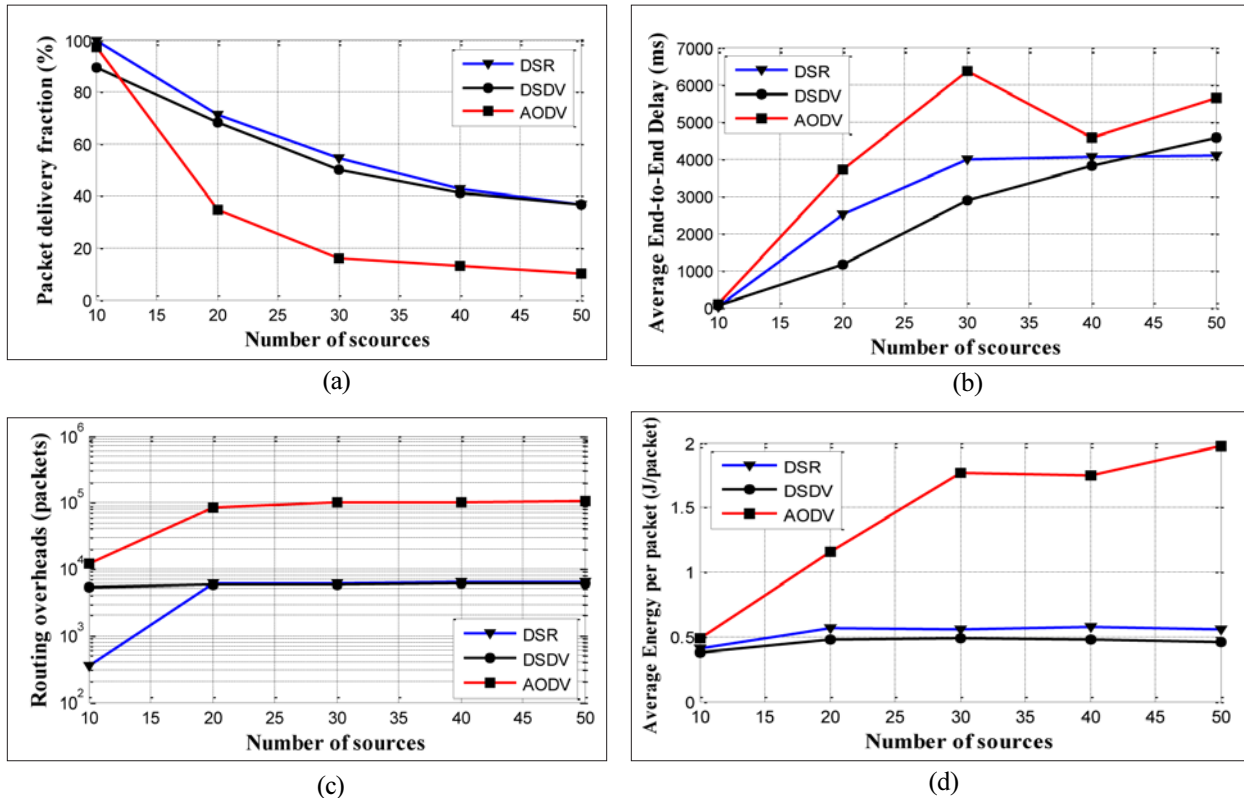
(a)

(b)

(c)

(d)

Figure 4. Influence of the number of sources

Figure 4-(d) illustrates the energy consumption per delivered packet, for the three protocols, with respect to the change in the number of sources. Again, energy consumption in DSR and DSDV are almost stable regardless of the traffic load even though the consumption in case of DSR is a little bit higher. The increase in energy consumption for the AODV protocol is almost linearly proportional to the increase in the number of sources. It is found that, for the AODV protocol, as the number of traffic sources increases from 10 to 30, the energy consumed by the routing protocol is increased by a factor of 3.5.

5.4 Influence of the generated traffic model
Figure 5 depicts the effect of traffic generation models, on the performance of the three protocols, with respect to the increase in the number of data connections (number of sources).

The PDFs performance, using CBR and Poisson models to generate traffic from the sources in the network, for the three protocols are shown graphically in figure 5-(a). From this figure, we can observe that the PDF performance results for DSR protocol, using Poisson model, have the highest values (almost 100%). However, for the case of CBR traffic type, the PDF performance for DSR protocol begins at very high values and starts to gradually degrades when the number of sources reaches 30. We also observe that the PDF results of the AODV protocol, for the case of CBR traffic sources, start at very high values and as the number of sources increases, the PDF results decrease. It is noticed that for both Poisson and CBR traffic types, the DSDV protocol has a moderate PDF for various numbers of sources.

The average end-to-end delay performance results, for the three protocols, are shown in figure 5-(b). We observe that the average end to end delay results, using Poisson traffic sources for the three protocols, are almost identical, although the DSR protocol shows lower values for the average end to end delay (almost less than 30ms), when compared to the AODV and DSDV protocols' results. This is because of the availability of alternative routes in case of routing failures, as the alternative routes enable this protocol to avoid the new route discovery latency, which ultimately contributes to the average delay. For CBR traffic sources, the average end-to-end delay results, for the three protocols, start at low values, and then start to increase dramatically after 10 sources for AODV, and slightly after 30 sources for DSR and DSDV.

The amount of control information required for the case of the DSDV protocol is almost not affected by the number of active

sources, irrespective to whether the sources generate traffic using CBR or Poisson models, as illustrated in figure 5- (c). The DSR protocol has managed to maintain the routing overhead results almost at their lowest values, for both Poisson and CBR sources. The AODV protocol shows the highest overhead results, using CBR sources.
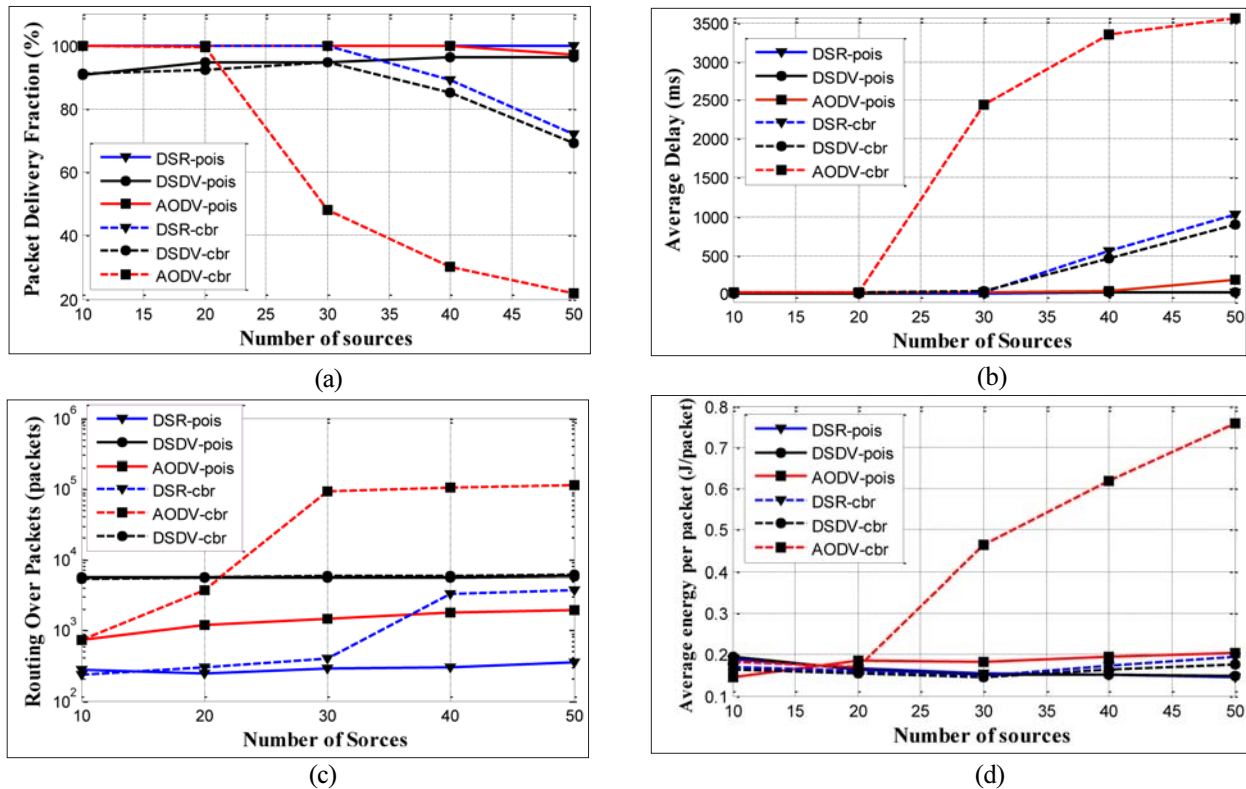

(a)

(b)

(c)

(d)

Figure 5. Influence of the generated traffic model

Figure 5-(d) shows the average energy consumed per delivered packet against different number of sources. The energy consumption of both DSR and DSDV is almost steady with increase in the number of sources. It is noticed that, for the AODV protocol, as the number of traffic sources increases, the routing energy increases. DSR protocol has performed better than the other two protocols due to cache. The important observation one can notice here, for the three routing protocols, is that the average energy consumption, for the case of the CBR sources, is always less than that encountered for the case of Poisson sources.

6. Discussion of Results and Comparison

A little research works have been reported in literature that addressed the performance of MANET routing protocols on WSNs, as mentioned in section II. But most of them studied these protocols taking into consideration small size, low node density and light load networks with CBR generated traffic model.

The work presented here aims to extend the previous research works, and to investigate the effect of different parameters (such as: area size, percentage of active nodes, node densities and generated traffic model) in the performance of the studied protocols for static deployed WSN, and to investigate their scalability and capabilities to support the routing tasks for WSN. The presented results show that: for a low node density and small sized network, most of the studied protocols still show good performance, but as the network size or node density increases (i.e. scalability); some kind of performance degradation has been noticed for both AODV and DSDV.

The presented simulation results show that the studied routing protocols give different levels of strength, depending on the scenario at hand. The only protocol that shows consistently stronger performance relative to the other protocols is the DSR protocol. This means that we can still rely on MANET routing protocols to deliver reliable performance in realistic WSNs.

7. Conclusions

In this paper, three MANET's routing protocols, namely DSR, AODV, and DSDV, have been studied and investigated to be employed as routing protocols for static deployed WSNs. The investigation is carried out using some simulation models, to evaluate and compare the performance of these protocols, in terms of the average end-to-end delay, packet delivery fraction, routing overhead and the energy consumption per delivered packet, with the impact of the network size, the network density, the number of sources and type of the generated traffic model.

In comparing the performance results of the tested simulation models for the WSN, using these routing protocols, it is found that in most of the tested scenarios the DSR protocol performs better. In this respect, although the DSDV protocol has a relatively low packet delivery fraction, the DSDV performance comes next to the DSR protocol.

For DSR protocol, because of the multiple paths that are already registered and kept in the route cache of the nodes, a good degree of reliability and stability is provided by the network. DSR protocol exhibits moderately high PDF, low latency and energy consumption, and managed to adapt to the changes in the network like node density and network size.

The Poisson traffic sources is usually used to model the generated traffic for multimedia applications. With Poisson traffic, clustering occurs in short term but smoothes out over the long term. The aggregate traffic becomes smoother (less bursty) as the number of sources increases, which decreases the chance for the congestion to occur for the transmitted data packets. Traffic connections were aggregated yielding an ever bursty traffic model. So the overall routing protocols performance appears to be better with Poisson traffic model.

8. Future Work

In this paper, the assumption for the network to be flat and has a static centered sink node. In the future, we plane to check other assumptions like cluster architecture and different locations for the static sink. It is also ought to investigate the case if the sink is made mobile and collect the sensed data from the sensor sources as well as to consider the case for a combination between static and mobile sinks within the same network.

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