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Performance Evaluation of Dynamic Source Routing Protocol (DSR) on WSN

Hasein Issa Sigiuk[1] and Ali A.S. Ihbeel[2]

[1]Electrical and Electronic Engineering Department, University of Tripoli, Tripoli, Libya
sigiuk@mwc.ly
[2] Electrical and Electronic Engineering Department, University of Tripoli, Tripoli, Libya
ali.ihbeel@yahoo.com

Abstract: Wireless Sensor Network (WSN) has been regarded as a distinguished Ad Hoc Network that can be used for a specific application. Since a WSN consists of potentially hundreds of low cost, small size and battery powered sensor nodes, it has more potentials than others Ad Hoc networks to be deployed in many emerging areas. A number of routing protocols have been implemented to route the packets in these networks. One of these routing protocols is Dynamic Source Routing protocol (DSR). In this paper, an attempt has been made to evaluate the performance of DSR routing protocol using some simulation network models, to investigate how well this protocol performs on WSNs, in static and mobile environments, using NS-2 simulator. The performance study will focus on the impact of the network size, network density (up to 450 nodes), and the number of sources (data connections). The performance metrics used in this work are average end-to-end delay, packet delivery fraction, routing overheads, and average energy consumption per delivered packet.

Keywords: Wireless Sensor networks; Ad Hoc Networks; DSR Protocol; and Performance study.

I. INTRODUCTION

Wireless sensor network (WSN) is a wireless network consisting of small nodes with sensing, computation, and wireless communications capabilities [1]. The sensors measure ambient conditions in the environment surrounding and then transfer measurements into signals that can be processed to reveal some characteristics about phenomena located in the area around sensors [2].

However, sensor nodes are constrained in energy supply and bandwidth. Such constraints, combined with a typical deployment of large number of sensor nodes, have posed many challenges to the design and management of sensor networks [2]. Distinguished from traditional wireless communication networks, for example, cellular systems and Mobile Ad Hoc Networks (MANETs), WSNs have unique characteristics, for example, denser level of node deployment, higher unreliability of sensor nodes, and severe energy, computation, and storage constraints [3], which present many new challenges in the development and application of WSNs.

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, cover many areas such as: disaster management, border protection, combat field surveillance, and any place where humans cannot easily access or unsafe to human life [4].

Although sensor networks and MANETs 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. The differences include that: the sensor nodes are usually densely deployed in a field of interest and the number of them 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, or energy depletion; 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].

There are many routing protocols which have been proposed for Ad Hoc networks. These include: Ad hoc on Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Destination Sequenced Distance Vector (DSDV), Temporally Ordered Routing Algorithm TORA and Optimized Link State Routing (OLSR). These protocols have been investigated on the MANETs in the past few years [7, 8, 9]. The Performance investigation of these protocols, on the MANETs, has produced many useful results. We have seen very limited findings on how these Ad hoc routing protocols perform on WSNs [4, 5, 6, 11, 12].

The objective of this research is to carry out a systematic performance study on DSR, and in particular its capability to be used as a routing protocol on WSNs, as it was originally designed to be used in MANETs.

In this paper a performance study is to be conducted for DSR protocol, where some specific parameters, such as network size, network density (up to 450 nodes), and number of sources (data connections) are considered and investigated for their effect on the performance of WSN.

The rest of the paper is organized as follows: Section II includes the recent related works. The DSR routing protocol description is summarized in section III. The simulation environment and performance metrics are described in Section IV. The experimental results are presented in section V. The paper is concluded in section VI.

II. Related Works

Z.Zhang and et al [4] investigate how well Ad Hoc routing protocols work on WSNs with a different number of sources. Average end-to-end delay, packet delivery fraction and routing overheads were examined for 50 nodes in (1500×300) m^2 network for five routing protocols namely AODV, DSR, DSDV, TORA and OLSR. The simulation study carried out for these routing protocols, using different scenarios, showed that there are some merits and drawbacks. The performance comparison of these routing protocols showed that the AODV always was performing better on all WSN tested models with single or multiple sources. The DSDV was next to the AODV despite of the relatively low packet delivery fraction of the DSDV.

M. N. Jambli and et al [5] evaluated the capability of AODV on how far it can react to network topology change in Mobile WSN. They investigated the performance metrics namely packet loss and energy consumption of mobile nodes with various speed, density and route update interval (RUI), for 9 nodes in (100×100) m^2 network. The presented results showed a high percentage of packet loss and the reduction in total network energy consumption of mobile nodes if RUI is getting longer due to serious broken link caused by nodes movement.

M. Pandey and et al [6] presented an analytical study of the average jitter of AODV Routing protocol in wireless sensor networks, for different simulation time and mobility conditions. The performance measurements were carried out for the AODV routing protocol for different simulation times and network topologies and under different mobility conditions. The paper investigated the impact of different mobility models on the performance of 105 nodes in (500×500) m^2 wireless sensor networks. Although the presented results did not present a steep comparative orientation of the results towards a specific routing protocol but the comparative study leads towards some interesting results.

Peter Kok and et al [11] performed some simulation experiments using EAR, Gradient Broadcast (GRAB), Gradient Based Routing (GBR), DSR, and AODV routing protocols,in terms of packet latency, packet delivery fraction and average energy consumption per delivered packet. The experimented simulation models consist of 400 nodes with 10% and 50% active source nodes. The simulation results demonstrated that a routing protocol which its design based on a combination of routing parameters exhibits collectively better than other protocols with their design based on just hop-count and energy or those using flooding.

III. Dynamic Source Routing Protocol (DSR)

The distinguishing features of DSR are: low network overhead, no extra infrastructure for administration and the use of source routing. Source routing implies that the sender had full knowledge of the complete hop-by-hop route information to the destination. The protocol is composed of the two main mechanisms of Route Discovery and Route Maintenance. Normally routes are stored in a route cache of each node. When a node likes to communicate to a destination, first it checks for the route for that particular destination in the route cache. If yes, the packets are sent with source route header information to the destination. In the other case, if the route is not available at the route cache; then the node will initiate the route discovery mechanism to get the route first. The route discovery mechanism will flood the network with route request (RREQ) packets, and then the neighbors will receive RREQ packets and check for the route to destination in their route cache. If the route is not in their caches rebroadcast the RREQ, 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 add to its route cache. In any case the link on a source route is broken; 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 [13].

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.

IV. Simulation Environment & Setup

A. Simulation Model

In our experiments we use NS-2 (version 2.32), a discrete event simulator widely used in the networking research community, as a flexible tool for networking researchers to investigate how various routing protocols perform with different network configurations and topologies [14]. NS-2 simulator was validated in [10] and verified in a number of later publications, e.g. [8]. There are two scenarios, Static, and Mobile.The wireless sensor network application under consideration in this work is environmental data collection wireless sensor network, i.e. is one of 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 remains sleep most of the time and report measurements frequently to the base station (sink). The deployment of large scale sensors in such applications either static or mobile and they may be equipped with effective power scavenging methods, such as solar cells [1]. In some other applications, sensors are mounted on robots, animals or other moving objects, which can sense and collect relevant information [5]. In the simulation, 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, the source nodes follow a Gaussian distribution in generating packets.

To allow comparison with other experiments [4, 5, 6, 8], we use 512 byte data packets and CBR traffic. For the impact of network size we simulate populations of 100, 200, 300, 400, and 450 nodes in areas of 2121m×425m, 3000m×600m, 3675m×735m, 4250m×850m, and 5000m×900m for 200s of simulation time with 10 CBR sources. We choose the above combinations of areas and number of nodes involved to work with approximately the same node density and simulation area proportions. This density of nodes is high enough to allow a meaningful comparison of the protocols; a markedly lower density may cause the network to be frequently disconnected, and then an investigation of the efficiency of different routing protocols is even more complicated. For the impact of network density (populations), we simulate populations of 100, 200, 300, 400, and 450 nodes in an area of 2125m×2125m with 10 CBR sources. In addition to that, we simulate 10%, 20%, 30%, 40%, and 50% CBR traffic sources for 2121m × 425m network size with 100 nodes. This number of sources allows us to investigate scalability of protocols when the traffic load is changed from light load to heavy load. Such settings is more realistic for WSNs.

All peer-to-peer connections are started at times uniformly distributed between 0 and 100s. The number of unique traffic sources is 70% of the total number of sources. The chosen sending rate is 4 packets/s. Each data point presented in this paper is an average of five runs, each lasting for 200 s of simulated time. The IEEE 802.11 Distributed Coordination Function (DCF) is used as the Medium Access Control Protocol with the suggested parameters to model 914MHzLucentWaveLAN DSSS radio interface at a 2 Mb/s data rate. The adjusted parameters in the simulation are given in table.1.

TABLE.1: PARAMETERS USED IN THE SIMULATION

Parameter	Mobile Scenario	Static Scenario
Max. number of nodes (N)	450 nodes	450 nodes
MAC type	IEEE 802.11/ DCF	IEEE 802.11/ DCF
Propagation model	Two ray ground	Two ray ground
Traffic type	Constant bit rate	Constant bit rate
Agent	UDP	UDP
Queue length	50 packets	50 packets
Connection Rate	4 pkts/sec	4 pkts/sec
Tx power	0.2818 W	0.2818 W
Transmission range	250 m	250 m
Initial energy	200J	200J
Simulation time	200 seconds	200 seconds
Node mobility	Random waypoint	NA
Pause time	50 sec	NA
Max speed of mobile node	5 m/sec	NA

TABLE.1: PARAMETERS USED IN THE SIMULATION

B. Performance Metrics

The evaluation is done using the following metrics:

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:

(∑ Individual data packet latency)/ (∑ 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) ***Energy Consumption per Delivered Packet:*** This measures the energy expended per delivered data packet. It is expressed as:

(∑ Energy expended by each node)/ (Total number of delivered data packets)

V. SIMULATION RESULTS

A. Impact of the number of nodes

The density of nodes expected to have a significant influence on the performance of DSR. Low density may cause the network to be frequently disconnected. High density increases the contention. This experiment shows the effect of changing the node density (number of nodes in the network) on the performance of the DSR protocol. Figure 1 depicts the PDF, average end-to-end delay, ROH, and average energy consumption per delivered packets measured with 100, 200, 300, 400, and 450 nodes for static and mobile deployment scenarios. In terms of PDF, it is found that, for both static and mobile nodes, the performance of the DSR is slightly degraded at low node density. However, as the reliability of the network is improved with the increase in the

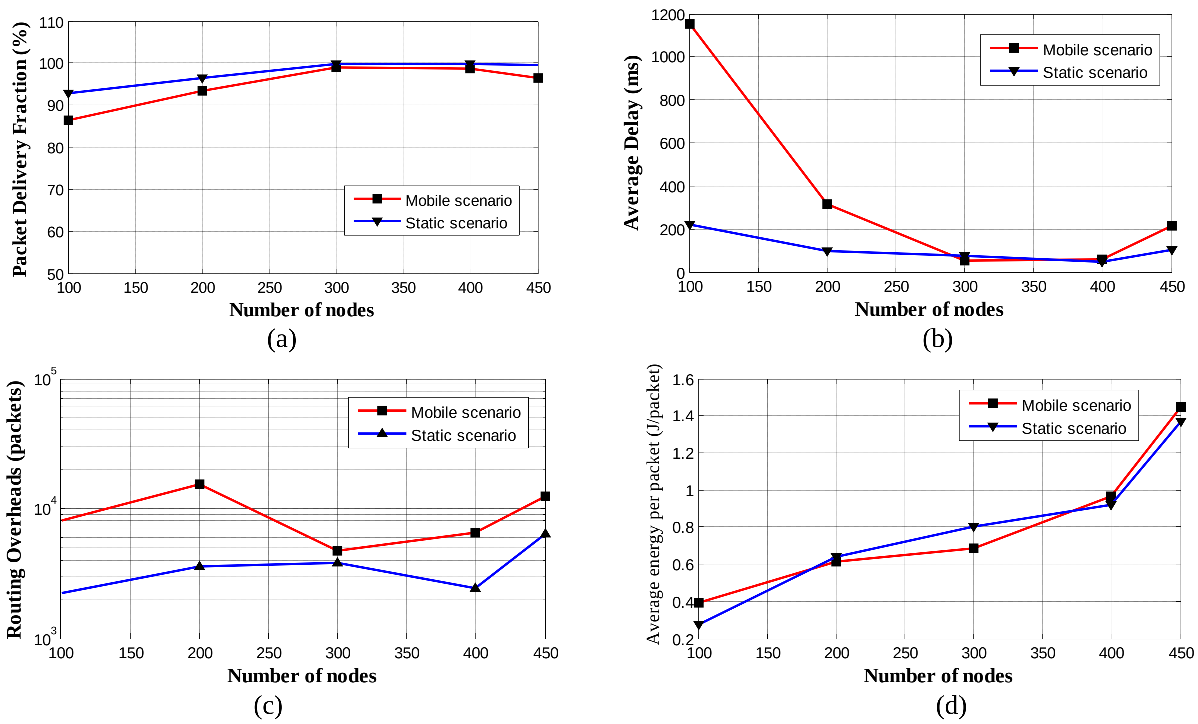

Figure.1: Impact of the number of nodes.

number of nodes, it is noticed that the PDF for static node deployment performs better as the node density increase, as shown in figure 1-(a). 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 increase.

From figure 1-(b), it is noticed that, for both static and mobile deployments, the best average end-to-end delay exhibited by DSR when the number of nodes in the network are between 300 and 400; it is almost less than 0.1 s. However, the average end-to-end delay is found to be degraded as the node density decreases, especially for mobile node deployment case.

In terms of ROH, as shown in figure 1-(c), it is noticed that the DSR protocol generates a higher routing load for mobile nodes deployment. There is minor increase in the routing overheads as the number of nodes increases.

As shown in figure 1-(d), the Average energy consumption increases as the number of nodes in the network increases.

B. Impact of the network size

In this experiment we study the performance of the DSR protocol in areas of 2121m × 425m, 3000m × 600m, 3675m × 735m, 4250m × 850m, and 5000m × 900m populated by 100, 200, 300, 400, and 450 nodes, respectively. It is worth to mention that for all the above combinations of areas and nodes, the density of nodes is kept constant. Figure 2 shows the simulation results for this experiment. In terms of PDF, as shown in figure 2-(a), the DSR performs well with the changes made in the network size. However its performance declines beyond 200 nodes for mobile scenario. It is noticed that the DSR managed to deliver more than 95% in small size networks (less than 200 nodes), however, for larger networks the performance declines. Generally, for both scenarios, it is noticed that as the number of nodes grows beyond 200 nodes, (the network size increased), the PDF starts to decline.

In terms of end-to-end delay both static and mobile scenarios exhibit in a similar fashion, for small sized networks, as shown in figure 2-(b).However, as the number of nodes grows, for larger networks (more than 200 nodes), there will be a noticeable degradation in the end-to-end delay performance, especially for the mobile scenario.

Figure 2-(c) shows that the DSR protocol has demonstrated significant lower routing overheads for the static scenario, in comparison to that of the mobile scenario. It is noticed that the overhead increases as the network size becomes larger.

According to the results presented in figure 2-(d), for the average consumed energy per packet, it is noticed that the DSR protocol has demonstrated a remarkable performance with lower energy consumption for small sized networks. The consumed energy increases as the network size increases.

C. Impact of the number of sources

Figure.3 depicts the effects of network loading on the performance of the DSR protocol by increasing the number of data connections (number of sources), from 10% to 50% for 100 nodes in the network. Figure 3-(a) shows that the PDF declines with the increase in the number of active sources for both scenarios. The average end-to-end delay performance of both scenarios, as shown in figure 3-(b), degrades as the number of connections increases in the network, and with the mobile scenario shows more sharp increase in the delay. The decline in the network average latency performance results for the DSR protocol appears to coincide with the performance results obtained for the PDF experiment.

The results presented in figure 3-(c) show that the DSR protocol has demonstrated a lower ROH for light traffic in the network. As the number of connections increases, the ROH performance results are almost moderate and consistent.

Figure 3-(d) shows that the DSR protocol consumes more energy for a heavy traffic network, and the results for average energy consumption appear to exhibit in a similar fashion to that experienced in the ROH performance test.

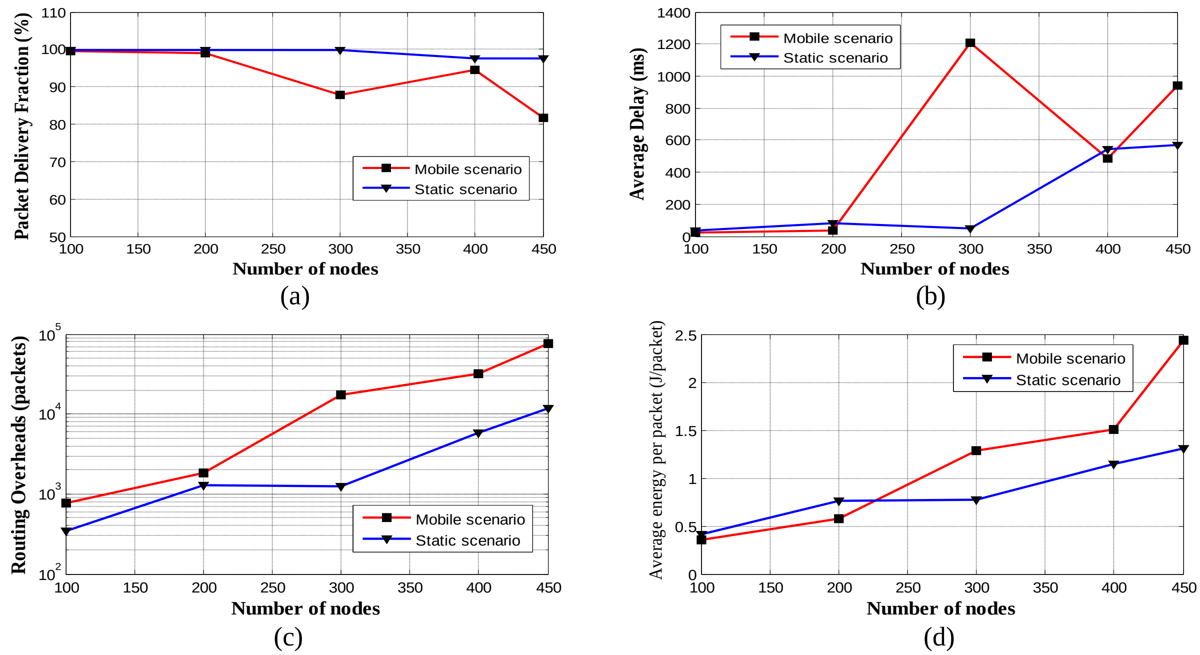

Figure.2: Impact of the network size.

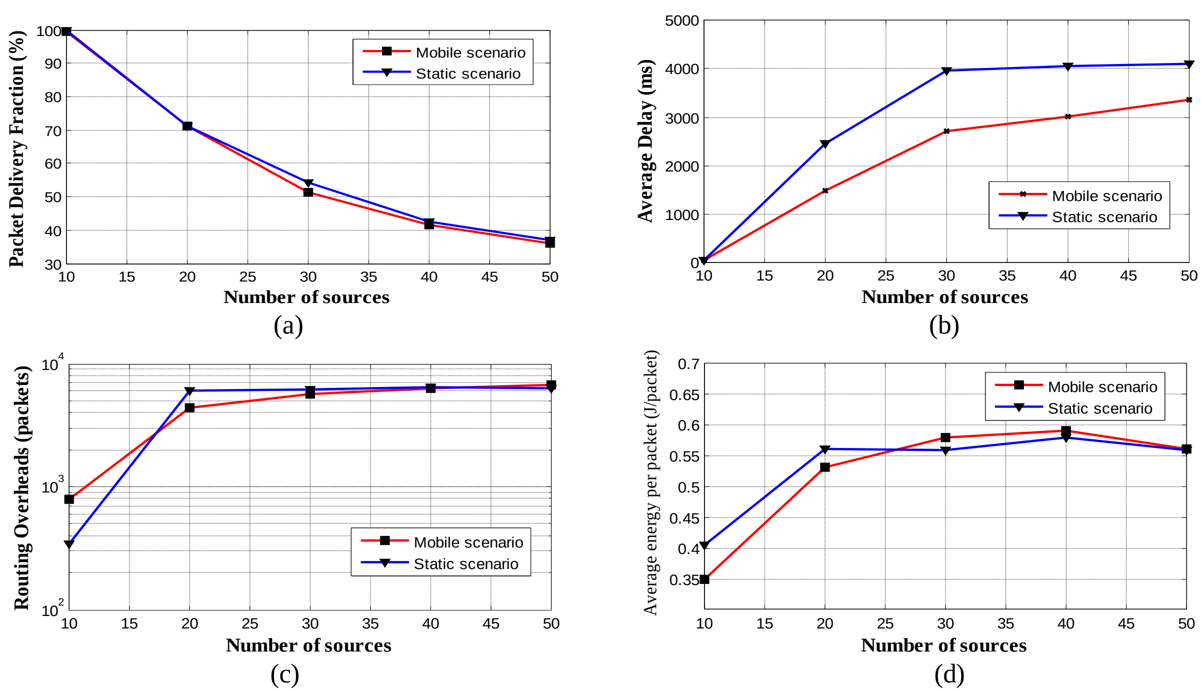

Figure.3: Impact of the number of sources.

This indicates that the energy consumed is proportional to the ROH in the network.

Generally, as one can see from the presented experimental results for the DSR protocol, it is noticed that the performance of WSN degrades as the number of connections in the network increases.

VI. Conclusions

In this paper, we have presented a performance evaluation for DSR protocol under various WSN scenarios using different performance metrics which are the average end-to-end delay, packet delivery fraction, routing overhead and the energy consumption per delivered packets, with the impact of the network size, network density, and the number of sources.

It is found that in most of the tested scenarios, the DSR protocol performs well and its performance is better for the static scenario application. Because of the multiple paths that are already registered and kept in the route cache of the nodes, where a good degree of reliability and stability is provided by the network. The DSR protocol exhibits high PDF, low latency and energy consumption, and managed to adapt to the changes in the network like density and size. Under heavy load conditions, it is noticed that there is performance degradation, in terms of PDF and delay.

The work presented here aims to find out the effect of different parameters on the performance of the DSR routing protocol in WSN. The results though don't present a steep comparative orientation of the results towards a specific routing protocol, but the comparative study leads towards some interesting results. Further research is needed to find out the most suitable protocol for each application.

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