Performance Evaluation of Mobile Ad-hoc Routing Protocols on Wireless Sensor Networks for Environmental Monitoring

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Abstract — **The birth of the Wireless Sensor Network (WSN) was motivated by military applications such as battlefield up until the industrial and civilian applications started to take advantage of the technology in many areas including environmental monitoring. In this paper, performance evaluation of different Mobile ad-hoc routing protocols implemented in WSN has been carried out for environmental monitoring scenario. When this type of application is considered, longer network life and low latency are the primary factors for successful system operation. The network is assumed to be floating on the surface of a small lake, with one base station connected to a wireless wide area network, receiving the sensor measurements. All other nodes are identical and they each have the same sensing, computation and communication capabilities. The study focused on the impact of rapid mobility caused by the surface movements. The performance metrics used in study are average jitter, average delay and packet Energy consumption in transmission and reception mode. Ultimately AODV has performed better as a MANET routing protocol in a WSN when high mobility and dynamic topologies are introduced. This leads to understand that despite the limitations of WSN, MANET routing protocols can perform yet better than WSN routing protocols in mobile environments.**

Keywords — Wireless Sensor networks; Mobile Ad-hoc networks; Mobility; Routing; Environmental Monitoring

I. INTRODUCTION

The Wireless Sensor Network (WSN) was developed in the early 70s with the US military as the main customer [1]. Three decades later when commercial applications based on ad-hoc technology finally emerged, they required a new fresh look, because they were considerably different from traditional military applications, the costly military systems could not be exported to civilian applications such as disaster recovery, traffic monitoring, home security or habitat monitoring [2].

WSNs have started to find their way into a wide variety of systems such as the environmental field [3], the main objectives of environmental monitoring systems are to evaluate the effect of any unusual activities at an early stage for any unforeseen effect [4]. These results or predictions can only be based on the previous data gathered from the same area of interest and ecological behavioral patterns. For this reason mainly the longer the environmental monitoring system operated the quality of the gathered data will be higher [4].

Tracking and localizing various types of moving objects became an important research topic for the environmental monitoring applications, for example, the authors in [5] presented work based on tracking litter movement while floating on the surface of water body, alongside gathering data of specific environmental parameters in certain locations to analyze the impact of floating litter on the surroundings. Various work has been done on solving this problem using different techniques, however, most of these mobile sensors have very stringent constraints on the cost and complexity.

It should also be pointed out that the service offered by WSN is not simply to move bits from one place to another, but instead to provide answers, these answers should respond to questions, for example, what are the regions where the temperature is above the specified threshold? What is the path followed by the herd? Thus, responding to these types of questions implies taking into account geographic scopes, which is a requirement that is not needed in most other networks [6]. Indeed, in some applications for example the address of individual nodes is irrelevant and location becomes a more important attribute. In general, communication paradigms routing and infrastructure are affected by the nature of the application that the sensor network is used for [7].

Recently a significant attention has been given to ad-hoc networks caused by two confluent forces, on one hand there is a technology ambition resulting in creation of new smaller more powerful devices, as WSNs would potentially consist of hundreds of battery powered and small sized low cost sensing nodes, on the other hand there is the network design space and the routing protocols, consequently, even more new types of ad-hoc applications are evolving [8]. In addition to one or two sensors the nodes will be equipped with wireless communications device and microprocessors; therefore there is a big concern on power consumption. As a result

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the routing protocols must be designed to reduce power drain, but not on the cost of the overall efficiency of the network. Consequently, in this paper, we major matrices such as latency and jitter which effects the overall network performance alongside with the energy model metrics which evaluate the energy consumption of each routing protocol.

In this paper, we present a comparison study of well-known MANET and WSN routing protocols. All protocols are tested based on wireless sensor network virtual devices operating on a highly mobile environ-mental monitoring scenario. We are evaluating which MANET routing protocols would perform better than traditional WSN routing protocols in high mobility scenarios. The rest of this paper is organized as follows: Section 2, a brief introduction of the tested routing protocols is outlined, Section 3, outlines the related work in this area, Section 4, an analysis of simulation results. The paper concludes in Section 5.

II. INTRODUCTION TO THE ROUTING PROTOCOLS

The task of routing can be defined as the action of addressing data traffic between pairs of nodes such as source and destination. This action is performed by the nodes in which case acts as routers; these physical nodes maintain their routing table by means of a routing algorithm [9]. good routing means low energy consumptions as well as high data delivery rate with fraction of delay [9], and due to the energy limitation of WSN this just made it very challenging to meet these high acceptation mainly due to the fact that the topology changes constantly and routes which were initially efficient can quickly become unfeasible.

The dynamic properties within the Ad-hoc network in general require an implementation of active topology discovery and maintenance mechanism to do any kind of deterministic routing, one example is approach called pro-active routing [10], attempt to maintain an updated view of the network, for instance Landmark ad-hoc routing (LANMAR) [11], Accordingly, another approach was established that could perform without the necessity of increasing control traffic, known as reactive routing such as ad-hoc On-Demand Distance Vector Routing (AODV) [12], the aim of reactive routing is to only find connections when desired. However, the down side is that it requires extra round trip latency and a higher chance of route failure in exchange for control traffic that scales linearly with the amount of messages to be sent [10]. Alternatively, hybrid routing approaches is introduced by combining the best features of proactive and reactive routing [10]. A description of the tested protocols follows:

Dynamic Source Routing (DSR): is reactive routing protocol, where intermediate nodes are able to utilize the route cache information efficiently to reduce the control overhead [13]. Distinguishing feature of DSR include low network overhead. By 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 [13]. Route discovery mechanism, floods the network with route request (RREQ) packets. RREQ packets received by the neighbors, and checks for the route to destination in its route cache, if it is not in cache 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 able to 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 re-initiated [13].

On demand Distance Vector Routing (AODV): offers quick adaptation to dynamic link conditions, low re-source constrain and low network utilization. The proto-col adapts the similar route discovery mechanism as in DSR [14]. However, route maintenance in AODV adapts table driven mechanism, keeps only single route for each node. AODV relies on sequence number based mechanism to keep track of the freshness of the route entry also to avoid route loops. All the routing packets carry these sequence numbers. Also it maintains timer-based state information of various states in each node. Whenever a route entry is not used for long time the entry will be erased from the route table. Nodes keeps monitor 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 in-form all sources in the subnet using the link when a failure occurs [14].

Location-Aided Routing (LAR): LAR is on-demand routing protocol using geographical location information to limit the area for discovering a new route to a smaller zone known as ”request zone” [15]. Instead of flooding the route requests into the whole network, only nodes in the request zone will forward them meaning that the RREQ messages are limited to request zone only and nodes within request zone forward these requests. Any nodes not located in the request zone simply discard the packet. Thus, the routing overhead is widely reduced. Identifying the request zone is demonstrated by specifying the request zone in RREQ message clearly. If no route has been discovered then the source node initiates another route discovery with wider request zone after certain timeout interval timer. Second type of zone LAR uses is the Expected Zone which helps to determine based on location and velocity if the destination and it is expected to contain the location of destination [15].

Dynamic MANNET On demand (DYMO): is a reactive, multi-hop unicast routing protocol [16]. DYMO is defined as an enhanced version of AODV. The routing operation within DYMO is divided into route discovery and route maintenance. Routes are discovered on demand when the originator initiates hop-by-hop distribution of a RREQ message throughout the network to find a route to the target, currently not in its routing table. This RREQ message is swamped in the network using broadcast and the packet reaches its destination. The target then sends a RREP to the source. Upon receiving the RREP message by the source, routes have been established between the two nodes. For maintenance of routes which are in use, routers elongate route lifetimes upon successfully forwarding a packet. In order to react to changes in the network topology, routers monitor links over which traffic is flowing [16]. When a data packet is received for forwarding and a route for the destination route is broken, missing or unknown, then the source of the packet is notified by sending a route error (RERR) massage [16].

Landmark ad-hoc routing (LANMAR**):** is an effective proactive based routing protocol which uses the same approach of Fisheye State Routing (FSR), routing table and Node distance is evaluated using hop counts in the given network topology [11]. LANMAR stores a specific address each node reflects its position within the hierarchy this enables the protocol to discover and maintain a specific route [11]. When a node requires sending a packet within its hierarchical region, the route information is identified from the routing table stored within the hierarchical region. Otherwise, node evaluates the logical subnet field of the destination and the packet is forwarded towards the landmark for that consistent sub-net topological changes and route information will be updated periodically within the hierarchical nodes within one hop distance [11].

III. Related Work

The authors in [17], presented an evaluation of three routing protocols of WSN to discuss that the routing protocols used for wireless sensor networks should support network scalability, and they should continue to perform well as the workload increases. The tested protocols are probabilistic geographic routing protocol (PGR), beacon vector, routing protocol (BVR) and flooding protocol (FP) using prowler simulator to determine which one is efficient for scalability through several metrics which are throughput, latency, energy consumption and delay, it was concluded that BVR is most efficient for scalability.

The authors in [12], presented an improved version of AODV is presented in his work tested for sensor network. The simulation result is analyzed and compared based on IEEE 802.11 and IEEE 802.15.4 using QualNet 4.5, this experiment showed during 130 or 200 seconds simulation time the improved AODV performed better in terms of finding the shortest routing path operating on IEEE 802.11 and IEEE 802.15.4.

The authors in [20] presented an extensive simulation study comparing MANET routing protocols; using a variety of workload such mobility, load and size of the ad-hoc networks was presented. The differences of AODV, CBRP, PAODV, DSDV and DSR routing protocols is discussed, and the authors concluded that AODV shows the less end-to-end delay and throughput. Routing overhead in DSR is higher than CBRP instead of less number of route request packets, while largest over-head are shown by AODV. The original AODV routing protocol is outperformed by pre-emptive routing protocol.

IV. Simulation and Results

This paper presents performance analysis of MANET protocols such as LANMAR, AODV, LAR1, DSR and DYMO operating on WSN standards IEEE 802.15.4. The Simulations have been carried using QualNet 7.3 simulator [18]. This paper explores the performance of parameters such as average jitter, average delay and energy efficiency. The operational scenario represents a typical WSN floating on the surface of steady water surface of a small lake, this system supposed to monitor environmental parameters such as water temperature, water saintly and pressure therefore varying traffic load and random way point mobility model is used, the random waypoint model is a random model for the movement of mobile devices, representing the change of their location, velocity and acceleration over time [20], and the size of terrain 1500m*1500m. The following table shows the simulation attributes:

Table 1. SIMULATION ATTRIBUTES.

Attributes	Values
Protocols studied	AODV,LAR1,DSR, LAN-MAR and DYMO
Sources	Multiple source and Destination and one
Antenna type	Omni Directional
Number of nodes	46 nodes
Simulation time	1 hour multi seed 35
Simulation area	1500 *1500m
Node trajectory model	Way Point model mobility
Traffic types	CBR,FTP
Rate of packet generation	10 packets/sec
packet size	512 byte

V. Performance Study

In order to compare the protocols in question, the quantitative metrics were used to measure and evaluate the performance of the simulated routing protocols, for all metrics, the average over multiple experiments were determined. Each of these metrics parameters can be described briefly as follows.

- Average Jitter: Average jitter is a performance characteristics used to measure deviation from true periodicity eventually of inactivity in packet across a specific network. When a network is stabilized with constant latency it will have no jitter. Packet jitter is expressed as an average of the deviation from the network main latency [19].

- Delay**:** This performance metric is used to measure the average end-to-end delay of data packet transmission. It represents the time between packets generated by the source to their [18] .

- Energy Model: this represents two performance characteristics which influence the performance of the system in general not only the routing process, these are:

    - Energy-consumed-in-Receive-mode
    - Energy-consumed in-Transmit-mode

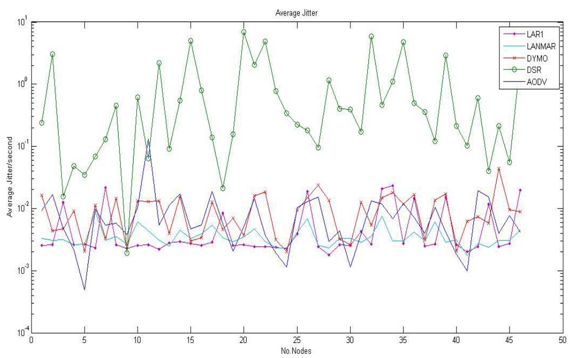

Figure 1. Average Jitter

In this experiment DSR shows the highest value of jitter in Figure1, on the other hand AODV alongside with LANMAR at the average value of 0.423971 outperformed DYMO and LAR1 which was not expected giving that the last two supposed to be used widely in IEEE 802.4 standards but it was obvious that they cannot handle mobility that well, the instability shown specially by LAR1 is unwanted in such environment.

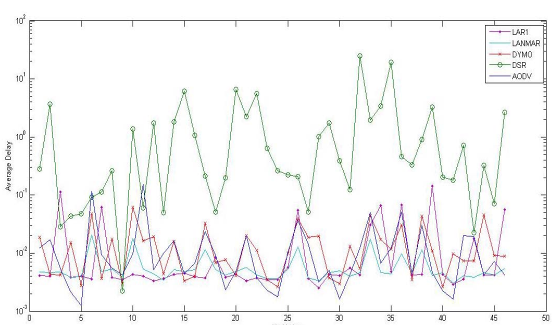

Figure 2. Average Delay

As mentioned earlier, the average delay is calculated by subtracting time at which first packet was transmitted by the source node from time at which first data packet arrives to the destination. Figure 2, clearly shows DSR again had the highest latency at peak value 19.95 byte/sec. DYMO and LAR1 showing instability but his again can be because of the amount of mobility introduced by the network scenario but in general both maintained reasonable value varying from 0.01 byte/sec to 0.1 byte/sec, in the other hand AODV and LANMAR is showing better performance by giving less delay in delivering the hitting lowest value at 0.001 byte/sec.

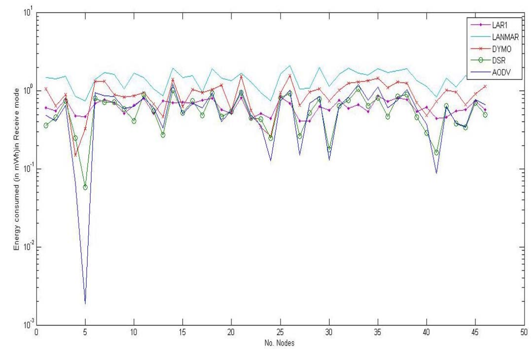

Figure 3. Energy Consumed in Receive Mode

Regarding the amount of energy these protocols consume when receiving packets it has been observed that AODV is doing better consuming less than 0.001 mW/h alongside with DYMO as it is expected because DYMO was derived from AODV specially to operate in WSN, as for the rest of the protocols they show slight predictable unstable curve at the peak value of approximate value of 1 mW/h.

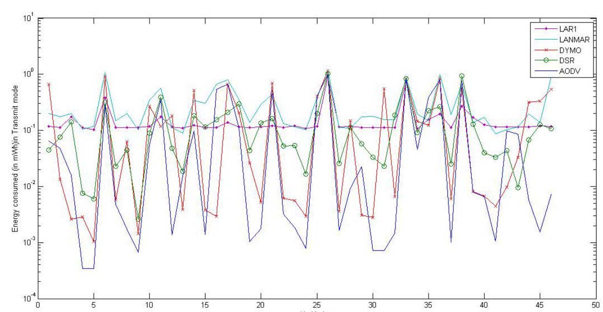

Figure 4. Energy Consumed in Transmit Mode

Although transmission packets consumes more energy transmitting packets then receiving them, AODV and DYMO consuming less power when transmitting data then the rest of the, AODV has performed better than DYMO in this one as its power consumption vary from 0.001 mW/h to 1mW/h.

VI. CONCLUSION

In this paper we observed that energy is an important optimization objective in WSN. The energy consumed during communication is more dominant than the energy consumed during processing due to the limited storage capacity, which could be considered as drawbacks of sensor networks. We also observed that mobility patterns are an important factor effecting routing process as well as network life time.

Based on these observations we compared the impact of energy constraints and random way point mobility pattern in physical layer and application layer of the nodes, of the networks in which AODV offers the better combination of energy consumption performance. AODV gives better average jitter and delay performance compared to LAR1 LANMAR, DYMO and DSR. By the end of simulation time we noticed a rapid change and instability in the performance of LAR1 and DYMO regarding the application performance, also there has been slight instability regarding the transmission and the reception mode of AODV and DYMO over time.

This evaluation helped us to highlight a wide-range of issues related to routing in WSNs. The routing protocols have to be effectively enhanced or new routing approaches have to be implemented, to resolve challenges in dynamic topology and rapid movements. Future perceptions of this work are focused towards enhancement of one of the routing protocols tested in this paper. The enhanced protocol should be energy efficient which could cope with dynamic topological changes and higher mobility.

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