Performance Analysis of WSN Routing Protocols in Flat and Irregular Terrain

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Abstract— Routing protocols in wireless sensor networks (WSN) allows node to send and receive packets. There are several routing protocols for WSN but it is not easy to fix on which one is efficiently best. In this paper, a comparative analysis of routing protocols is provided. ZRP (Zone Routing Protocol) and IERP (Interzone Routing Protocol) and three on demand routing protocols AODV (Ad-hoc On Demand distance Vector), DSR (Dynamic Source routing) and DYMO (Dynamic Manet On demand) protocols based on IEEE 802.15.4 is analyzed in 1000mx1000m flat terrain area and in Digital Elevation Model (DEM, irregular area) and compared in this paper. Comparative performance evaluation is done based on performance measuring metrics like Throughput, Average end-to-end delay, Average jitter and Residual battery capacity by using Qualnet 7.1 simulator tool. From the simulation results and analysis, the routing protocol that performs better is evaluated.

Key words: Wireless Sensor Networks, Routing Protocols, DEM, Qualnet 7.1, PAN-C, Coordinator

I. INTRODUCTION

Nowadays wireless sensor networks (WSNs) are implemented in so many fields. A wireless sensor network consists of a large number of small sensor nodes that are compactly deployed in the monitoring region communicating over radio. The nodes in these networks are connected by wireless links and the function of these nodes are sensing and monitoring the events like physical or environmental conditions such as temperature, pressure, motion or pollutants etc when located in the environment and sending those sensed data to the base station. In order to guarantee the best possible use of this technology, different routing protocols performances need to be tested. These kinds of networks are very flexible and attractive for many realistic applications such as natural disaster recovery, habitat monitoring, target tracking [4].

Figure 1 shows the WSN architecture [4]. First, all sensor nodes are pre-deployed in the monitoring area, with the observer then sending the appropriate monitoring commands to particular targets. All the nodes are connected to one wireless subnet and then applications are applied on some nodes. Few nodes are configured as Coordinator and one node is configured as PAN-Coordinator (PAN-C) which collects the data from all Coordinators and other nodes.

IEEE 802.15.4 focuses on low-rate and low-power solutions for reliable wireless monitoring and control. It supports short-range operation, reasonable battery life, and maintains a simple and flexible protocol stack. For IEEE 802.15.4 MAC layer defines two types of nodes FFD and RFD. FFDs (Full Function Devices) are equipped with a full set of MAC layer functions and RFDs (Reduced Function Devices) are equipped with a reduced set of MAC layer functions. FFDs can communicate with all nodes but an RFD can communicate with a single FFD and are most of the time terminal devices.

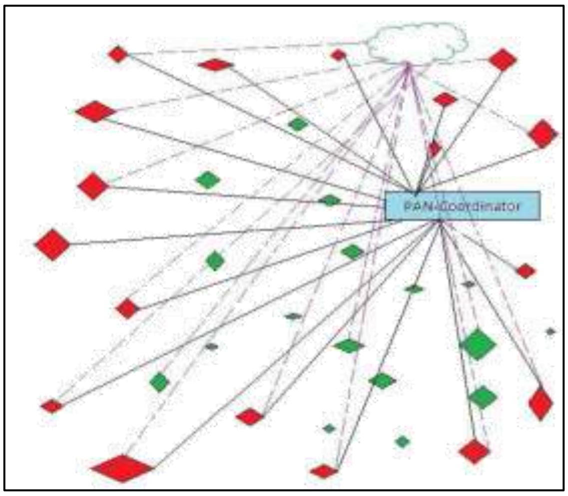

Fig. 1: Architecture of WSN

In wireless network, routing protocols play a significant role in managing the creation, design, and maintenance of the topology of the network [1, 2, 3, 4]. Power management is an important concern in WSNs because wireless sensor nodes are usually battery powered, and an able use of the available battery power becomes an important concern especially for those applications where the system is expected to operate for long durations. This requisite for energy efficient operation of a WSN has encouraged the development of new protocols in all layers of the communication stack. In this paper reactive protocols like Ad-Hoc on-Demand Routing (AODV), Dynamic Source Routing (DSR), Dynamic MANET On-demand Protocol (DYMO) and Interzone Routing Protocol (IERP) and hybrid protocol like Zone Routing Protocol (ZRP) are discussed and compared for various performance metrics like Throughput (bits/sec), Average End-to-End Delay (sec.), Average Jitter (sec) and Residual Battery Capacity (mAhr).

II. OBJECTIVES

The objectives of the study are:
i) To have a common understanding of Wireless Sensor Network protocols like AODV, DSR DYMO, IERP and ZRP. (ii) To perform the quantitative comparative evaluation of these protocols under different terrain considerations using simulator to emulate the real world scenario.

The rest of the paper is organized as follows. A brief overview of the protocols is given in Section 3. Related work is presented in Section 4. Then the Network Simulation is discussed in Section 5. Next, in Section 6, Simulation Results are presented. Finally, the paper is concluded in Section 7.

III. OVERVIEW OF PROTOCOLS

The routing protocols are classified as follows based on the way the network information is obtained in these routing protocols.

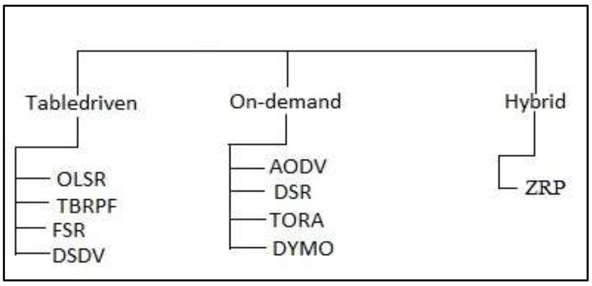

Fig. 2: Classification of Routing Protocols

The table driven (proactive) protocols maintain routing information about each node in the network. The information is updated throughout the network periodically or when topology changes. Each node requires to store their routing information. The on-demand (reactive) routing protocols look for the routes and are created as and when required. Hybrid protocols use the best features of both the on-demand and table driven routing protocols.

A. Dynamic Source Routing (DSR) Protocol:

The distinguishing features of DSR [2] are 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. 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 source 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 in the route is broken; the source node is notified with a route error (RERR) packet. Once the RERR is received, the source removes that route from its cache and route discovery process is reinitiated.

B. Ad-Hoc On-demand Distance Vector (AODV) Routing Protocol:

AODV offers quick adaptation to dynamic link conditions, low resource constrain and low network utilization. The protocol adapts the similar route discovery mechanism as in DSR. However, route maintenance in AODV adapts table driven mechanism, keeps only single route for each node irrespective of multiple route 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 also to avoid route loops. All the routing packets carry these sequence numbers. Whenever a route entry is not used for long time the entry will be erased from the route table. Nodes keep on monitoring the link status of next hop 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.

C. Dynamic MANET On-demand (DYMO) Routing Protocol:

The Dynamic MANET On-demand (DYMO) routing protocol [15] is a reactive, multihop, unicast routing protocol. The DYMO is a memory concerned routing protocol and stores minimal routing information and so the Control Packets is generated when a node receives the data packet and it doesn't have any valid route information. The basic operations of DYMO are similar to AODV that is route discovery and route maintenance.

D. Interzone Routing Protocol (IERP):

The Interzone Routing Protocol (IERP) is the reactive routing component of the Zone Routing Protocol (ZRP). IERP adapts existing reactive routing protocol implementations to take advantage of the known topology of each node's routing zone, provided by the Intrazone Routing Protocol (IARP). The availability of routing zone routes allows IERP to suppress route queries for local destinations. The BRP (Bordercast Resolution Protocol) forwards the IERP route queries to border nodes.

E. Zone Routing Protocol (ZRP):

It is a hybrid wireless networking routing protocol. ZRP [6] was designed to reduce the processing overhead and speed up the packet delivery by choosing the most efficient routing protocol to be used throughout the route. The network is divided into overlapping, variable size zones. A node may be within multiple overlapping zones. If the destination node is in the same zone as the source node, the IARP that is a proactive routing protocol is used inside routing zones. IARP uses an already stored routing table to deliver the packet immediately.

If the route extends outside the packet's originating zone, a reactive protocol IERP is used between routing zones. IERP checks each successive zone in the route to see if the destination exists in that zone. This reduces the processing overhead for those routes. Once the zone with the destination node is confirmed, the proactive protocol IARP is used to deliver the packet.

IV. RELATED WORK

In [1] the performance of AODV protocol is analyzed using NS2 simulator. It is being concluded that sensor nodes works better in small terrain regions as compared to large terrain regions as Packet Delivery Ratio is more for small simulation area and less as area increases. Delay is nearly constant for small area and it increases as the area increases. In [2], ZRP component protocols IARP and IERP and three on demand routing protocols AODV, DSR and DYMO based on IEEE 802.11 have been analyzed and compared in this paper using QualNet (version- 7.1). In [3] reactive routing protocols AODV, DSR and DYMO based on IEEE 802.11 are analyzed and a summary is present about each protocol with respect to different performance metrics.

In all the above papers, authors analyzed the proposed issues of sensor networks and presented a categorization and comparison of these routing protocols. They gave a selection of particular routing protocol adapted for specific application in different area. They showed that it is not possible to design a routing algorithm which will have the best performances under all scenarios and for all applications.

V. NETWORK SIMULATION

Test cases using 250 nodes in a 1000mx1000m Cartesian (flat) terrain area and in DEM are created and AODV, DSR, DYMO, IERP and ZRP routing protocols are applied and their performance is compared. Scenario is developed using QualNet 7.1simulator that provides scalable simulations of wireless networks to analyze the performance of different routing protocols in WSN with Zigbee application. In the scenario one node is Full Function Device (FFD) and acts as a Pan Coordinator (PAN-C), other 25 nodes are also FFDs that act as Coordinators and rest of the nodes are Reduced Function Devices (RFD). There are about 20 Zigbee applications used in this scenario. All Zigbee applications are destined at PAN-C (Node 232) from different source nodes. No mobility is provided to the PAN-C. Simulation is done for a simulation time of 450 seconds and the results are analyzed using different protocols both without mobility and with mobility to the nodes. The performance evaluation of the AODV, DSR, DYMO, IERP and ZRP protocol is analyzed on the QualNet 7.1 [7]. The parameters that are considered in the scenario are shown in the table-1 [4]. The traffic nodes communicate with the PAN-C and exchange packets when they are in the range of PAN-C. The traffic nodes which are not in the range of PAN-C they communicate with PAN-C using Coordinators.

Using the parameters given in the table-1 two scenarios are simulated as shown in figure-3 and 4 with routing protocols AODV, DSR, DYMO, IERP and ZRP without mobility and with mobility for the nodes and statistics are collected for the same.

PARAMETER	VALUE
Qualnet	7.1
Terrain Area	1000m x 1000m
Simulation time	450s
Channel Type	Wireless channel
Channel frequency	2.4 GHz
Packet size	70 bytes
Mac protocol	802.15.4
Node placement	Random
Number of nodes	250
Number of Zigbee used	20
Routing protocol	AODV,DSR,DYMO,IERP,ZRP

Table 1: Simulation Parameters

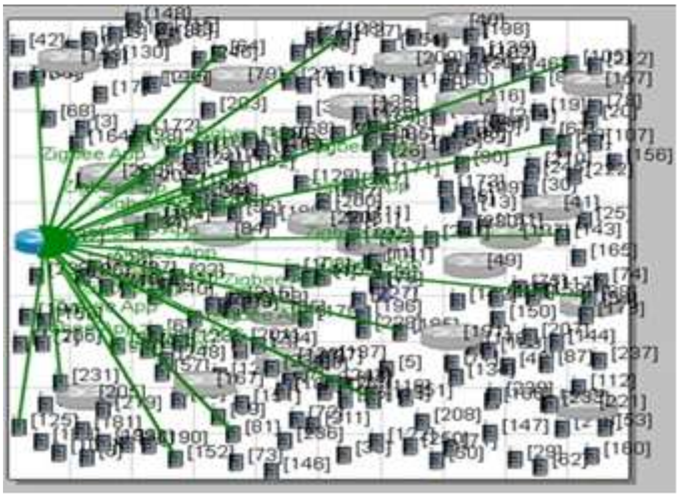

Fig. 3: Simulation Scenario in Flat Terrain

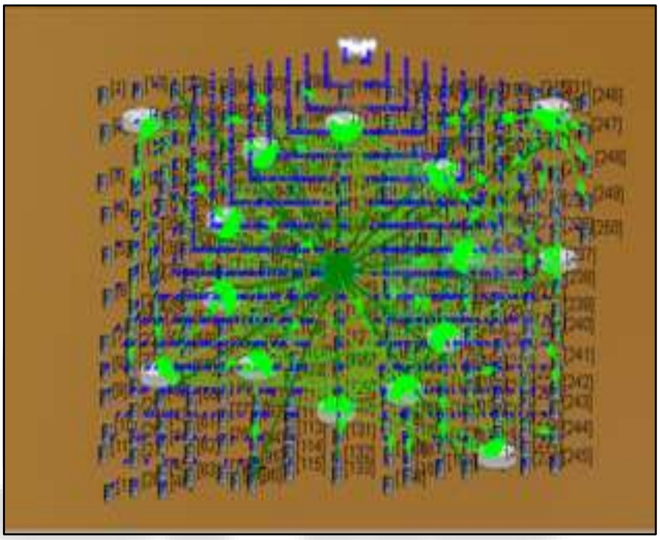

Fig. 4: Simulation Scenario in DEM

VI. SIMULATION RESULTS

The performance metrics like Throughput, Average End-to-End Delay, Average jitter and Residual battery capacity for the routing protocols like AODV, DSR, DYMO, IERP and ZRP is compared and which routing protocol is best suited for the chosen scenario is evaluated and plotted using Qualnet 7.1 and are as shown below:

1) Throughput (bits/s): Throughput is the average rate of successful data packets received at destination.
2) Average End-to-End Delay (s): A specific packet is transmitting from source to destination and calculates the difference between send times and received times.
3) Average jitter (s): Variation of the packet arrival time.
4) Residual battery capacity (mAhr): The amount of energy present in battery after completion of data transfer for a particular time interval.

A digital elevation model (DEM) is a digital model or 3D representation of a terrain's surface commonly for a planet (including Earth), moon, or asteroid created from terrain elevation data. DEMs are commonly built using data collected using remote sensing techniques, but they may also be built from land surveying

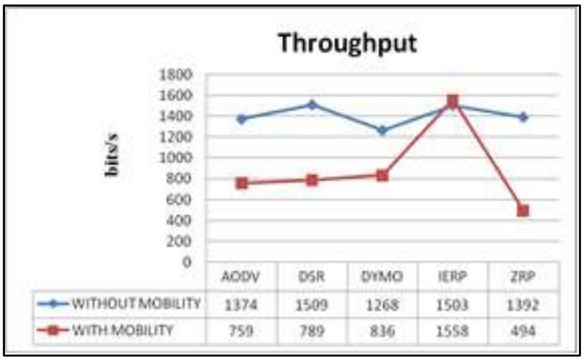

Fig. 5: Throughput Received Per Protocol

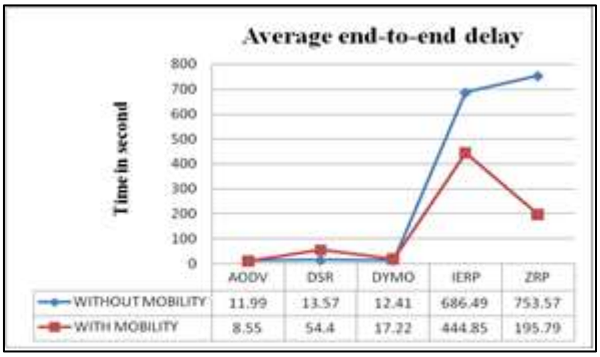

Fig. 6: Average End To End Delay Per Protocol

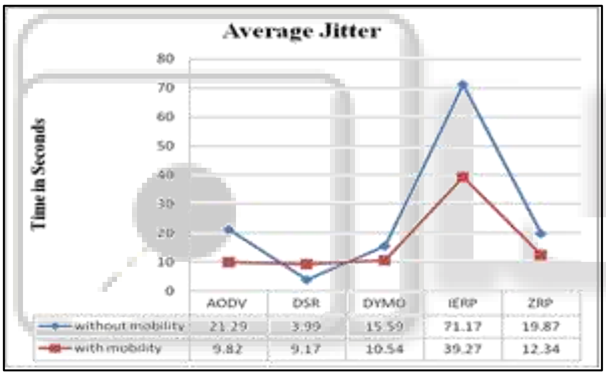

Fig. 7: Average Jitter per Protocol

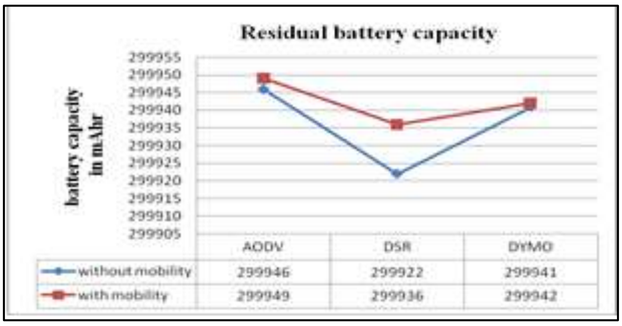

Fig. 8: Residual Battery Capacity of Traffic Nodes Per Protocol

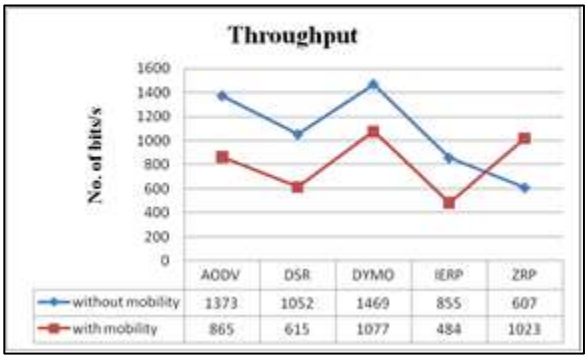

Fig. 9: Throughput Received Per Protocol in DEM

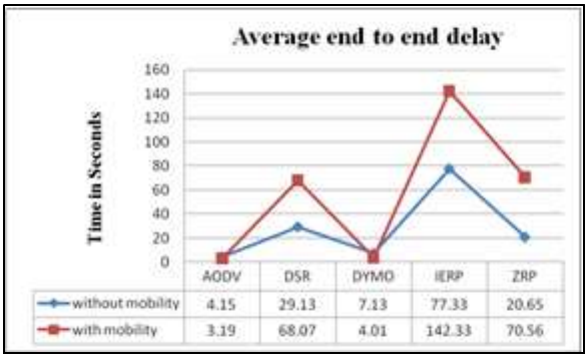

Fig. 10: Average End To End Delay Per Protocol In DEM

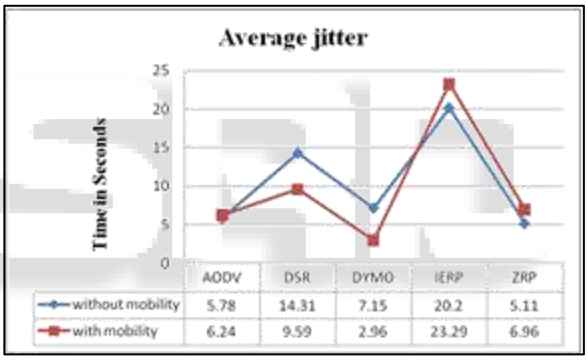

Fig. 11: Average Jitter per Protocol in DEM

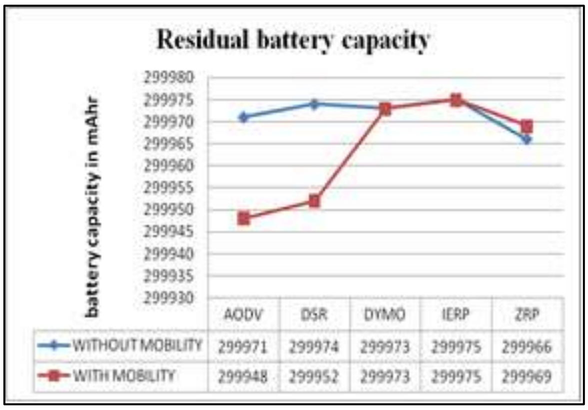

Fig.12: Residual Battery Capacity of Traffic Nodes per Protocol in DEM

VII. CONCLUSION

Test cases using 250 nodes in a 1000mx1000m flat terrain area and DEM were created and AODV, DSR, DYMO, IERP and ZRP routing protocols were used. For the first scenario, in flat area it is found that for both cases without mobility and with mobility to nodes, IERP performs better than all other routing protocols for all the performance metrics except average delay. IERP has high end-to-end delay which follows ZRP which has highest end-to-end delay value. Following IERP, AODV comes next in performing better with respect to all metrics.

For the second scenario, in DEM it is found that for both without mobility and with mobility to nodes, DYMO performs better than the remaining routing protocols. Even though DSR has high throughput next to DYMO, but end-to-end delay is more in it. Next comes AODV whose performance is good with respect to all metrics except residual battery capacity. AODV and ZRP have least residual battery capacity.

In future work we can try to find methods to reduce end-to-end delay for Interzone Routing Protocol (IERP). Further we can analyze the results for more number of metrics in order to get better idea about performance of routing protocols and even we can include security issues under comparison criteria for the routing in wireless sensor networks.

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