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Performance Comparison and Analysis of On-Demand, Table-driven and Hybrid Routing Protocols in 3D

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Abstract: The interaction between randomly distributed sensor nodes in an underground environment can lead to establishment of a network system with efficient data delivery. There has been an increasing interest in building mobile sensor networks due to its favorable advantages and applications. This paper focuses on the analysis of factors like data received, end-to-end delay, throughput, jitter and energy consumed by sink node when different routing protocols viz. On-Demand, Table-Driven and Hybrid are applied in the same 3D network design and the sink node is kept static. It is shown here how the performance of data communication is affected when using IEEE 802.15.4 standard. The analysis is done to show the applicability of various routing protocols for agricultural monitoring. Extensive simulations are done using QualNet 6.1 network simulator to validate the results.

Keywords: sensor nodes, mobility, routing protocols, Qualnet 6.1

1. INTRODUCTION

A wireless sensor network (WSN) is an uncommon network with a substantial number of sensor nodes used to monitor physical or ecological conditions. As WSN has no framework, its sensor nodes convey by means of wireless radio interfaces, which creates confusion during data transmission. Hence, correspondence in sensor nets is normally accomplished via hop by hop manner, in light of conveyed directing conventions. WSNs have constrained assets for use in social occasion information. One of the intrinsic restrictions of a wireless sensor node is its constrained vitality assets: Each WSN sensor node is battery worked, making battery reviving or substitutions troublesome or even outlandish. Even though mass minimal effort generation of sensor nodes will be doable soon, battery limit just doubles at regular intervals of 30 years. Because of such moderate changes in battery limit, vitality imperative issues are probably not going to be settled at any point in the near future. Vitality productive steering conventions for WSNs are vital [1-3].

The parts of sensor node are incorporated on solitary or different sheets, and bundled in a few cubic inches. A wireless sensor network comprises of few to thousands of nodes which convey through wireless channels for data sharing and agreeable handling. A client can recover data of his/her enthusiasm from the wireless sensor network by putting questions and assembling comes about because of the base stations or sink node [4]. The base stations in wireless sensor networks carry on as an interface amongst clients and the network. Wireless sensor networks can likewise be considered as a disseminated database as the sensor networks can be associated with the Internet, through which worldwide data sharing ends up noticeably attainable. Wireless Sensor Networks comprise of number of individual nodes that can cooperate with the earth by detecting physical parameter or controlling the physical parameters, these nodes need to team up to satisfy their undertakings as normally, a solitary node is unequipped for doing as such and they utilize wireless correspondence to empower this joint effort.

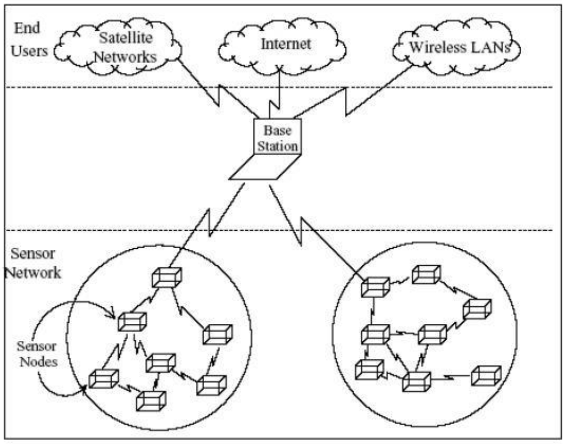

Fig. 1: Basic structure of wireless sensor network

2. AD HOC ROUTING PROTOCOLS

A routing protocol indicates how nodes speak with each other, dispersing data that empowers them to choose courses between any two nodes in a particular network. Routing calculations decide the particular decision of course. Every node has from the earlier learning just of systems it is connected to directly. A routing protocol shares this data first among quick neighbors, and after that all through the system. Along these lines, nodes pick up learning of the topology of the system. The particular attributes of routing protocols incorporate the way in which they abstain from routing circles, the way in which they select favored courses, utilizing data about bounce costs, the time they require to reach routing joining, their adaptability, and different components [5].

An ad hoc routing protocol is a standard that controls how nodes choose which approach to course parcels between neighboring nodes in a particular scenario. In ad hoc network, nodes are not comfortable with the topology of their systems. Instead, they need to find it: normally, another node reports its essence and tunes in for declarations broadcast by its neighbors. Every node finds out about others adjacent and how to contact them, and may declare that it also can contact them [6].

Sensor Networks can be grouped on the premise of their method of working and the sort of target application into three noteworthy sorts, namely, Proactive (Table Driven), Reactive (On Demand) and Hybrid routing protocols [7].

TABLE I. COMPARISON OF TABLE DRIVEN AND ON DEMAND ROUTING PROTOCOLS

Proactive (Table Driven)	**Reactive(On Demand)**
Path from every node to every other node in the network	Path from source to destination only
Routes are prepared to utilize momentarily	Routes built when required for higher association setup delay
Periodic course- update packets	Course updates when essential
Big routing tables	Little or no routing tables
Large overhead and less latency	Less overhead and more latency
Examples: DSDV, OLSR, WRP, IARP.	Examples: AODV, DSR, IERP, LAR1.

Hybrid routing protocol is basically the blend of Table Driven and On Demand routing protocols. Its directing is proactive for short separations and reactive for long separations. Its main advantage is that there is no course setup latency for short distance connections and also brings about lower routing overhead. This type of protocol simply makes and endeavors to consolidate the positive properties yet its hindrance is that it makes the convention extremely mind boggling. Example: Zone Routing Protocol (ZRP), Border Gateway Protocol (BGP), Enhanced Interior Gateway Routing Protocol (EIGRP).

3. SIMULATION OVERVIEW

Using Qulanet Network Simulation 6.1, a scenario was designed for further evaluation. In this scenario, 100 nodes were placed randomly in a region measuring 100 m × 100 m, where in each layer, 20 nodes were placed at a gap of 10 meters between each layers, starting from the ground level. Node number 70 being the sink node was made sure to be kept on the ground level as it is supposed to be the base station of the entire network. Figure 2 shows the design of the network used for the experiment conducted for this paper.

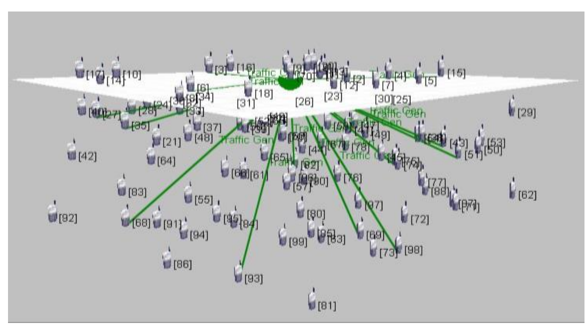

Fig. 2: Design of the network in 2D

The necessary input parameters given are noted in Table 2 below and thus simulation was conducted in batch experiments by varying routing protocols to obtain the necessary resultant graphs. Node number 70 was taken as sink node for this simulation work, as

IEEE 802.15.4 standard was considered for designing purpose. There were 20 applications used to connect random sensor nodes to the sink node, using traffic generator

TABLE II. SIMULATION PARAMETERS FOR WSN

Parameter(s)	Value(s)
Deployment strategy	Random
Total number of nodes	100
Terrain in 3D	100 m × 100 m × 40 m
Mac layer	IEEE 802.15.4
Packet reception model	PHY 802.15.4 Reception model
Modulation model	O-QPSK
Simulation time (sec.)	1000
Channel frequencies (Zigbee)	2.4 GHz
Routing protocols	IERP, DSR, IARP & ZRP
Traffic type	TRAFFIC-GEN
No. of applications	20
Packet size (bytes)	50
Path loss model	Two-Ray Ground Propagation
Battery capacity (mAhr)	200
Transmission range (m)	100
Antenna type	Omnidirectional
Energy model	Generic
Temperature (K)	290
Noise factor	10
Energy model	Generic
Supply voltage (V)	6.5

4. ROUTING PROTOCOLS

In this experiment, we needed to compare the performance of three different categories of Ad Hoc Routing protocols, so as to conclude which is more suitable for terrestrial data communication in 3D network design. So, having tried several routing protocols, best results obtained from each kind have been taken into consideration for further analysis. The following description will give us a brief idea about the routing protocols used [8].

- Intrazone Routing Protocol (IARP) – It is from the Table driven category. IARP is a restricted degree proactive routing protocol, which is utilized to help an essential worldwide routing protocol [9]. The extent of IARP is characterized by the routing zone range: the separation in hops that IARP route refreshes are transferred. Each node communicates with its nearby node inside its own routing zone. This makes every node keep up a neighborhood routing table which contains the route to the node in its routing zone. The bigger the zone span is, the more neighborhood routes it can hold. Obviously, this may bring about significantly more routing movement, hence reducing delay. When routes are found, it offers improved, constant, route upkeep. Connection failures can be skirted by numerous jump ways inside the routing zone.
- Interzone Routing protocol (IERP) - It is from the On Demand category. IERP is the reactive directing segment of the Zone Routing Protocol (ZRP). IERP adjusts existing receptive directing convention usage to exploit the known topology of every node's encompassing r-bounce neighborhood. The accessibility of directing zone courses enables IERP to smother course questions for nearby goals. At the point when global route revelation is required, the directing zone based border cast administration can be utilized to productively control course inquiries outward, instead of indiscriminately handing-off queries from neighbor to neighbor. Once a course has been found, IERP can utilize routing zones to naturally divert information around fizzled joins. Likewise, imperfect course fragments can be recognized and activity re-steered along shorter ways. [10]
- Dynamic Source Routing (DSR) - It is also from the On Demand category. In DSR every data bundle to be transmitted conveys the entire succession of nodes by which the parcels must go to achieve the target. This property is known as source routing, and requires the sender to know the entire route to the goal. This depends on two fundamental procedures: (a) the route discovery process and (b) the route maintenance process [11]. The route discovery process depends on flooding and is utilized to powerfully find new routes. The route maintenance process occasionally identifies and informs systems topology changes.
- Zone Routing Protocol (ZRP) – ZRP is a hybrid routing protocol appropriate for a wide assortment of versatile impromptu systems, particularly those with huge system ranges and differing portability designs. Every node proactively keeps up courses inside a neighborhood area (alluded to as the routing zone). The proactive support of routing zones additionally enhances the nature of found routes; by rolling out them stronger to improvements in arrange topology [12]. The ZRP can be designed for a specific system by appropriate choice of a solitary parameter, the routing zone span.

5. NETWORK PARAMETERS

Number of messages received (M): It is known to be the total number data messages that successfully reach the PAN coordinator without collision in the way.

Throughput (Th): It is measured by the total number of data frames collected at the sink node in one round of simulation time. The efficiency of a network highly depends on this parameter

Delay (D): It is the end to end delay which refers to the time needed for a packet to be transferred from source to destination. It may vary greatly with the application of other routing protocols in the same network

Jitter (J): It is known to be the variation in delay of packets received. It is an unstoppable effect that occurs due to electromagnetic interference and crosstalk with the carriers. Too much jitter degrades the performance of the network.

Network lifetime (NL): It is estimated by residual energy of the nodes in the network. The total energy consumed E(c) is calculated by the total initial energy E(i) and total residual energy left after simulation E(f) [13-14].

$$E(c) = E(i) - E(f) \quad (1)$$

On the basis of this parameter, network lifetime can be calculated as:

$$NL = \frac{(E(i) \times T)}{E(c)} \quad (2)$$

6. Process of Simulation

Fig 3 shows a flowchart, which gives an idea about the procedure that was followed while conducting this software simulation in Qualnet Network Simulator 6.1.

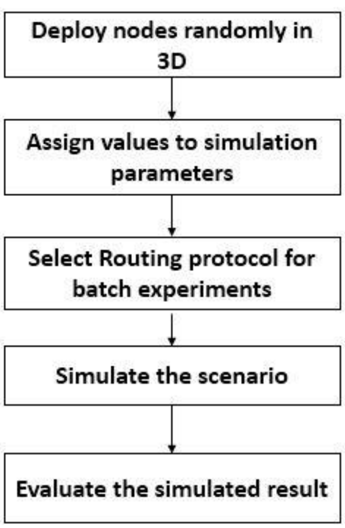

Fig. 3: Flowchart of the process of simulated work

7. Outcome of the Experiment

In this section, we showed the results collected from simulation work done in Qualnet 6.1, where mainly five parameters were evaluated, which are messages received, throughput, jitter, delay the average network lifetime of the design. The analysis was done on the basis of simulation conducted in batch experiments by considering different routing protocols in the same network design, for one thousand seconds. The graphs plotted from the results are shown below and they give a clear idea about the response of the designed scenario on the basis of varying routing protocols using three different types, On Demand (IERP & DSR), Table driven (IARP) and Hybrid (ZRP) routing protocols. IEEE 802.15.4 standard was used where sink node plays the major role, as it communicates with all the sensor nodes available for necessary data communication.

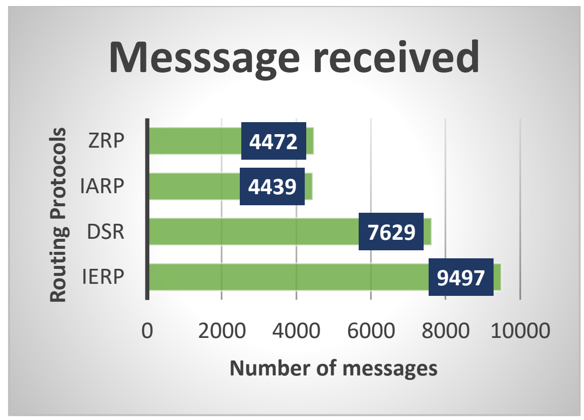

Fig. 4: Comparison of messages received with variation in routing protocols

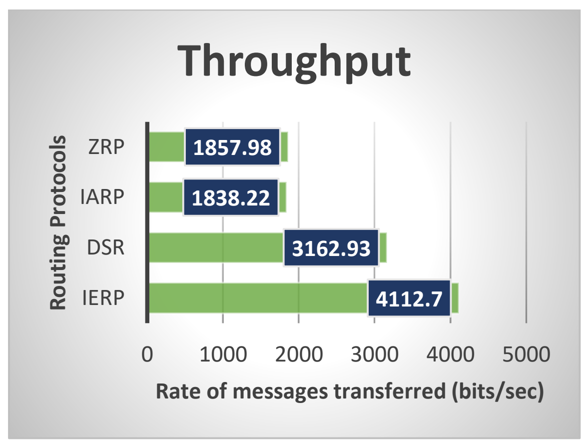

Fig. 5: Comparison of throughput with variation in routing protocols

Figure 4 and figure 5 shows the variation in outcome for parameters like messages received and throughput respectively. Among all, IERP and DSR are comparatively giving better results, which are both On Demand routing protocols. Table driven or Hybrid routing protocols should not be taken into consideration when efficient data communication is taken into account for 3D network design, as in real life there is more possibility of data loss due to complicated underground environments.

In figure 6 and figure 7 below, delay and jitter are found to be very low for DSR, IARP and ZRP routing protocols. Hence, the unexpected value of IERP makes it unsuitable for use, when delay is taken into account for network design. Thus, again On Demand routing protocol is advisable for use in terrestrial data communication.

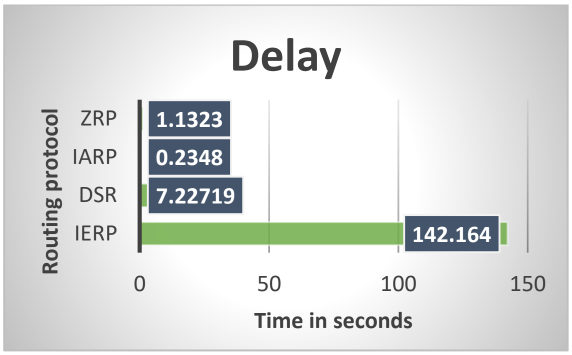

Fig. 6: Comparison of delay with variation in routing protocols

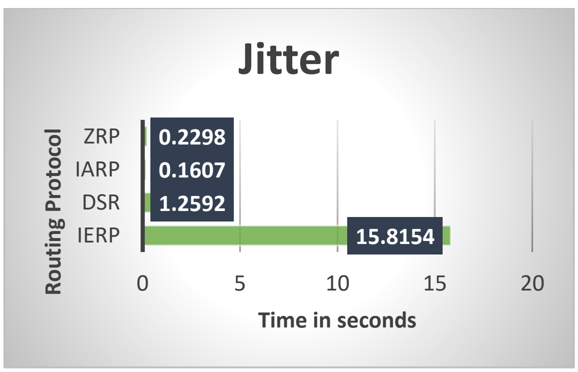

Fig. 7: Comparison of jitter with variation in routing protocols

Figure 8 below shows the network lifetime comparison of the sink node verses all the 100 nodes used in the network scenario. Using eq (1) and (2), the calculation was done where sink node was found to survive for around 10.5 hrs while for all the nodes the number was seen to vary largely from around 30 hrs to 41 hrs. On Demand routing protocols was found to be more energy sufficient compared to Table Driven or Hybrid routing protocols.In this simulation, 200 mAhr battery value was considered, hence according to our need , the battery value needs to be increased for longer network lifetime.

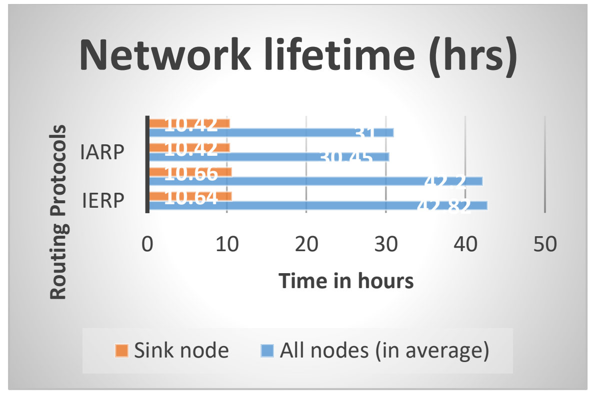

Fig. 8: Comparison of Network lifetime of all nodes verses sink node

8. Conclusion and Future Scope

In this paper, the performance analysis was done for three different categories of Ad Hoc Routing protocols namely Table Driven (IARP), On Demand (IERP and DSR) and Hybrid (ZRP) routing protocols. It can be concluded from the graphical presentation of parameters like messages received, throughput, delay, jitter and network lifetime that On-Demand routing protocol is more suitable for better efficiency of terrestrial data communication in 3D. In future, field testing can be done for verification of the software based results for error detection as in real life there will be more data loss due to complicated underground environments. Also further research can be done using 3D network designs for better understanding of underground terrestrial communication.

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