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IMPACT OF NODE DENSITY ON ARCHIMEDES' SPIRAL BASED MOBILE NETWORK DESIGN IN 3D

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Abstract: Wireless Sensor Technology has entered into a new phase with all the research going on based on its efficient data delivery. Its favourable advantages and applications are the reason behind growing interest in this field. In this paper, this work is related to the impact of node density on a particular 3D terrain to determine its optimum performance. The use of Archimedes' Spiral was introduced to compare with static and random mobility conditions in both 2Dand 3D network designs to prove that communication can be improved when mobility is introduced. The simulation and 3D network design to prove that communication can be improved when mobility is introduced. The simulation results were impressive which when researched on higher levels and done field tests, may prove to be a better practical application of wireless sensor network in the field of agriculture.

Keywords: sensor nodes, Archimedes' spiral, wireless, 3D, network design.

I. INTRODUCTION

In a wireless sensor network, the sensor nodes are designed such as to monitor certain events and help solve the problems that may arise in a particular scenario. It has wide application area [1-4] but the focus in this work is mainly in the agricultural sector where sensor network may be designed for terrestrial deployment [5-8]. Sensor networks have been currently emerging as a great way to improve agriculture quality, productivity and resource optimization. Now a day's researchers are willing to do analysis and work further using WSN. Lot of new technologies in WSN is becoming available for improving agricultural quality. Precision agriculture is one of them, which is a field that provides suitable scenarios for the deployment of wireless sensor networks (WSNs). The wireless sensor network is built of few to several hundred or even thousands of sensor nodes. Each sensor node comprises of several parts such as a radio transceiver, microcontroller, an electric circuit for interfacing with the sensors and an energy source. The topology can change from a straightforward star network to a progressed Multi-hop interlock network. The communication technique between the jumps of the network can be either routing or flooding. Also, many routing protocols have been designed for WSNs which mainly differs depending on its wide range of application and network topology [9-11].

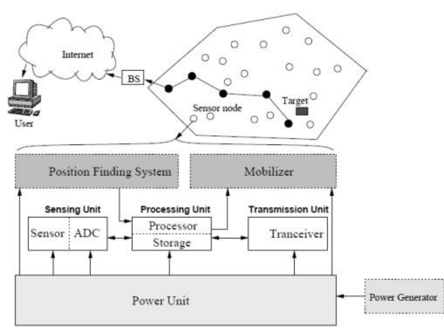


Fig 1: Overview of Wireless Sensor Network

However, the varying of node density in a particular area can have an impact on the efficiency of network design as shown in the work of this paper. Figure 1 shows a basic overview of Wireless Sensor Network and the internal units of a sensor node.

II. RELATED WORK

Based on node density variation in a wireless sensor network design, some research work has been conducted by scholars using several network simulators. Routing protocol also played a major role in these simulation works.

In [12] the authors evaluated the performance analysis of Optimized Link State Routing (OLSR) and Source Tree Adaptive Routing Protocol (STAR) at application layer by varying number of nodes using QualNet 5.0 simulator. From their simulated work, it was seen that OLSR showed better performance compared to STAR with increase in node density for a particular area.

In [13] the authors used QualNet 5.0.2 Network simulator to conduct a study of using both CBR and FTP traffic patterns for comparing three different routing protocols (AODV, DSDV and DYMO) with node variation from 20 to 150. Their analysis showed optimum performance of AODV when using both CBR and FTP application hence it was preferable when set up in large terrain.

In [14] CBR was used as traffic pattern and AODV as Routing protocol on a 1000*1000 m terrain and simulation was conducted using NS2 network simulator by varying node density. With increase in node density, packet ratio and delay was observed to have increased due to congestion in the network. The scenario with 50 nodes had optimum results showing most suitable among the range of 25 to 125 nodes.

In [15] high speed mobile nodes were taken in the design scenario and having taken three routing protocols (AODV, DSDV and DSR), simulation was conducted in NS-2 network simulator by varying node density from 40 to 100 nodes and ANOVA tool was used to confirm the correctness of the result. The results showed that with increase in node density the efficiency improved, and also AODV performed better among all.

III. Archimedes' spiral

Archimedes spiral is a mathematical concept which mainly includes a shape starting from a point called the center and winds about it with continuous increase in the radius and at a steady speed, hence varying the distance. It is named after the third century BC Greek Mathematician Archimedes. The bend in the spiral is followed out counterclockwise as the sweep of the circle and the point of turn both keep running from 0 to 2π. Eq. (1) is the basic equation for this pattern.

$$\boldsymbol{r = a + b\theta} \qquad \textbf{(1)}$$

Where θ is polar angle, and r is the distance of the radius, a and b are real numbers. Changing the parameter a will turn the winding, while b controls the separation between progressive turns.

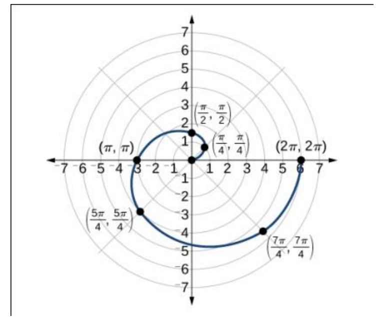


Fig 2: Archimedes' Spiral

Fig 2 above depicts one complete spiral with θ being π/2. Hence, the mobility of sink node can be assigned to move in Archimedes' spiral to ensure better data transmission over the entire area. Also, the length of the spiral can be calculated as shown in eq. (2) as follows:

$$\boldsymbol{S = \frac{\alpha}{2}\left[\theta\sqrt{1+\theta^2} + log\left(\theta + \sqrt{1+\theta^2}\right)\right]} \textbf{(2)}$$

IV. Simulation Scenario

In this network design, the dimension of terrain was taken to be100m*100m*40m and on the basis of node density, there were four random node deployment of 50, 100, 150 and 200 nodes. Having taken traffic generator as application type, DYMO was used as Routing protocol and IEEE 802.15.4 standard as MAC Layer. The size of data packet sent was 50 bytes and number of application was kept constant as 25. Battery was taken to be 200mAHr and the energy model was taken as linear. The simulation was conducted for 1000 seconds. Three different conditions were taken into account such that in first case sink node was kept static, second case the sink node was allowed random mobility while in third case sink node was assigned Archimedes' Spiral mobility pattern. All the three scenarios were conducted with the variation of node density. Node 70 was kept fixed as the PAN Coordinator throughout all the simulations.

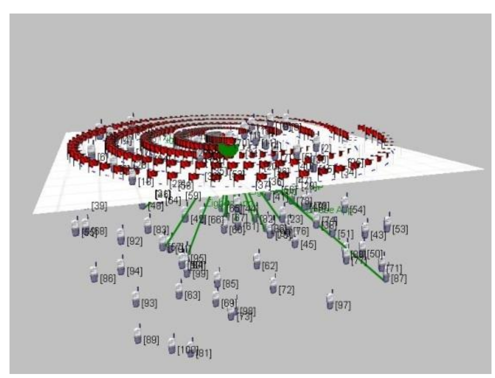


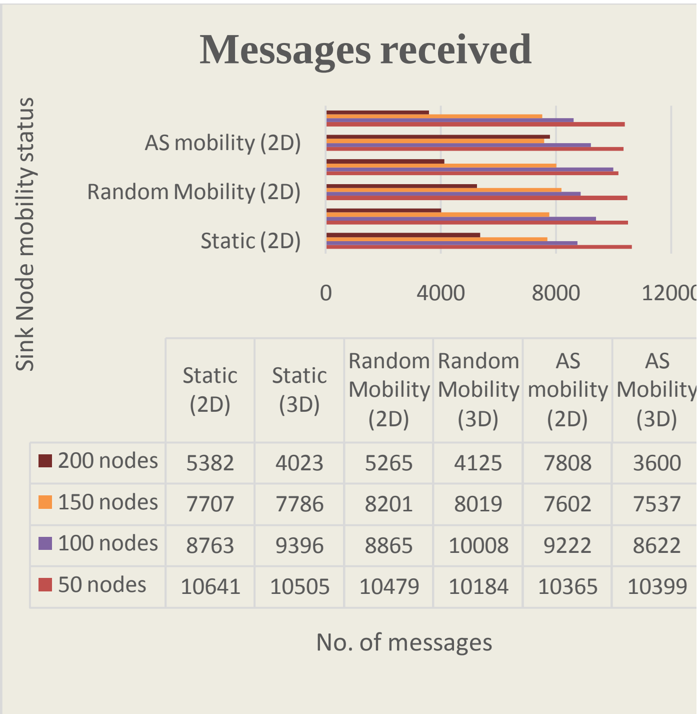
Fig 3: Deployment of 100 nodes in 3D using QualNet 6.1

V. Results and Discussion

In this section, the simulated results of static, random mobility and Archimedes' Spiral based mobility of sink node with the variation of node density have been presented in graphical form which represents several performance metrics as analyzed and discussed in details below.

A. Messages received

In figure 4 below, 50 nodes is showing optimum condition among all the varied scenarios of node density. When sink node was considered to be mobile, number of messages received was found to be lesser but significantly large difference was not noticed. However, 3D scenarios are showing lesser value comparatively, due to increase in distance with the sink node.

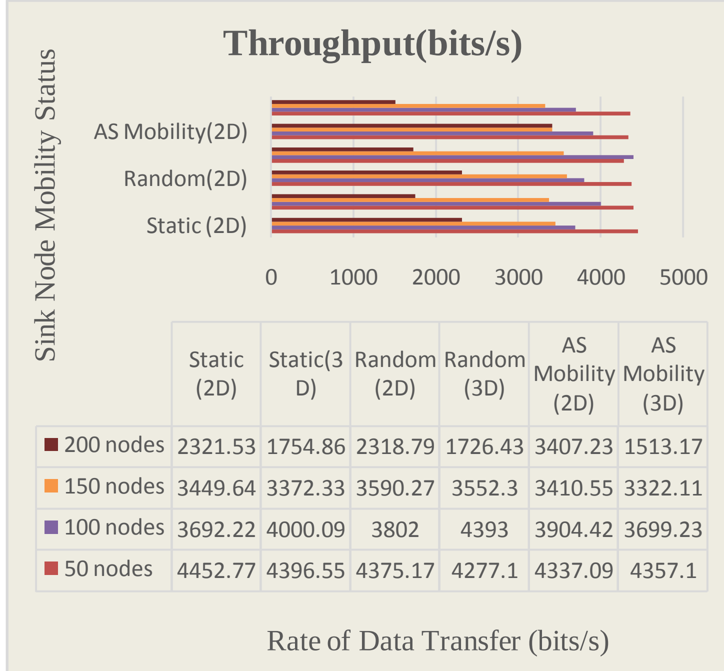


	Static (2D)	Static (3D)	Random Mobility (2D)	Random Mobility (3D)	AS mobility (2D)	AS Mobility (3D)
200 nodes	5382	4023	5265	4125	7808	3600
150 nodes	7707	7786	8201	8019	7602	7537
100 nodes	8763	9396	8865	10008	9222	8622
50 nodes	10641	10505	10479	10184	10365	10399

Fig 4: Performance comparison of Messages received (Static vs Mobile sink node)

B. Throughput (bits/s)

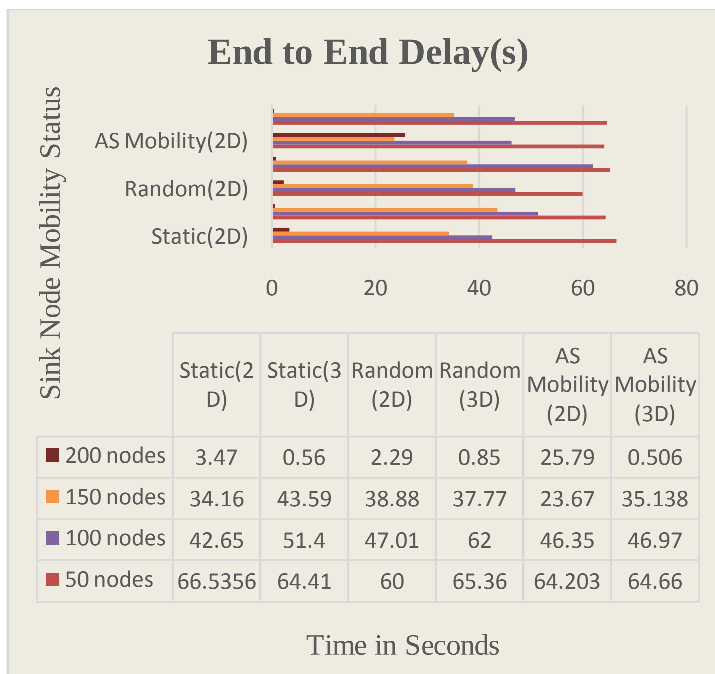
In figure 5 below, 50 nodes is giving better throughput among all the varied scenarios of node density. When sink node was taken to be mobile, throughput was found to have improved by a small margin. Overall, 3D scenarios are not found to vary much.



	Static (2D)	Static(3D)	Random (2D)	Random (3D)	AS Mobility (2D)	AS Mobility (3D)
200 nodes	2321.53	1754.86	2318.79	1726.43	3407.23	1513.17
150 nodes	3449.64	3372.33	3590.27	3552.3	3410.55	3322.11
100 nodes	3692.22	4000.09	3802	4393	3904.42	3699.23
50 nodes	4452.77	4396.55	4375.17	4277.1	4337.09	4357.1

Fig 5: Performance comparison of Throughput (Static vs Mobile sink node)

C. Average End to End Delay (s)



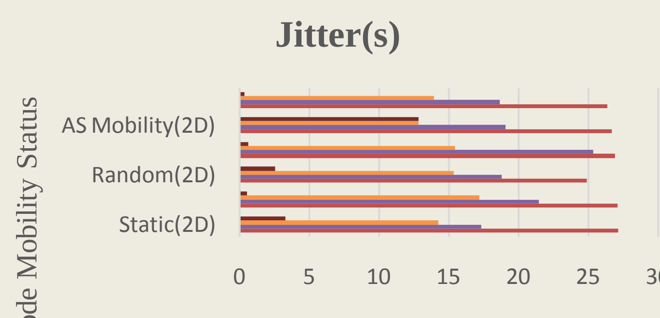
	Static(2D)	Static(3D)	Random (2D)	Random (3D)	AS Mobility (2D)	AS Mobility (3D)
200 nodes	3.47	0.56	2.29	0.85	25.79	0.506
150 nodes	34.16	43.59	38.88	37.77	23.67	35.138
100 nodes	42.65	51.4	47.01	62	46.35	46.97
50 nodes	66.5356	64.41	60	65.36	64.203	64.66

Fig 6: Performance comparison of End to End Delay (Static vs Mobile sink node)

In figure 6 above, there was minimum delay when 50 nodes were taken into consideration, while for 200 nodes, it is found to be least. For mobile sink node, the variation in delay is not found to be constant as the movement of sink node makes it comparatively easier to collect data across the terrain.

D. Average Jitter (s)

In figure 7 below, the result was found to be similar to figure 6 as 200 nodes show minimum jitter and 50 nodes show the highest value as expected. For mobile sink node, the variation of jitter was found to be uneven which is because with the movement of sink nodes, it becomes easier to collect data across the terrain.



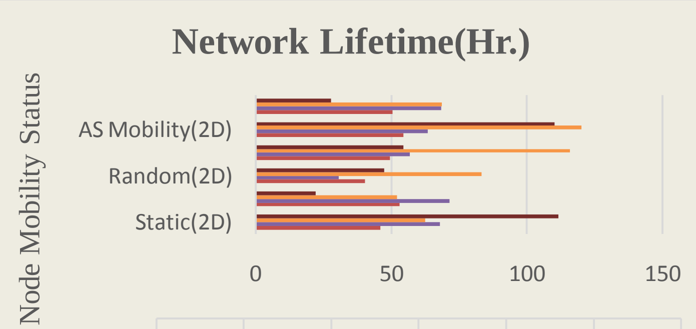
	Static(2D)	Static(3D)	Random (2D)	Random (3D)	AS Mobility (2D)	AS Mobility (3D)
200 nodes	3.31	0.56	2.566	0.65	12.85	0.366
150 nodes	14.27	17.22	15.38	15.48	12.86	13.93
100 nodes	17.33	21.45	18.83	25.38	19.092	18.69
50 nodes	27.1468	27.11	24.92	26.94	26.68	26.365

Time in Seconds

Fig 7: Performance comparison of Jitter (Static vs Mobile sink node)

E. Network Lifetime (Hrs.)

In figure 8 above, the graph overall proves that with increase in node density, the battery consumption by each node decreases, hence making the overall network design energy efficient. 150 nodes with Archimedes' Spiral based sink mobility were found to have the highest value. However, mobility of sink node does not affect the overall network lifetime much and was found to be around 10.4 hrs. in almost all the simulations conducted.



	Static(2D)	Static(3D)	Random (2D)	Random (3D)	AS Mobility (2D)	AS Mobility (3D)
200 nodes	111.53	22.24	47.32	54.46	110.12	27.91
150 nodes	62.5	52.12	83.23	115.74	120.12	68.7
100 nodes	67.94	71.46	30.69	56.88	63.42	68.43
50 nodes	46	53.14	40.41	49.44	54.41	50.53

Time in Hours

Fig 8: Performance analysis of network Lifetime (All nodes vs Sink node)

VI. CONCLUSION

The selection of appropriate node density for a particular terrain is very important as it can contribute to both efficiency and economic value of the wireless sensor network design. In this study, the impact of Archimedes' Spiral based sink mobility was compared with static and random mobility of sink node and was shown how it can contribute to the performance of the network scenario. Thus, under the IEEE 802.15.4 standard, most important performance metrics were investigated with varying node density. For messages transferred and throughput, 50 nodes were found to be optimum and the values degraded with increase in node density. While, for End to End Delay and Jitter, the values were found to improve with increase in node density. Thus it can be concluded that, for data communication purpose, 50 nodes with Archimedes' Spiral Based Sink Mobility can be considered to be optimum for this particular terrain.

REFERENCES

[1] Monir, Raunak, Ranjana Thalore, and Partha Pratim Bhattacharya, "Performance Comparison and Analysis of On-Demand, Table-driven and Hybrid Routing Protocols in 3D," *Mody University International Journal of Computing and Engineering Research*, vol. 2, no. 1, Feb. 2018, pp. 20-25.

[2] Thalore, Ranjana, Jyoti Sharma, ManjuKhurana, and Manish Kumar Jha, "QoS evaluation of energy-efficient ML-MAC protocol for wireless sensor

networks", *AEU-International Journal of Electronics and Communications*, vol. 67, no. 12, Dec. 2013, pp. 1048-1053.

[3] Khurana, Manju, Jyoti Sharma, Thalore Ranjana, and Manish Kumar Jha, "Direction determination in wireless sensor networks using grid topology", *Journal of Emerging Technologies in Web Intelligence,* vol. 5, no. 2, May. 2013, pp. 166-170.

[4] Thalore, Ranjana, Partha Pratim Bhattacharya, and Manish Kumar Jha, "Performance Comparison of Homogeneous and Heterogeneous 3D Wireless Sensor Networks," *Journal of Telecommunications and Information Technology,* vol. 2, Feb. 2017, pp. 32-37.

[5] Ferdoush, Sheikh, and Xinrong Li, "Wireless sensor network system design using Raspberry Pi and Arduino for environmental monitoring applications," *Procedia Computer Science,* vol. 34, Aug. 2014, pp. 103-110.

[6] Younis, Mohamed, Izzet F. Senturk, Kemal Akkaya, Sookyoung Lee, and FatihSenel., "Topology management techniques for tolerating node failures in wireless sensor networks: A survey," *Computer Networks,* vol. 58, Jan. 2014, pp. 254-283.

[7] Rawat, Priyanka, Kamal Deep Singh, HakimaChaouchi, and Jean Marie Bonnin, "Wireless sensor networks: a survey on recent developments and potential synergies," *The Journal of supercomputing,* vol. 68, no. 1, Apr. 2014, pp, 1-48.

[8] Ojha, Tamoghna, SudipMisra, and Narendra Singh Raghuwanshi, "Wireless sensor networks for agriculture: The state-of-the-art in practice and future challenges," *Computers and Electronics in Agriculture,* vol. 118, Oct. 2015, pp. 66-84.

[9] Gutiérrez, Joaquín, Juan Francisco Villa-Medina, Alejandra Nieto-Garibay, and Miguel Ángel Porta-Gándara, "Automated irrigation system using a wireless sensor network and GPRS module," *IEEE transactions on instrumentation and measurement,* vol. 63, no. 1, Aug. 2013, pp. 166-176.

[10] Ramesh, Maneesha Vinodini, "Design, development, and deployment of a wireless sensor network for detection of landslides," *Ad Hoc Networks,* vol. 13, Feb. 2014, pp. 2-18.

[11] Thalore, Ranjana, Jyoti Sharma, Manju Khurana, and Manish Kumar Jha, "QoS evaluation of energy-efficient ML-MAC protocol for wireless sensor networks," *AEU-International Journal of Electronics and Communications,* vol. 67, no. 12, Dec. 2013, pp. 1048-1053.

[12] Varshney, Pankaj Kumar, G. S. Agrawal, and Sudhir Kumar Sharma. "Relative performance analysis of proactive routing protocols in Wireless Ad hoc Networks using Varying Node Density." *Invertis Journal of Science & Technology* 9, no. 3 (2016): 161-169.

[13] Kumar, Subodh, G. S. Agrawal, and Sudhir Kumar Sharma. "Impact of CBR, FTP Traffic Patterns and Varying node density on Performance of Routing Protocols in MANETs." *IJCSMC* 4, no. 1 (2015): 262-269.

[14] Atole, Akshay M., Apurva D. Asmar, Nikhil R. Nemade, Kailash P. Tambe, and Vivek Deshpande. "Performance analysis of QoS parameters of WSN by varying density of the network." *Indian Journal of Science and Technology* 9, no. 29 (2016).

[15] Goswami, Subhrananda, Subhankar Joardar, Chandan Bikash Das, Samarajit Kar, and Dibyendu Kumar Pal. "Performance Analysis of Three Routing Protocols in MANET Using the NS-2 and ANOVA Test with Varying Speed of Nodes." In *Ad Hoc Networks*. InTech, 2017.