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Performance Evaluation of IoT Routing Protocols

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***Abstract*— Just as the tremendous measure of new information rising as the world modernizes. The significance of IoT-empowered advancements is no less significant in different areas. The IoT insurgency is changing the whole range of processing-based administrations. Another influx of quick foundation advancement is clearing the globe, including basically everything advanced server farms, supercomputers, groups, installed frameworks, servers, and organizations to control matrices, sensors, gadgets, apparatuses, cell phones, and instruments. The IoT worldview makes actual items with detecting capacities, incorporating those with labels, tech-savvy meters, buyer electronic gadgets, wellbeing sensors and gadgets, and portable things like advanced mobile phones, robots, vehicles, and home machines.**

The paper examines the different routing protocols available for ensuring the smooth communication of items in the Internet of Things, the simulations of the protocols discussed in this paper, and the pros, disadvantages, and problems mentioned earlier.

Index Terms—**Routing Protocols, IoT, Mobility Models, NetSim**

Introduction

According to [1], the number of devices connected with IoT by the end of 2020 will be 8.74 billion, while the following year, in 2030, the figure might triple (25.4 billion).

Despite an increment from the prior year, 2020 spending was not precisely the same as the estimated due to the worldwide Covid-19 pandemic. The amount of money spent in 2019, 2020, and 2023 is given in **Error! Reference source not found.**

Figure 1: An Estimated Spending on IoT [2]

If we talk continent-wise, the Asia Pacific area held the most considerable portion of the IoT market. North America came in second, trailed by Europe, the Middle East, and Africa.

From the above figures, a person can perceive how in-demand IoT has become in the everyday lives of humans around the globe.

This massive technical advancement has far-reaching economic and societal consequences, potential research prospects and difficulties. New research initiatives, knowledgebase creation, and training of a new IT workforce are all urgently needed. IoT applications generate enormous amounts of data in a variety of forms. Data analytics algorithms that are efficient, functional, and reliable are required for data storage and analysis.

In transportation, correspondence through IoT-associated robotized vehicles is ready to be a distinct advantage for the transportation business. Many cars, from mechanized trucks to transports and shared traveler vehicles, are used to benefit from such applications at different scales. These vehicles can conclude their moves and administrations using onboard sensors, like cameras and radars. Notwithstanding, their onboard sensors alone cannot find their general surroundings.

In sports and diversion, we see advancing gaming instruments and the conveyance of video and music as new means of amusement. Essentially, in business and exchange, we need the aftereffects of mind-boggling information examination (for example, real estate, securities exchange, and other venture instruments) accessible continuously on our cells. [3]

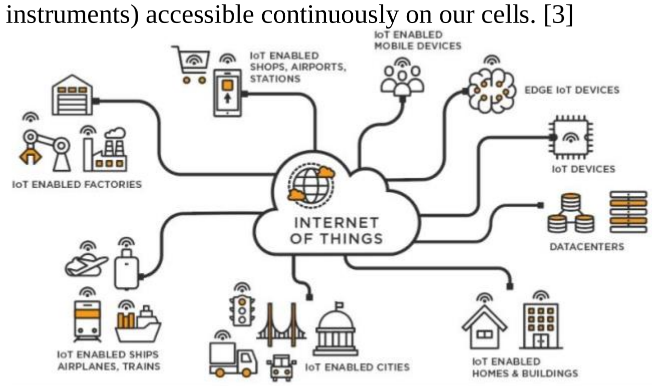

Figure 2: A physical representation of IoT [1]

2.1. Literature Review

Internet of Things is a cooperation between the physical and the digital world. It alludes to a method of interconnected, web-associated objects that can gather and move information over organizations without human mediation. The computerized world is associated with the actual world utilizing plenty of sensors and actuators.

If we talk about communication systems, there is no such thing as a standardized architecture. There are many different organizations around the globe; some of these are significantly larger, and others are small. Along with that, IoT is not only being used in businesses. It is also being used in homes and other walks of life. Given all these different environments, it was nearly impossible to have a standardized model. Every architecture has its advantages and disadvantages.

IoT technologies enable objects or gadgets, not computers, to act cleverly and settle on synergistic choices valuable to specific applications. They change “things” from being latently figuring and settling on individual decisions to effectively and universally imparting and teaming up to decide on a solitary essential choice. The hidden advancements of omnipresent processing installed sensors, light correspondence, and web conventions permit IoT to provide users with enormous benefits.

2.2. Components Of IoT Solutions

2.1.1. Information Flow Model

The information flow model for IoT is relatively conventional in its I-P-O (input -processing-output). Sensors provide the input while processing on local computers, in the cloud, or on data platforms, and the output may be displayed on remote actuators. Since every data communication technology is different, some sensors or actuators might need some gateway device. This gateway device is usually called a hub.[4]

2.1.2: Sensors and Actuators

Depending on the type of data transmission being used in different businesses, sensors or actuators are chosen. The distinctions between sensors and various data sources might be hazy in complicated systems. It might be possible that the input of some IoT devices or applications comes from some machines’ output. In some cases, there is no need for sensors(information). There will be no need to have an actuator in other circumstances, as the output may be generated from one of the IoT applications by another IoT application’s input. [5] [4]

2.2.3: Gateways and Data Acquisition Systems

The structure and capacity of gateways vary broadly, from little installed Linux frameworks to traditional remote switches

It links to the instrument system, whereas Net getaways employ Wi-Fi and wired LANs to connect to the device web and execute additional processing. [5]

2.2.4: Edge IT

In this phase of IoT engineering, the pre-arranged information is moved to the IT world. Particularly, edge IT frameworks achieve enhanced examination and pre-processing.

ML algorithms are utilized to pre-process information before it is shipped off the server farm or cloud. This method dissects advanced information to diminish information volume, select fundamental details, and show data in pie diagrams, charts, and dashboards. This sort of handling is frequently done on gadgets close to the sensors, as in an on-location wire close [4]

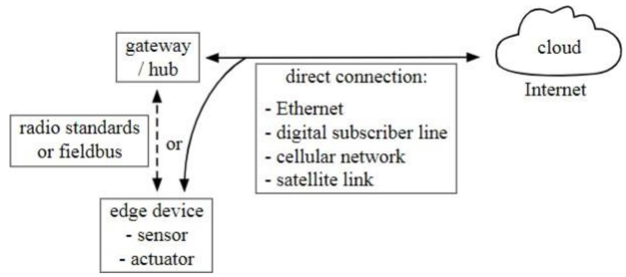

Figure 3: Architecture of IoT Solution [5]

2.3 : Data Link Protocol

2.3.1 : IEEE 802.15.4

IEEE 802.15.4 is the most regularly utilized IoT standard for MAC [6]. It is pointed toward giving the fundamental lower network layers for a small individual region organization, WPAN. [7] The central prerequisites are minimal expense, low-speed pervasive correspondence between gadgets. [8]

In 2008 IEEE 802.15.4e was made to expand IEEE 802.15.4 to support back low power correspondence. It utilizes time synchronization and channel bouncing to empower high dependability, minimal expense, and meet IoT correspondences necessities [9]

Table 1: Features of 802.15.4 [3]

Features	802.15.4
Names of Applications	Smart Agriculture, Environment, and Sensors
Network Support	Sensors
Channel	CSMA/CA
Frequency	2.4 GHz, Sub-1 GHz
Range	100 m Devoid of any repeaters

2.4 : Network Layer Protocols

In this section, we are discussing the two types of routing protocols used in this layer of IoT applications

2.4.1 : RPL

RPL stands for Routing Protocol for Low-Power and Lossy Networks. RPL is an IPv6 Routing Protocol for Low Power and Lossy networks that utilizes an advanced course (DODAG) for sending traffic from/or to a focal authority hub called a sink hub or LBR (LLN Border Router) [10]. RPL uses OF(Objective Functions) to do routing metric calculations [9]

The steps are mentioned below: [11]

- Each node first sends out a DODAG Information Object (DIO) to publicize itself as a root.
- The DIO contains multiple information like the rank, metric calculations, OF, and much more.
- A message is broadcast to the whole network to ensure that DODAG can be built progressively.

- After the root is successfully established, the node that wants to communicate with the root sends out a Destination Advertisement Object (DAO). The root acts as a parent.
- The root then decides to which node the information should be sent.
- If other new nodes want to access these communications or join this network, they must send the root a DODAG Information Solicitation (DIS).
- The root then responds with DAO-ACK if it has allowed those nodes to join the network.
- RPL hubs can be stateless, generally expected, or stateful. A stateless hub keeps track of its folks, as it were. Just root has comprehensive information on the whole DODAG. Henceforth, all interchanges go through the root of each situation.
- A stateful hub monitors its youngsters and guardians, and subsequently, when imparting inside a sub-tree of the DODAG, it does not need to go through the root.[12] [11]

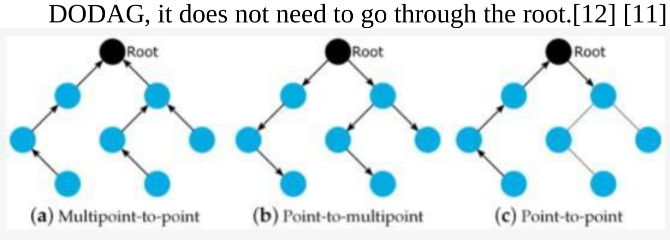

Figure 4: Traffic Flow through RPL [11]

2.4.2 : AODV

The complete form of this is AD-hoc On-Demand Distance Vector Protocol. It has been famous among numerous researchers since its discovery; the fundamental strengths of Ad-Hoc Networks are that the nodes have no central area.
This protocol incorporates two cycles to establish a route and the management of the route

- Before the source nodes can send packets of information to the destination node, the path between itself and the destination nodes is present in the routing table. If the path is present only, then data is sent. Otherwise, the path is defined then the information is transmitted.
- An RREQ packet is generated by the sender node and broadcast to the neighboring nodes.
- If the packet arrives at the destination node, then an RREP is sent to the sender node.
- If the packet containing information arrives at a node other than the destination node, the packet is broadcasted to the next hoop.
- Repeat points three and four if the packet arrives at a node other than the destination node.
- The RREQ packet is broadcasted in flood mode while the RREP is unicast.[14] [15]

Nonetheless, the Ad Hoc network is generally feeble; the correspondence mode is remote, and the nodes can enter and exit the network unreservedly.

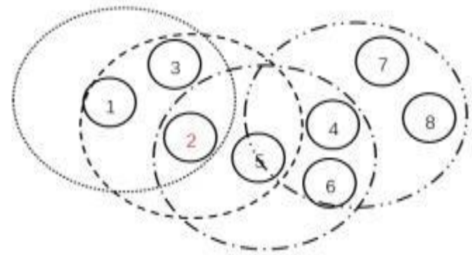

Figure 5: Data Communication in Ad-Hoc Network [15]

2.5 : Mobility Models

2.5.1 : Random Way Point Model (RWP)

In RWM, the nodes can move openly with no impediments and limitations. Boundaries like the speed and bearing of the nodes are picked arbitrarily. Alongside its masters, there are two significant issues of the irregular waypoint model: abrupt stop and fast shift in course. This mobility model comprises periods of random motion separated by pauses.[16]

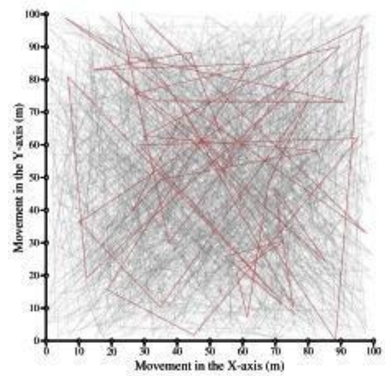

Figure 6: Node Trajectory in RWP [16]

2.5.2 : Random Walk Model (RWM)

The main difference between RWP and RWM is that this model has no pause times. All the nodes during the first phase have random directions with a random velocity. Although unexpected, this velocity is uniform in that it is selected uniformly at each interval. [16]

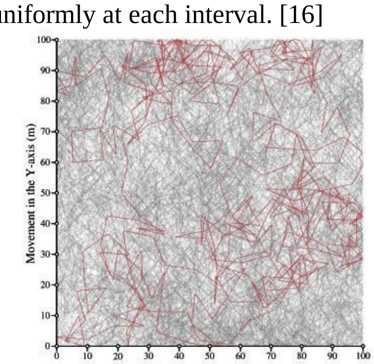

Figure 7: Nodes Trajectory in RWM [16]

3.1 : Methodology

3.2 : NetSim Simulator

NetSim is a start-to-finish, full-stack, bundle-level organization test system and emulator. It gives network designs an innovation advancement climate for convention demonstrating network R&D. NetSim is an efficient tool. It shows results in two formats after the simulation is run and the results come. A graph also shows throughput, delay, number of packets sent, and much more. [17]

3.2 : Throughput

Throughput is the number of packets that are completely moved during reenactment time. The amount of information (data) transferred from the source to the objective in a suitable time interval. Throughput can be determined as far as Mbps, Kbps, and Gbps. The answer of throughput is in percentage (%) [14], [18]

$$Throughput = \frac{Data\ to\ be\ transmitted}{Time\ taken\ to\ trasnmit\ the\ data}$$

3.3 : Delay

Delay is the time taken for the packets to reach their destination. There are several different types of delay in networking. [19] Some of them are mentioned below:

3.4 : Simulation Setup

The purpose of this paper was to see the performance evaluation of IoT Routing Protocols. It is necessary to compare the values of throughput and delay of that network to see how that network works.

I will be using NetSim to carry out the simulations. The network choice is IoT, and 16 wireless devices will be used in the simulation. Since NetSim allows two routing protocols in the network layer, i.e., RPL and AODV. The simulation was carried out using these protocols, and the mobility models were changed for both of these protocols.

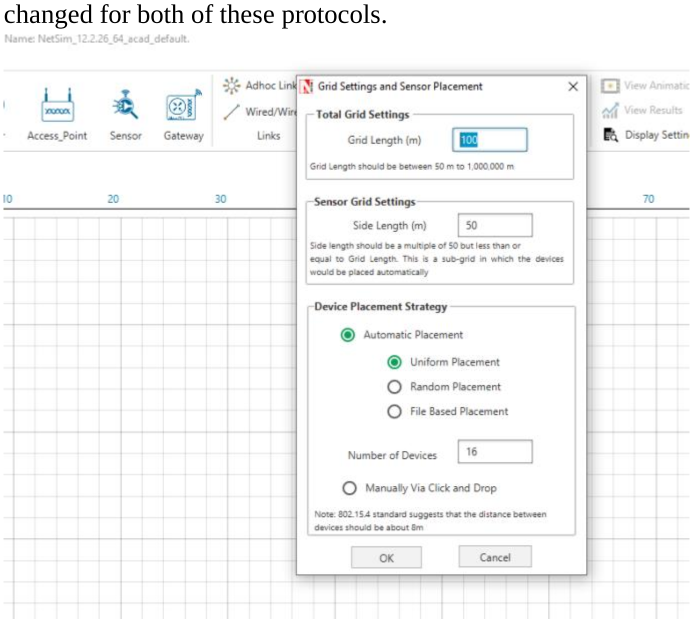

Figure 8: Grid Setting and Sensor Placement in NetSim

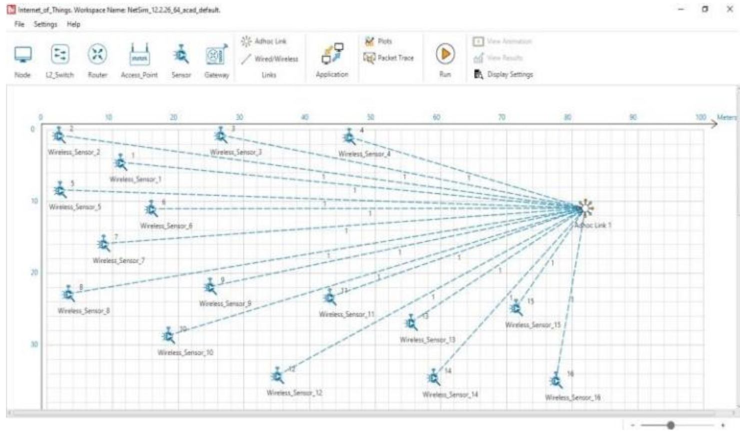

Figure 9: Network Design for Simulation

04: Results and Discussion

4.1 : Steps in Simulations

4.1.1 : Step # 01

First, we will launch NetSim. From the Chose a Network option. I am going to choose the Internet Of Things.

Figure 10: Face Of NetSim

4.1.2 : Step # 02

I rearranged all the sensors to make sure that all of them are easily visible by changing their positions.

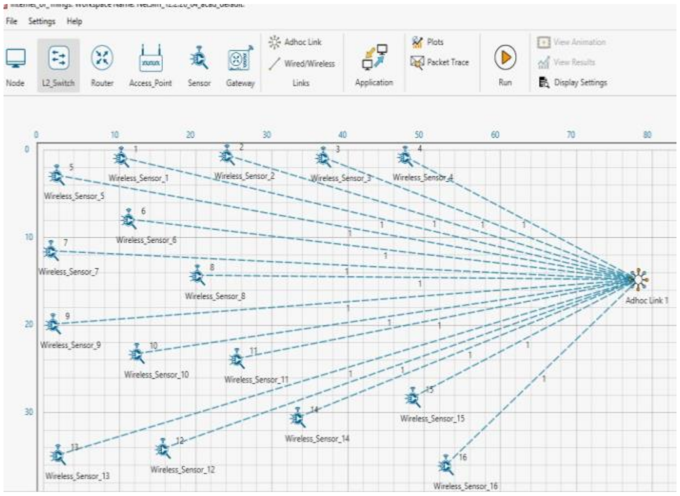

Figure 11: IoT Workspace

4.1.3 : Step # 03

We need to connect the Adhoc to Lowpan_Gateway using an Adhoc Link for this IoT simulation to work.

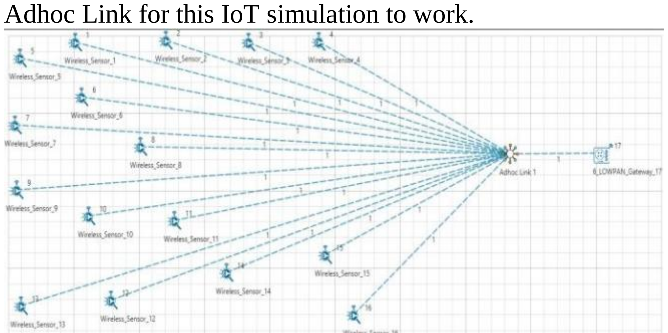

Figure 12: Link Connection to Gateway

4.1.4 : Step # 04

It is time for us to start the simulation. First, I will calculate the throughput and delay by choosing the "No Mobility Model" and using AODV Protocol in the network layer.

Figure. 13 is a screenshot of Wireless Sensor 1, but all the sensors will have the same configuration that can be seen in this picture

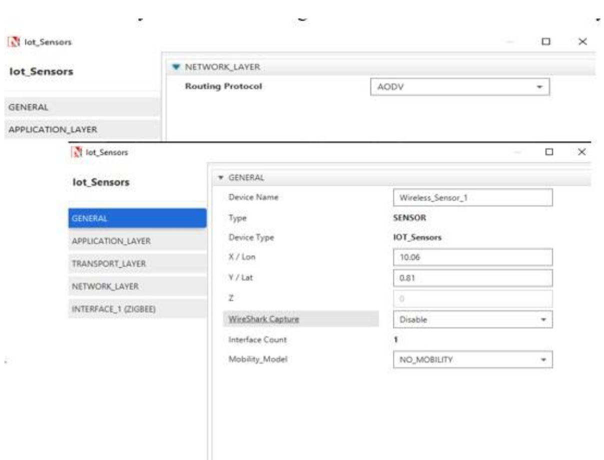

Figure. 13: Configuration Of Sensors using AODV

Figure 14 is a screenshot of Wireless Sensor 1, but all the sensors will have the same configuration of RPL that is shown in this picture

.

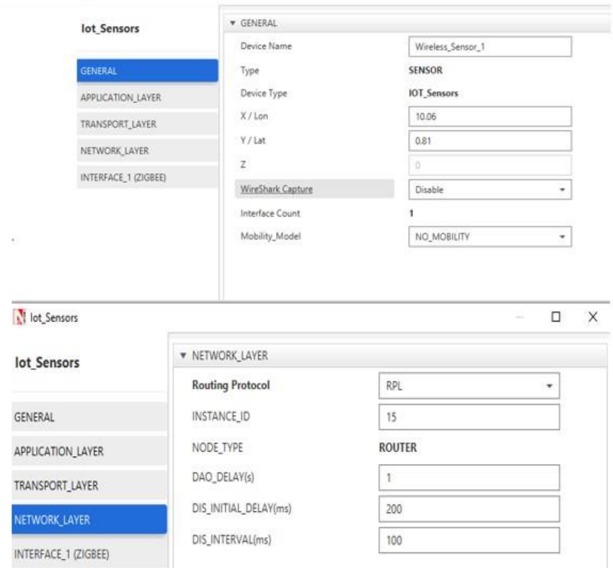

Figure 14: Configuration Of Sensors using RPL

4.1.5 : Step # 05

This simulation result is calculated using "No Mobility Protocol," and the network layer is "AODV."

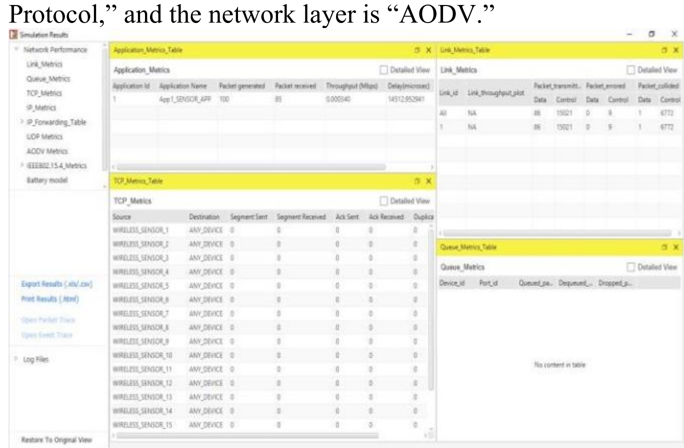

Figure 15: Simulation Result of AODV Protocol

4.1.6 : Step # 06

This simulation result is calculated using the "No Mobility Model," and the network layer is "RPL."

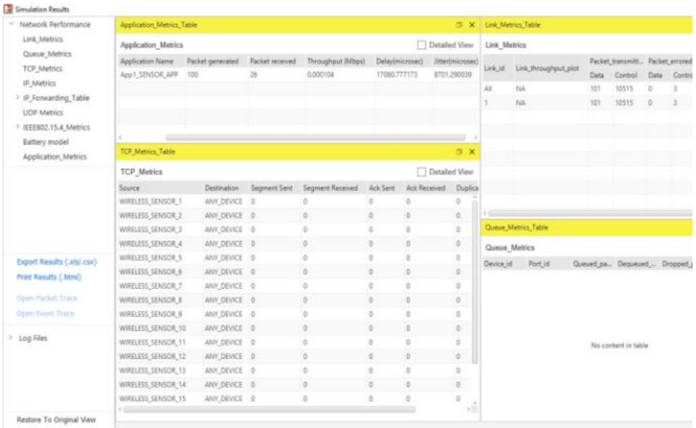

Figure 16: Simulation Result of RPL Protocol

4.1.7 : Step # 07

In the below simulation, the chosen mobility model is "the Random Way Point Model" and the protocol is AODV.

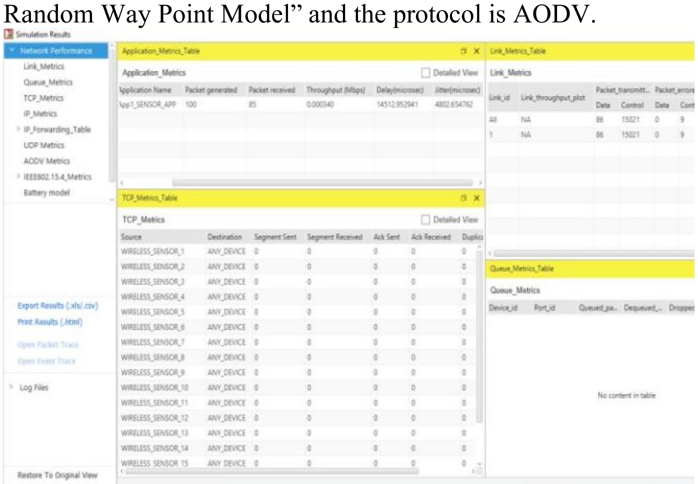

Figure 17: Simulation Results of AODV using Random Way Point Model

4.1.8 : Step # 08

All the configuration settings are the same as above. Only the mobility model is changed. The Mobility Model now is the "Random Walk Model."

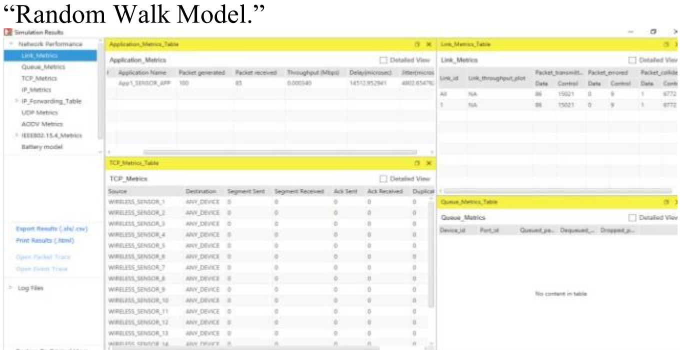

Figure 18: Simulation Results of AODV using Random Walk Model

4.1.9 : Step # 09

All the configuration settings are the same as above. The mobility model is the same, but the network layer Routing Protocol is changed to "RPL." The Mobility Model is a "Random Way Point"

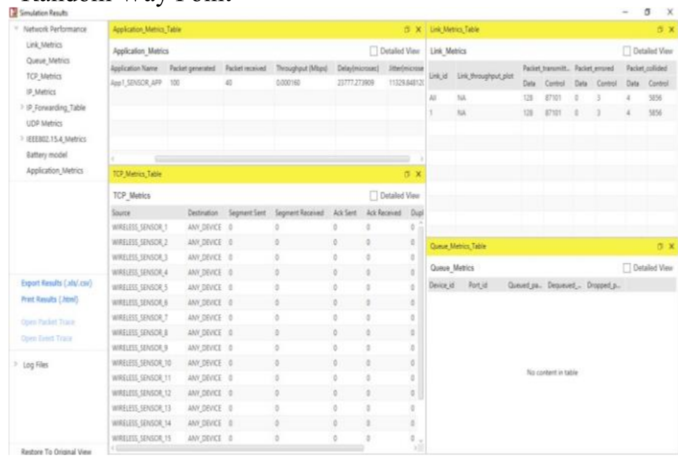

Figure 19: Simulation Results Of RPL using Random Way Point Model

4.1.10 : Step # 10

All the configuration settings are the same as "RPL," just the mobility model changed to "Random Walk."

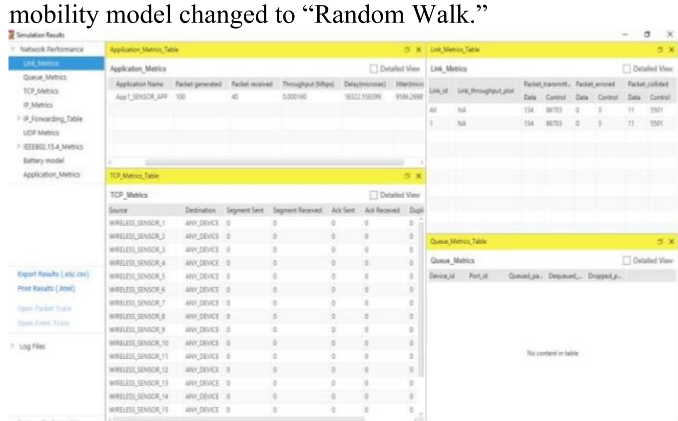

Figure 20: Simulation Results Of RPL using Random Walk Model

Table 2: Results of IoT Simulation

Network		Performance	
Protocol	Mobility Model	Throughput (Mbps)	Delay (microsec)
AODV	No Mobility Model	0.000340	14512.95
	Random Way Point	0.000340	14512.95
	Random Walk	0.000340	14512.95
RPL	No Mobility	0.000104	17060.777
	Random Way Point	0.000160	23777.27
	Random Walk	0.000160	18322.558

Conclusions

The Internet of Things (IoT) is a vast and rapidly growing network of physical objects. It helps people connect over a gigantic cyberspace and exchange data.

In this report, we studied IoT, its workings, and the routing protocols used with IoT devices. We also learned about some mobility models that can be used in harmonization with IoT networks and the use of NetSim Simulator to carry out the simulations of these designs.

From the above Table 2: Results of IoT Simulation using AODV Routing Protocols in an IoT design gives better results in all the Mobility Models we used. RPL Routing Protocols had variable results with the mobility model it was utilized. RPL showed better results when a mobility model was used compared to when no mobility model was used.

The results are judged based on the throughput and delay results generated by NetSim when we simulated all scenarios.

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References

[1] C. Bell, "What Is the Internet of Things?," in *Windows 10 for the Internet of Things*, 2021, pp. 1–25. doi: 10.1007/978-1-4842-6609-0_1.

[2] L. S. Vailshery, "Internet of Things (IoT) - statistics & facts | Statista," *Statista*, 2021. https://www.statista.com/topics/2637/internet-of-things/#dossierKeyfigures (accessed Nov. 20, 2021).

[3] N. Ahmed, H. Rahman, and M. I. Hussain, "A comparison of 802.11ah and 802.15.4 for IoT," *ICT Express*, vol. 2, no. 3, pp. 100–102, 2016, doi: 10.1016/j.icte.2016.07.003.

[4] P. Stokes, "4 Stages of IoT architecture explained in simple words | by Paul Stokes | Data Driven Investor | Medium," *Medium*, 2018. https://medium.datadriveninvestor.com/4-stages-of-iot-architecture-explained-in-simple-words-b2ea8b4f777f (accessed Nov. 21, 2021).

[5] M. Gregg, *The Technical Foundations of IoT*. 2017. Accessed: Nov. 19, 2021. [Online]. Available: https://web-a-ebscohost-com.ezproxy.apiit.edu.my/ehost/ebookviewer/ebook/bmxlYmtfXzE4MjU5MDRfX0FO0?sid=c808fa9c-8d24-4d3f-ad1c-11eec964be65@sdc-v-sessmgr01&vid=0&format=EB&rid=1

[6] Gartner Inc., "The Internet of Things and the Enterprise," *Ceeol.Com*, 2015, Accessed: Nov. 22, 2021. [Online]. Available: https://www.ceeol.com/content-files/document-729206.pdf

[7] Electronics Notes, "IEEE 802.15.4 Standard | Primer | Electronics Notes." https://www.electronics-notes.com/articles/connectivity/ieee-802-15-4-wireless/basics-tutorial-primer.php (accessed Nov. 22, 2021).

[8] S. A. IEEE, *IEEE 802.15.4z-2020 - IEEE Standard for Low-Rate Wireless Networks*, vol. 2020. 2020.

[9] T. Salman and R. Jain, "Networking protocols and standards for internet of things," in *Internet of Things and Data Analytics Handbook*, 2017, pp. 215–238. doi: 10.1002/9781119173601.ch13.

[10] O. Iova, P. Picco, T. Istomin, and C. Kiraly, "RPL: The Routing Standard for the Internet of Things... or Is It?," *IEEE Communications Magazine*, vol. 54, no. 11, pp. 16–22, Dec. 2016, doi: 10.1109/MCOM.2016.1600397CM.

[11] J. V. V. Sobral, J. J. P. C. Rodrigues, R. A. L. Rabêlo, J. Al-Muhtadi, and V. Korotaev, "Routing protocols for low power and lossy networks in internet of things applications," *Sensors (Switzerland)*, vol. 19, no. 9. Multidisciplinary Digital Publishing Institute, p. 2144, May 09, 2019. doi: 10.3390/s19092144.

[12] H. Lamaazi, N. Benamar, and A. J. Jara, "RPL-based networks in static and mobile environment: A performance assessment analysis," *Journal of King Saud University - Computer and Information Sciences*, vol. 30, no. 3, pp. 320–333, 2018, doi: 10.1016/j.jksuci.2017.04.001.

[13] D. Carels, E. de Poorter, I. Moerman, and P. Demeester, "RPL Mobility Support for Point-to-Point Traffic Flows towards Mobile Nodes," *International Journal of Distributed Sensor Networks*, vol. 11, no. 6, Jun. 2015, doi: 10.1155/2015/470349.

[14] O. P. Roy and V. Kumar, "Ad Hoc Network Based Energy Efficient Reactive Routing Algorithm for Internet of Things and VoIP," *SSRN Electronic Journal*, 2020, doi: 10.2139/ssrn.3516707.

[15] S. Yan and Y. Chung, "Improved Ad Hoc On-demand Distance Vector Routing (AODV) Protocol Based on Blockchain Node Detection in Ad Hoc Networks," *International Journal of Internet, Broadcasting …*, vol. 12, no. 3, pp. 46–55, 2020, doi: 10.7236/IJIBC.2020.12.3.46.

[16] B. Safaei *et al.*, "Impacts of mobility models on RPL-based mobile IoT infrastructures: An evaluative comparison and survey," *IEEE Access*, vol. 8, pp. 167779–167829, 2020, doi: 10.1109/ACCESS.2020.3022793.

[17] "Network Simulator, NetSim, Emulator, 5G, Military Communication, Vehicular networks." https://www.tetcos.com/netsim-pro.html (accessed Nov. 24, 2021).

[18] O. P. Roy and V. Kumar, "Ad Hoc Network Based Energy Efficient Reactive Routing Algorithm for Internet of Things and VoIP," *SSRN Electronic Journal*, p. 2019, 2020, doi: 10.2139/ssrn.3516707.

[19] AnshuMishra3, Shrishti_m180521ca and Jeevanyasa, "Delays in Computer Network - GeeksforGeeks," 2021. https://www.geeksforgeeks.org/delays-in-computer-network/ (accessed Nov. 24, 2021).