Analysis of Energy-Harvested Based Routing Protocol for Healthcare Monitoring System

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***Abstract*—People can now access the Internet in every industry today, including gaming, communications, and health. Virtually everyone has access to the Internet. Because individuals need to maintain excellent health and keep an eye on those who use the application, the Internet is now very useful in the health sector. Many individuals, particularly in the village, are unable to get to the hospital due to the distance between the two.**

If the patient is unable to travel to the hospital on their own, the simulation's design seeks to facilitate and speed up patient access to a hospital or health facility. However, the patient can also forecast his health using this method, regardless of how serious the situation is.

In this study, a system to explain the whole monitoring life cycle and crucial bodily states is designed and simulated. The key building block for effective and secure health monitoring is more in-depth discussions. A thorough analysis of the security risks affecting E-Health monitoring systems is then offered.

***Index Terms*—Internet, E-Health, Effectiveness**

I. INTRODUCTION

A wireless network of wearable computer devices is called a Wireless Body Area Network (WBAN). In recent years, WBAN has been regarded as one of the cutting-edge technologies in the field of health [1]. The WBAN application's remote health monitoring within the human body is its key feature. Implanted sensors in the body or worn sensors on the body can monitor physiological conditions, such as heart rate, pulse rate, body temperature, and blood pressure. WBAN is proposed based on the need for remote medical therapy.

E-health is one of the internet-connected programs that requires registration before users can access hospitals, doctors, insurance, etc. E-health enables patients to consult with a physician or nurse without waiting in a hospital line. E-health can also keep track of whether a patient's condition is good or bad.

The rate control strategy for implantable WBANs should have the following features due to the special nature of these devices: [2]. To gather sensed data from the sensor nodes, two sink nodes are positioned at the front and back of the human body, respectively. Direct communication or a middle forwarder node are both options for sending data from each sensor to the sink. However, when sending data to the sink, there will definitely be various prob- lems that arise such as the delay of the packet data sent from 1 node, and some throughput generated when sending packets from 1 node. However, not only throughput is obtained for the output, but there is how much energy con sumption is generated from 1 node in sending a data packet and the number of packets received from 1 node. Therefore, the purpose of this thesis is to determine how much throughput, energy consumption is generated, and how many packets are received from 1 node.

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II. BASIC CONCEPT

A. System E-Health

E-Health, or information and communication technology in healthcare, is a relatively new concept. The E-Health unit collaborates with partners at the national, regional, and international levels to enhance and advance ICT use in health development, from field applications to global governance. Stakeholder groups all agreed on the same topics, however they placed slightly different emphasis on them. These comprised the following subjects: (1) standardization and agreement Most stakeholders expressed a strong need for a more coordinated, thorough effort to define and unify the area; (2) eval- uation techniques and difficulties E-Health quality and effectiveness must be established through proving outcomes, yet stakeholders were dissatisfied with the sensitivity, validity, and reliability of current outcome metrics; (3) Good- ness, worth, and possibility for the future a high level of interest was produced by the intersection of the potential cost-effectiveness, efficiency, and enhanced clinical status of users of E-Health; (4) health inequities; and Al- though some stakeholders noted that the underprivileged are similarly at a disadvantage in terms of access to technology, many stakeholders claimed that traditionally underserved populations will notably benefit from E-Health applications.

B. System Usage

It is widely acknowledged that one of the main barriers to eHealth's wider adoption in practice would be the current infrastructure in place. The majority of healthcare systems in use today demand that individuals take their vital signs and report them to a data center. Patients with serious medical issues or chronic illnesses nevertheless require assistance in carrying out this task correctly. The deployment, operation, and management of patients are reduced by e- health monitoring systems. Patient-centric monitoring depends on the coop- eration of many sensors, including implantable, wearable, smartphone, and IoT sensors. Their configurations must be accessible to the patients to pre- vent confusing or uncomfortable settings.

C. WBAN in E-Health

A wireless network of wearable computing devices is known as WBAN. The WBAN system's operation is shown in the figure below. The traditional network infrastructure also links the health monitoring system to a medical server positioned at the top of the hierarchy. The physiological and nonphysiological factors can be sensed or observed by this sensor gadget since it functions near to the human body. In Fig. 1, the architecture will be displayed.

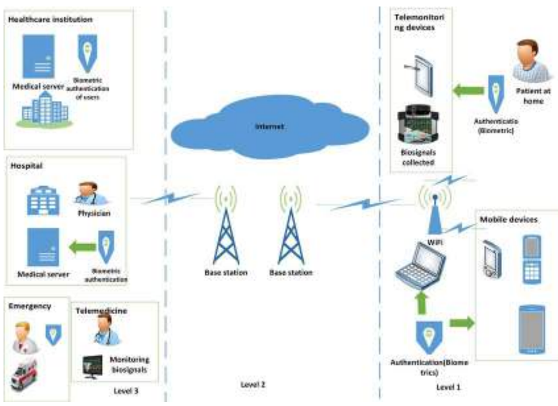

Fig. 1. System architecture in WBAN [8].

D. Routing in WBAN

In body area networks, clustering is used to address problems with path loss, network lifetime, end-to-end delay, and packet delivery. Two nodes are posi- tioned on the front and back sides of the human body to collect data from the sensor nodes. This protocol is created using a network-based solar energy forecast model. A node with more residual energy and energy collection capabilities is more likely to be chosen as the CH. For the purpose of comparing network through- put and the number of active nodes, the suggested protocol is put up against the LEACH protocol. In Fig. 2, the routing protocol will be displayed. Body Area Network Clustering Method (EH-RCB). End-to-end delays, packet delivery problems, and route loss are all fixed. Each sensor commu- nicates directly with the sink to send data. Direct connection is used in two situations: (1) when sensed data is essential, and (2) when the sensor node is nearer the sink node.

E. WBAN Architecture

A special-purpose sensor included into WBAN can connect on its own to a variety of sensors and devices both within and outside the human body. The author has divided the network architecture into four categories in this instance. The WBAN

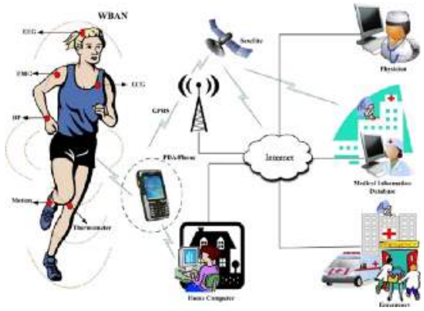

Fig. 2. Routing protocol in sensor networks [4].

Routing Protocols	Classification	Power Usage	Data Aggregation	Scala bility	Query Based	Over head	Data delivery model	QoS
SPIN	Flat / Src-initiated / Data-centric	Ltd.	Yes	Ltd	Yes	Low	Event driven	No
DD	Flat/ Data-centric/ Dst-initiated	Ltd	Yes	Ltd	Yes	Low	Demand driven	No
RR	Flat	Low	Yes	Good	Yes	Low	Demand driven	No
GBR	Flat	Low	Yes	Ltd	Yes	Low	Hybrid	No
CADR	Flat	Ltd		Ltd	Yes	Low	Continuously	No
COUGAR	Flat	Ltd	Yes	Ltd	Yes	High	Query driven	No
ACQUIR E	Flat/ Data-centric	Low	Yes	Ltd	Yes	Low	Complex query	No
LEACH	Hierarchical / Dst-initiated /Node-centric	High	Yes	Good	No	High	Cluster-head	No
TEEN & APTEEN	Hierarchical	High	Yes	Good	No	High	Active threshold	No
PEGASIS	Hierarchical	Max	No	Good	No	Low	Chains based	No
VGA	Hierarchical	Low	Yes	Good	No	High	Good	No
SOP	Hierarchical	Low	No	Good	No	High	Continuously	No
GAF	Hierarchical / Location	Ltd	No	Good	No	Mod	Virtual grid	No
SPAN	Hierarchical / Location	Ltd	Yes	Ltd	No	High	Continuously	No
GEAR	Location	Ltd	No	Ltd	No	Mod	Demand driven	No
SAR	Data centric	High	Yes	Ltd	Yes	High	Continuously	Yes
SPEED	Location/Data centric	Low	No	Ltd	Yes	Less	Geographic	Yes

Fig. 3. Taxonomy WBAN Routing Protocols [10].

portion, which is the first, is made up of multiple sensor nodes. These inexpensive, low-power nodes have inertial and physiological sensors that are put at crucial locations on the human body. All of the sensors can be used to continuously monitor movement, physiological data including heart rate, blood pressure, and ECG, as well as the environment. Large-scale monitoring systems based on wired connections are already in use. Any cable connection in a monitoring system can be uncomfortable and hard to wear when a person is wearing it, and it could limit his mobility. WBAN can therefore be an excellent answer in this regard, particularly in a healthcare system where a patient needs to be constantly monitored and needs to be mobile.

F. WBAN Application Scenario

Sensor nodes linked to or implanted into a human body may make up a Wire- less Body Area Network in medical settings. These sensor nodes can transfer wirelessly and sense biological data from the human body to a control device worn on the body or positioned in an easily accessible area over a short dis- tance. Medical signals such an electrocardiogram (ECG), electroencephalog- raphy, temperature, pulse rate, and blood flow should be able to detect sensor node electronics. The patient can gather data from the control devices, which are subsequently transported to distant locations in a wireless body area net- work for diagnostic and therapeutic reasons, incorporating another wireless network for long-range transmission, in order to know the outcome of the data.

G. Major source of Energy waste

The data link layer, also referred to as layer two of the Open Systems In- terconnection (OSI) model, has a sub-layer called MAC. Numerous tasks, including channel access control, transmission scheduling, data framing, er- ror handling, and energy management, are carried out by the MAC sublayer. Therefore, the MAC layer is the best level to solve the problems with energy efficiency. The main cause of energy waste in wireless networks is :

1) Packet Collision: Occurs when more than one packet is transmitted at once. Several MAC protocols for WBANs have been devised to min- imize energy usage. There is an increase in energy usage due to the collision-induced packets' need to be retransmitted.
2) When a node listens to an idle channel to receive data, this is known as idle listening.
3) Overhearing: Takes place when a node listens to the channel in order to catch packets that are meant for other nodes. 4. Packet Overhead: Describes the header information and control packets. Power consump- tion also rises when more control packets are used to carry out the data transfer procedure

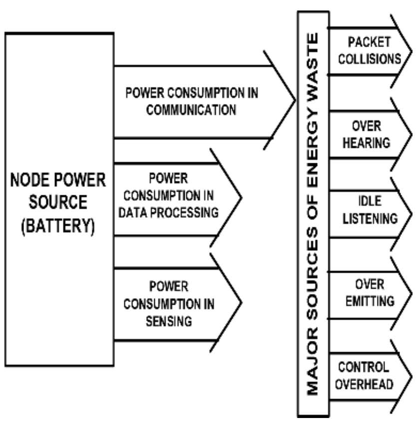

Fig. 4. Major Source of energy waste [9].

H. Energy-Efficient Medium Access Protocol

Popular protocol called the Energy-efficient Medium Access Protocol (EMAP) was created for WBANs to maximize energy efficiency. The core control mechanism is utilized to set a regular schedule for sleeping and wak- ing up. The power loss brought on by control packet overhead is minimized via cross-layer optimization. Eight on-body/implanted sensor nodes are be- lieved to coordinate with a star network topology with a single coordinator, or primary node. The majority of operations and processes are handled by the primary nodes.

I. Application vs Technologies

WBAN medical applications have the potential to significantly improve people's quality of life and meet numerous needs of older persons by enabling them to live independently, comfortably, securely, and healthily. Wireless technologies are used in communication among sensors and between the base station and sensors because wireless medium offers a very practical method for information exchange. The most popular and widely used standards are IEEE 802.15.1 (Bluetooth) and IEEE 802.15.4 (often referred to as ZigBee) in some applications, even though IEEE 802.15.6 is established to serve a variety of medical and non-medical applications. Data rate, interference caused by multiple technologies operating in the same space, and other factors need to be taken into account.

III. MODEL AND SYSTEM DESIGN

This chapter contains system general illustration and explanations of each process on the flowchart.

A. System Design

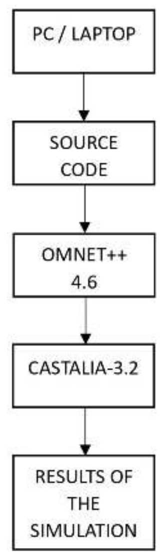

Fig. 5. System Design Block Diagram.

The idea of this project is to determine how much throughput is gener- ated from each given node. From the figure above, to determine how much throughput is generated we must run the simulation first. To run the application, we must have a device that can run the simulation. Then after having the device, we must have the source code to run the simula- tion. After the source code is obtained, we can run the simulation using the Omnet++ application and must have Castalia-3.2 installed.

B. Simulation Design

In this thesis, we looked into the operation of the wireless body area network. How many delays there were when sending data from one node to another, in terms of both throughput and packet delivery.

C. Algorithm of Energy Harvested-aware Routing protocol with Clustering approach in Body area network

Although there are methods and plans for traditional sensor networks. One of the basic, industry-specific WBAN technologies is routing. In order to maximize network lifetime and solve the route loss issue for nodes linked to the front and back of the human body, this protocol places more emphasis on consistent energy usage. The forwarder node that will transport the sensed data from the source to the final sink node is chosen using the Cost Function (C.F.). The amount of remaining energy, the distance to the receiver, and the transmitter node's data rate are taken into account while calculating C.F. When sending crucial data, this protocol typically uses single-hop com- munication.

D. Energy Analysis for Single and Multi-Hop commu- nication

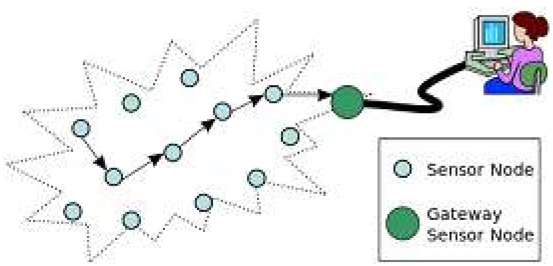

Fig. 6. Simple Linear Sensor Network [11].

The sensor node is used in WBAN in two steps: (1) Single-Hop (direct), and (2) Multi-Hop communication. If the distance between the sensor node and sink is larger, the single-hop transmission will use more energy and cause the node to die sooner. Through intermediary nodes, sensor nodes deliver data to sinks in multi-hop. According to Fig. above, a multi-hop communication transmission may use more system energy overall than a direct communication transmission to the sink node.

E. Throughput

Throughput is the measure of successful packets arrive at the destina- tion, throughput is measured in the bps (bit per second). The following is the equation of throughput:

$$Throughput = \frac{RecievedPacketxPacketLength}{Time}x8 \quad (1)$$

F. Routing Protocol

The goal of this research is to reduce end-to-end transmission de- lay while extending network longevity, stability, and communication throughput. Fig. 3 displays the suggested routing protocol's flowchart diagram.

IV. Result and Analysis

In this section, author will explain about the result of the thesis.

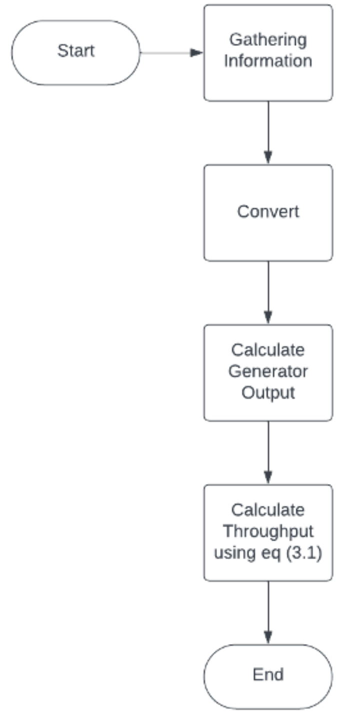

Fig. 7. Routing Protocol Flowchart.

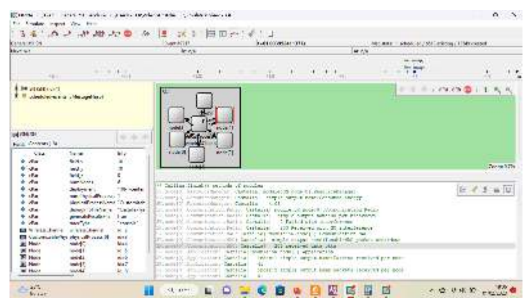

Fig. 8. Running Simulation in 6 Node.

A. Result in 6 Node

When simulating with 6 nodes, 7717 events send packets with a simula- tion time of 60 seconds from node 0 to node 5. The amount of packets received from the aforementioned outcome simulation is the same, at 41 for each node. However, with a packet rate of 0.7 packets per second, the average packet received across 6 nodes is 203 packets. The total energy used in the simulation over the course of 60 seconds is 21.05 millijoules.

B. Result in 12 Node

When simulating with 12 nodes, 25352 events send packets with a simu- lation time of 60 seconds from node 0 to node 5. The amount of packets received from the aforementioned outcome simulation is the same, at 41 for each node. However, with a packet rate of 0.7 packets per second, the average

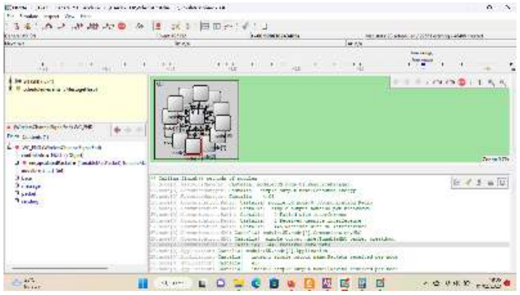

Fig. 9. Running Simulation in 12 Node.

number of packets received across 12 nodes is 447. The to- tal energy used in the simulation over the course of 60 seconds is 45.16 millijoules.

C. Result in 18 Node

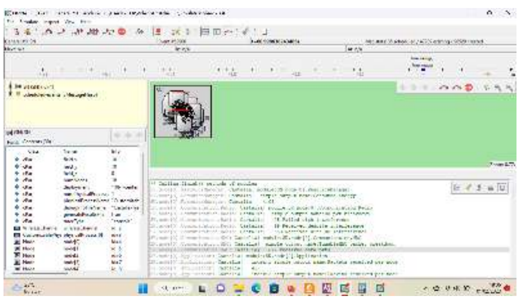

Fig. 10. Running Simulation in 18 Node.

With 18 nodes in the simulation, 52900 events transfer packets over a simulation period of 60 seconds from node 0 to node 5 in the network. The amount of packets received from the aforementioned outcome sim- ulation is the same, at 41 for each node. However, with a packet rate of 0.7 packets per second, the average packet received over 18 nodes is 672 packets. The total energy used in the simulation over the course of 60 seconds is 69.5 millijoules.

D. Result in 24 Node

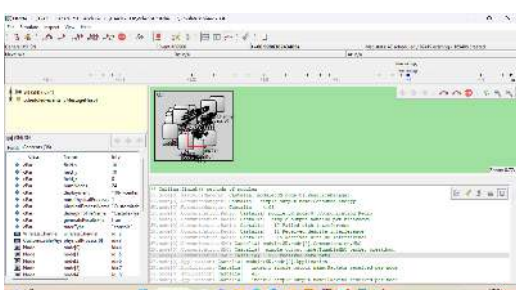

Fig. 11. Running Simulation in 24 Node.

When simulating with 24 nodes, 89900 events send packets with a simu- lation time of 60 seconds from node 0 to node 5. The amount of packets received from the aforementioned outcome simulation is the same, at 41 for each node. However, the average number of packets received over 24 nodes is 926, with a 0.7 packets per second packet rate. The total energy used in the simulation over the course of 60 seconds is 94 millijoules.

E. Result in 30 Node

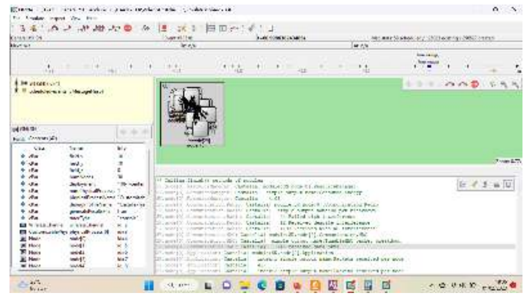

Fig. 12. Running Simulation in 30 Node.

With 30 nodes in the simulation, 135101 events transfer packets with a simulation time of 60 seconds from node 0 to node 5 in the network. The amount of packets received from the aforementioned outcome sim- ulation is the same, at 41 for each node. However, at a packet rate of 0.7 packets per second, the average packet received across 30 nodes is 1145. The total energy used in the simulation over the course of 60 seconds is 118.3 millijoules.

F. Result in 36 Node

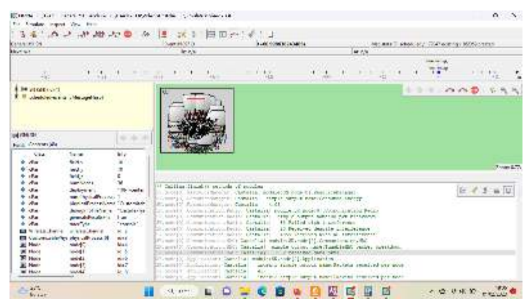

Fig. 13. Running Simulation in 36 Node.

With 30 nodes in the simulation, 135101 events transfer packets with a simulation time of 60 seconds from node 0 to node 5 in the network. The amount of packets received from the aforementioned outcome sim- ulation is the same, at 41 for each node. However, at a packet rate of 0.7 packets per second, the average packet received across 30 nodes is 1145. The total energy used in the simulation over the course of 60 seconds is 118.3 millijoules.

G. Average Throughput

The graph above shows that the average throughput will grow depending on how many nodes may be entered into the simulation if we simulate between 6 and 36 nodes. Nevertheless, the packet rate allotted to each node is the same,

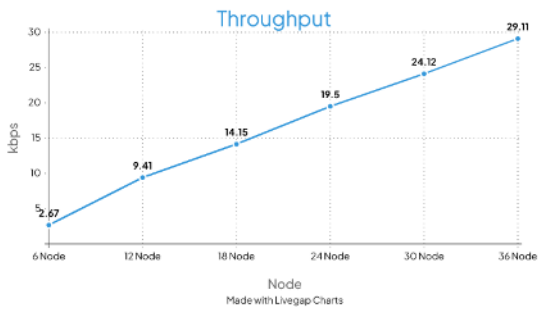

Fig. 14. Average Throughput.

at 0.7 packets per second. It follows that the larger the node, the higher the value of the packets that will be received.

H. Throughput per Node

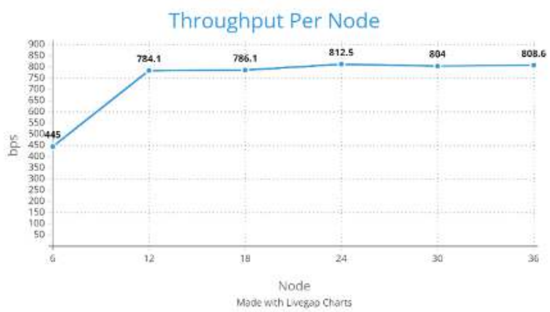

Fig. 15. Throughput per Node.

The throughput comparison for each node is just marginally different, as shown by the graph above. In order to determine how much through- put is produced by each node independently, the results of the preceding throughput are translated to bps. The number generated by each node itself is revealed in the conversion results, however the resulting num- ber is not very high because the packet rate specified is 0.7 packets per second.

I. Packet Received

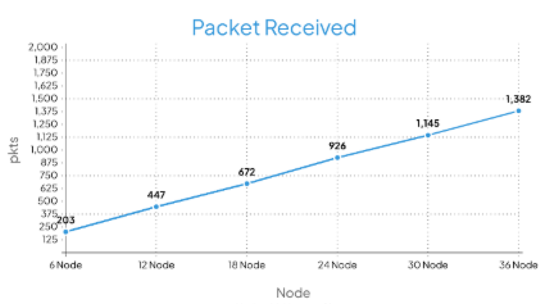

Fig. 16. Packet Receive in every nodes.

We may infer from the graph above that the average value of packets re- ceived would rise if we increased the number of nodes in the simulation from 6 to 36. The throughput value will be impacted. The throughput will be impacted by how many packets are received and created. Each node is given the same number of packets per second, or 0.7 packets per second. Conclusion: The value of the packets that are received will increase the greater the node that is provided.

J. Generated Packet Rate

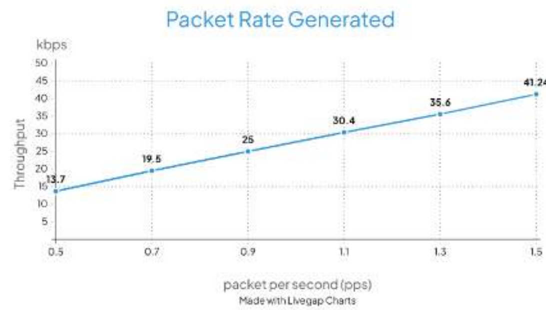

Fig. 17. Effect Application Packet Rate in One Node.

We may infer from the graph above that we sim 1 node. For instance, the author simulates 24 nodes with various packet rates ranging from 0.5 to 1.5 packets per second, which will affect how the throughput is calculated. The throughput figure will change based on the value of the packet that was received. The throughput value will increase as the number of packets received increases.

K. Total Energy Consumption

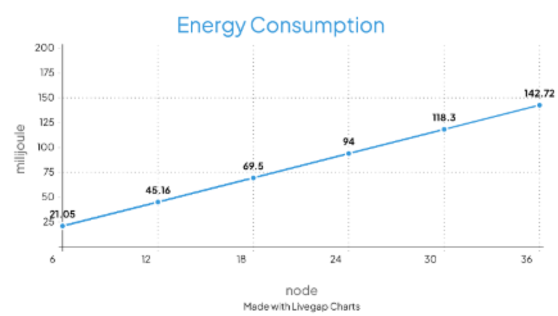

Fig. 18. Average of Energy Consumption.

We can infer from the graph above that there are variations in energy use between 6 and 36 nodes. 36 nodes in this simulation consume more energy, as shown by the graph. Due to a rise in node counts, energy consumption increases as spend increases. Despite the fact that all nodes have the same packet rate.

CONCLUSION

In order to examine the differences between one node and another node, the author used Castalia in conjunction with Omnet++ to research an energy-harvesting-based routing protocol. The results vary when 6 nodes are compared to 36 nodes. Energy usage, throughput, packet rate, packet generator, and packet received all varied.

There were several events from the simulation of 6 nodes to 36 nodes. However, there are some similarities among these 6 nodes, including throughput and the importance of each packet received. However, there is another distinction: the value of overall energy usage. The trials are then run using a single fixed node and various packet speeds. Therefore, the differences have an impact on the outcome. Throughput: 2.67 kbps, 9.41 kbps, 14.15 kbps, 19.5 kbps, 24.12 kbps, and 29.11 kbps are the results from the simulation. Additionally, the author employed 24 Nodes for the simulation of various packet rates in the packet generator. As a result, the value is nearly identical to throughput but somewhat higher.

V. Suggestion

The recommendation for additional research on a related subject is:

1) There is potential for variation in the energy used, packet rate, packet received, packet generator, and throughput.
2) Using Omnet++ and Castalia together to run a program is an option.

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