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The Impact of Routing Protocol in Green IoT Environment

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ABSTRACT

Technology is rapidly evolving to better daily human existence and directly impacts the earth's resource use. Reducing energy usage reduces carbon dioxide (CO2) emissions into the atmosphere, which can have negative consequences for the environment and human health. Achieving green Internet of Things (IoT) requires striking a balance between quick data transmission and economical energy consumption. The wireless sensor, part of the IoT system, is responsible for operating continuously without data delay. As a result, most wireless sensors collect raw data and transfer packets to another physical device, which will be evaluated later. Even though the sensors must still understand the routing topology on their own, the energy used to transport the packet to its destination can be reduced. Researchers have used various methods to reduce energy consumption, including alternative hardware and power management. Therefore, this study aims to see how using different types of routing protocols can impact energy consumption. The study was conducted using modelling and simulation to reduce variables influencing the result, such as signal strength, the earth's topography, and weather. The energy consumption can be viewed in detail using the NETSIM network simulator. Several topologies were designed to observe Ad-hoc On-demand Distance Vector (AODV) and Routing Protocol for Low-Power and Lossy Networks (RPL) energy consumption. The observation includes the energy consumption by the wireless sensor during establishing the connection, sending the packet, on standby and idling. Several results can be concluded during the end of the study. RPL consume a greater amount of energy during establishing a connection, while over a certain period, AODV consumes more energy when maintaining the connection. However, AODV still consumed a smaller amount of energy in a topology where wireless sensors were placed close to each other. Hence, the selection of routing protocol is essential as it can impact energy consumption, which has a major impact on achieving green IoT.

1. Introduction

The evolution of the Internet provides the medium for intelligent services for humans [1]. The communication broadens from human-human to human-object and object-object to ease daily human life [2]. The time to do a certain task can be shortened as a few steps can be done by the device itself. However, the implementation of IoT consumes a lot of energy and massive Carbon

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Dioxide (CO_2) emissions. Technology advancement leaves a carbon footprint on the environment; hence, researchers are increasingly looking into green IoT to balance the progress of technology with the environmental preservation [3-5]. This research will define several routing protocols used in IoT environments and make a simulation using Netsim to compare the energy consumption by each of them to see how it can contribute to achieving green IoT.

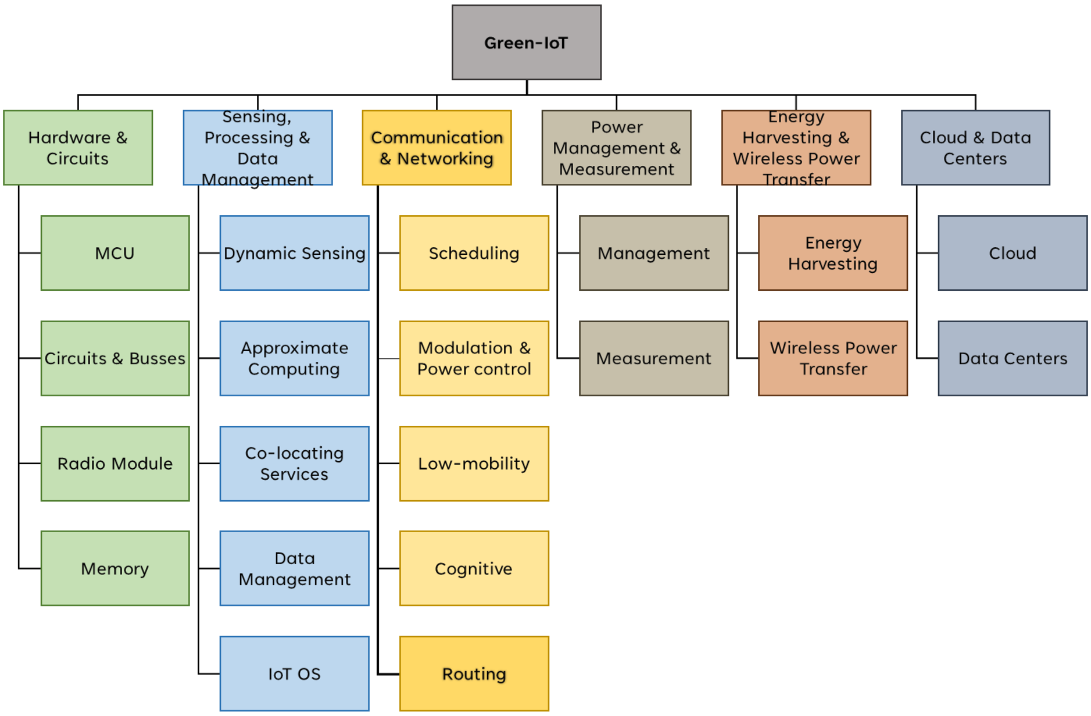

Fig. 1. Taxonomy of green IoT

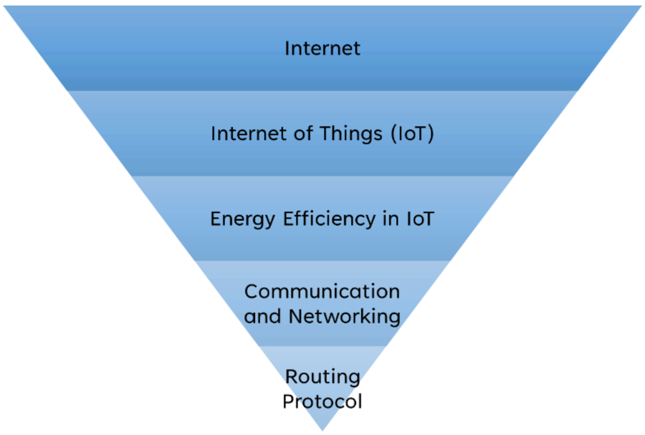

Fig. 2. Conceptual framework

This paper will start with the method of this study, in the methodology section, followed by the discussion of the obtained result in the results and discussion section. The summary and conclusion of this research will be at the end of this article.

2. Methodology

Two routing protocols are commonly used in IoT environment used by wireless sensor network, which is:

i. Ad-hoc On-demand Distance Vector (AODV)

This protocol works in find its destination by broadcasting Route Request Packet (RREQ) to all sensors in the network, reaching to the farthest sensors it can get. If no new sensors are found, the receiver of RREQ remember reverse route and continue broadcasting the packet until it reaches the destination. The destination sensor then acknowledges the connection by sending unicast message response with Route Reply Packet (RREP). The primary and backup route will be chosen based on the hop count [18].

ii. Routing Protocol for Low-Power and Lossy Networks (RPL)

This protocol works find its destination by broadcasting Route Request Packet (RREQ) to all sensors in the network to the furthers sensors it can get. If no new sensors found, receiver of RREQ remember reverse route and continue broadcasting the packet until it reaches the destination. The destination sensor then acknowledges the connection by sending unicast message responding with Route Reply (RREP). The primary and backup route will be chosen based on the hop count [19].

The initial simulation is to set distance as the parameter. Distance was chosen as number of nodes detect by each sensor depends on the distance. The higher the number of nodes detected nearby, the more option the nodes have to choose as a route. Energy used to forward a single packet is a constant. Depending on how the path selecting process by each of routing protocols, the observation will be conducted to see energy consumption used by each routing protocol. The distance parameters are set to 25-meter, 50-meter, 100-meter, 150-meter, and 200-meter. The simulation step is shown in Figure 3 below:

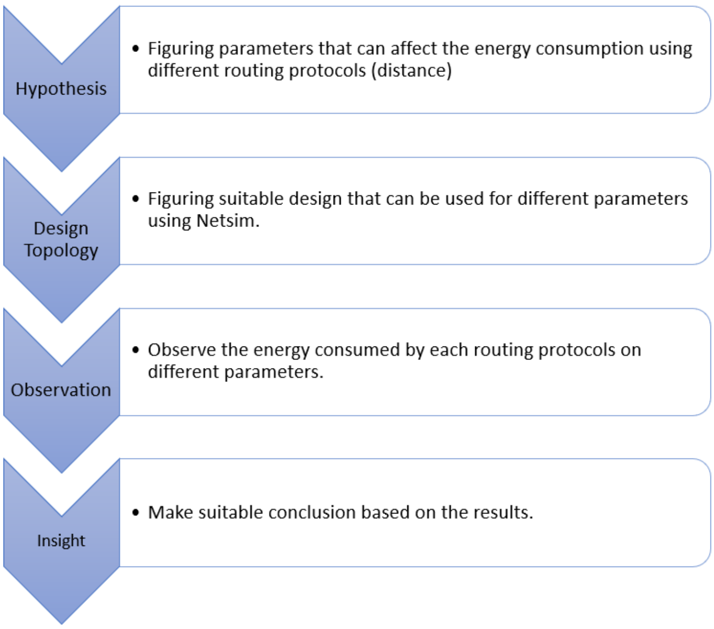

Fig. 3. Simulation step

Figure 4 below shows the network diagram of the topology used in the simulation.

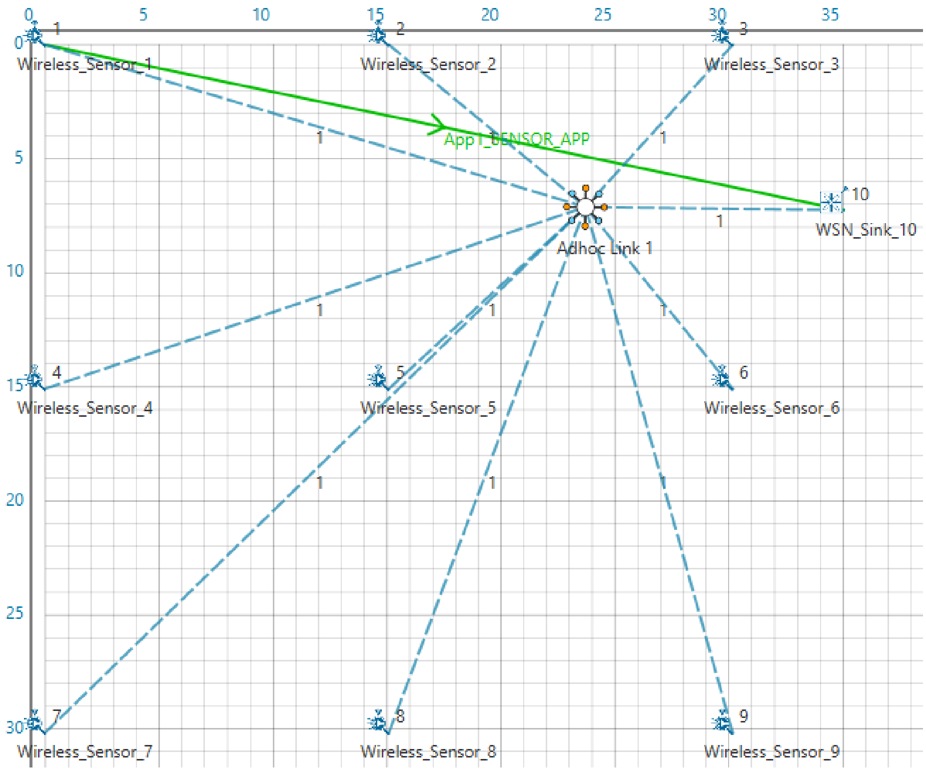

Fig. 4. Network diagram of the topology used

Mat *et al.,* [7] has performed a comprehensive flow visualization study on blunt-edge delta wing. The primary vortex is developed at certain chordwise position and progress upstream with angle of attack. However, there is no data in VFE-2 indicating that the vortex progressed up to the Apex region with angle of attack increases.

3. Results

3.1 Basic Packet Transfer

The simulation purpose is to study the energy consumption difference between the sender nodes, transfer route nodes, and idle nodes between the two routing protocols, AODV and RPL. Figure 5 shows the path taken to perform the packet transfer from sensor node 1 to the server.

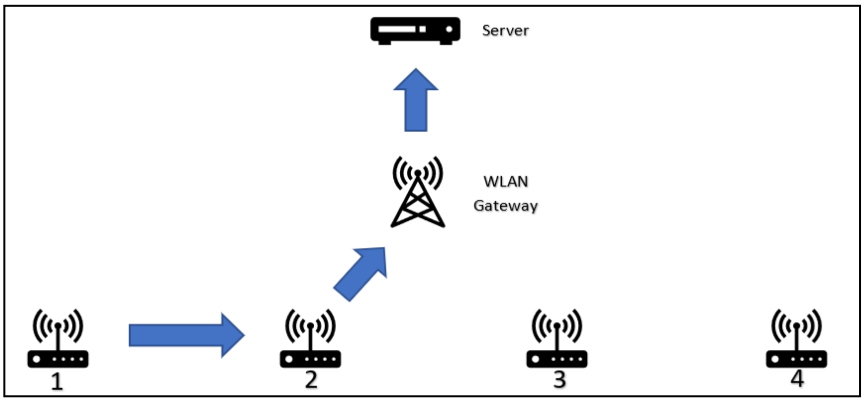

Fig. 5. Basic packet transfer using AODV and RPL protocols

Table 1 and 2 shows the energy consumed by each routing protocol to complete the task in 60 seconds.

Table 1
AODV basic packet transfer result

Device Name	Initial energy (mJ)	Consumed energy (mJ)	Remaining energy (mJ)	Transmitting energy (mJ)	Receiving energy (mJ)	Idle energy (mJ)
Sensor Node 1	6480.00	707.48	5772.52	8.18	2.00	697.30
Sensor Node 2	6480.00	710.62	5769.38	6.60	8.28	695.74
Sensor Node 3	6480.00	703.66	5776.34	2.29	1.78	699.59
Sensor Node 4	6480.00	703.08	5776.92	2.18	1.01	699.89
Total	25920.00	2824.83	23095.17	19.24	13.07	2792.52

Table 2
RPL basic packet transfer result

Device Name	Initial energy (mJ)	Consumed energy (mJ)	Remaining Energy (mJ)	Transmitting energy (mJ)	Receiving energy (mJ)	Idle energy (mJ)
Sensor Node 1	6480.00	719.78	5760.22	10.25	0.85	708.68
Sensor Node 2	6480.00	725.42	5754.58	8.00	11.58	705.83
Sensor Node 3	6480.00	718.54	5761.46	4.63	4.31	709.60
Sensor Node 4	6480.00	715.71	5764.29	4.57	0.07	711.08
Total	25920.00	2879.45	23040.55	27.45	16.81	2835.20

Figure 1 is the visualization of the energy consumption comparison based on Table 1 and Table 2. Each wireless sensor, whether in active or idle mode, consumed more energy when using RPL routing protocol than when using AODV routing protocol.

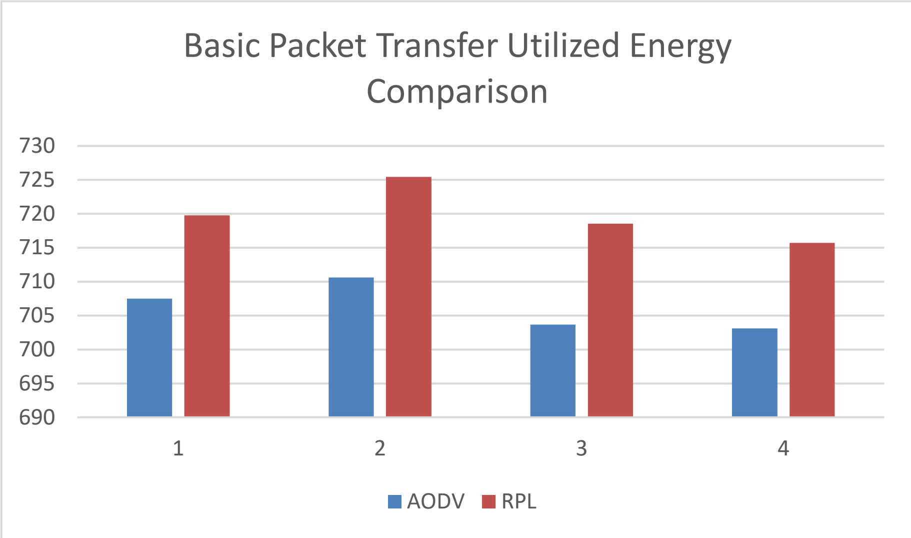

Fig. 6. Basic packet transfer utilized energy comparison

3.2 Simulation with Various Ranges of Topologies

The simulations were performed to observe the energy consumption of both RPL and AODV protocols if the nodes are located 50 meters, 100 meters, 150 meters and 200 meters from each other.

3.2.1 Simulation with range of 50 meters

This simulation consists of 9 wireless sensor nodes that were placed 50 meters between each other. This simulation was simulating on how data packets were being transferred from node 1 sensor to the server.

WLAN gateway and all other sensor nodes were in the range of wireless sensor node 1 and considered as its neighbour. Thus, sensor node 1 can transfer packet data directly to the WLAN gateway as shown in Figure 7.

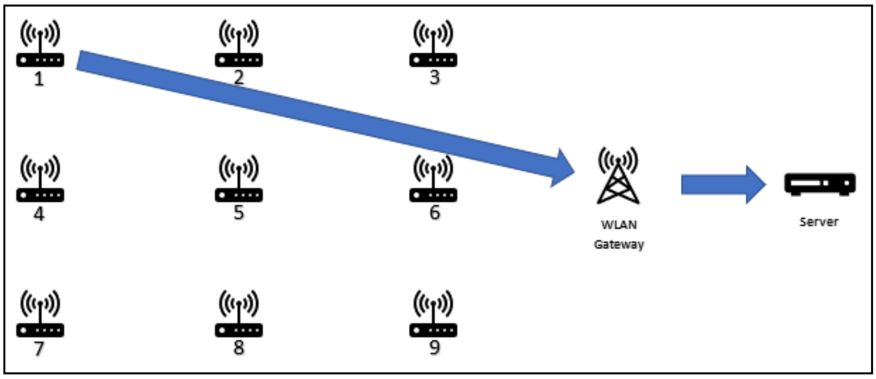

Fig. 7. Packet transfer route in 50 meters range

Table 3 below shows the result for 50 meters range packet transfer.

Table 3
50 meters range packet transfer result

Observed Result	AODV	RPL	Energy Difference [AODV-RPL]	Energy Difference Percentage
Energy Consumption (mJ)	772776.65	780558.89	-7782.23	-1.00 %
Energy Consumption Rate (mJ/min)	6439.81	6504.66	-64.85	-1.00 %

The graph in Figure 8 shows energy consumption were higher at node 1, 4, and 7 where those nodes became parent node using RPL. All wireless sensor nodes using AODV, except Sensor node 1, which was the packet sender consumed general amount of energy.

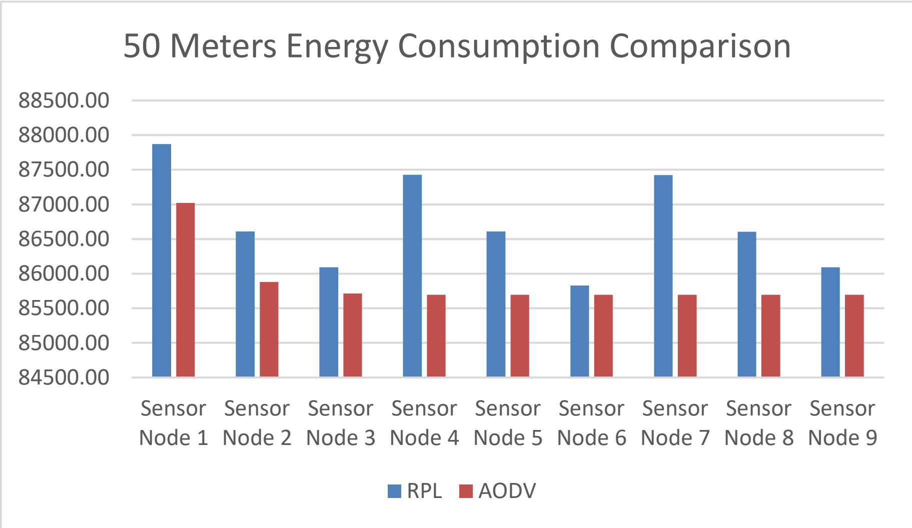

Fig. 8. 50 meters energy consumption comparison

3.2.2 Simulation with range of 100 meters

This simulation consists of 9 wireless sensor nodes that were placed 100 meters between each other. This simulation was simulating on how data packets were being transferred from sensor node 1 to the server.

Sensor node 2, 4 and 5 were in the range of wireless sensor node 1 and were considered as its neighbour. Thus, sensor node 1 has the option to go through sensor node 2 or 5 to transfer data packets to the WLAN gateway that contain the least hop count as shown in Figure 9.

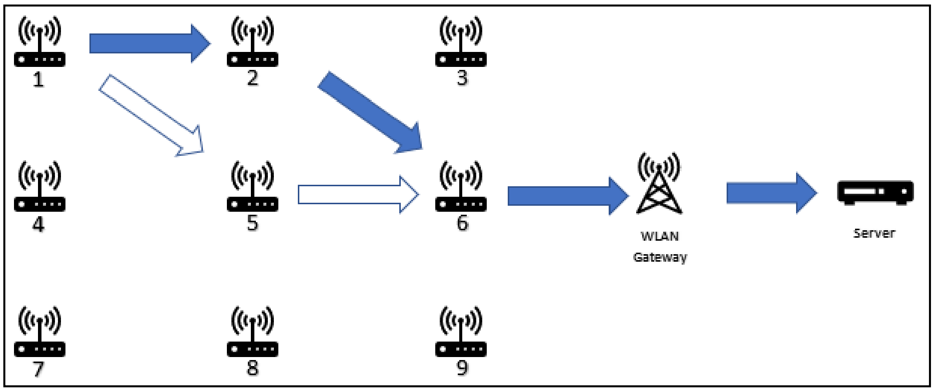

Fig. 9. Packet transfer route in 100 meters range

Table 4 below shows the result for 100 meters range packet transfer.

Table 4
100 meters range packet transfer result

Observed Result	AODV	RPL	Energy Difference [AODV-RPL]	Energy Difference Percentage
Energy Consumption (mJ)	808905.53	782838.99	26066.54	3.33 %
Energy Consumption Rate (mJ/min)	6740.88	6523.66	217.22	3.33 %

The graph in Figure 10 shows energy consumption for each wireless sensor nodes where RPL consumed smaller amount of energy in most of the sensors using wireless sensor 5 and 6 as the parent node. Using AODV, wireless sensor node 5 used the largest amount of energy to keep updating its routing table for all its neighbours.

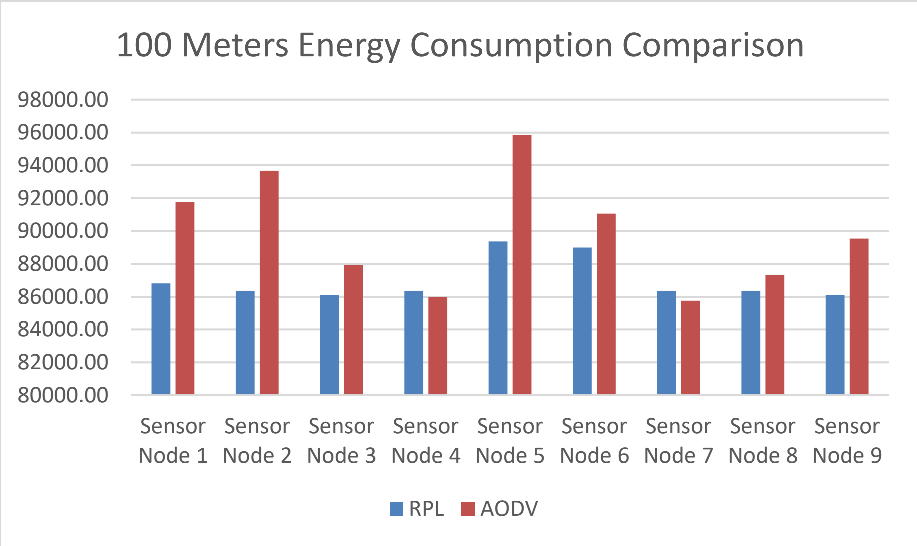

Fig. 10. 100 meters energy consumption comparison

3.2.3 Simulation with range of 150 meters

This simulation consists of 9 wireless sensor nodes that places 150 meters between each other. This simulation is simulating on how packet data being transferred from sensor node 1 to the server.

Sensor node 2 and 4 are in the range of wireless sensor node 1 and considered as its neighbor. Thus, sensor node 1 has option to go through sensor node 2 and 4 to transfer packet data to the WLAN gateway that contain the least hop count as shown in Figure 11.

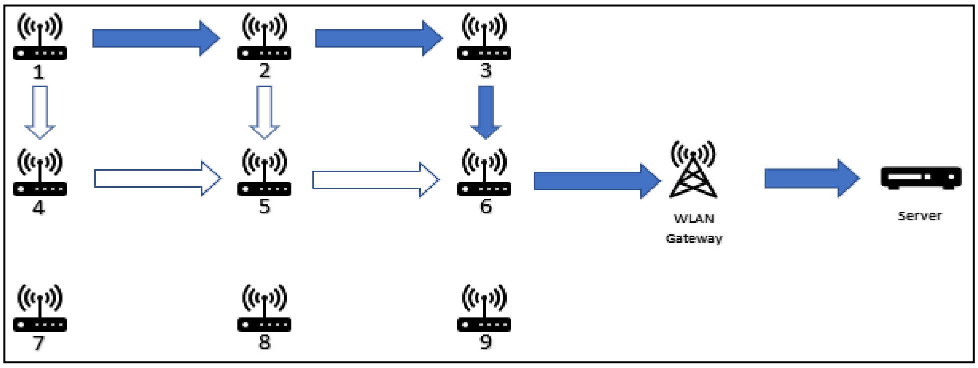

Fig. 11. Packet transfer route in 150 meters range

Table 5 below shows the result for 150 meters range packet transfer.

Table 5
150 meters range packet transfer result

Observed Result	AODV	RPL	Energy Difference [AODV-RPL]	Energy Difference Percentage
Energy Consumption (mJ)	804947.69	779659.37	25288.32	3.24 %
Energy Consumption Rate (mJ/min)	6707.90	6497.16	210.74	3.24 %

Based on the graph on Figure 12, RPL used wireless sensor node 4, 5 and 6 as its parent node where it used a slightly more energy to keep updating the routing table. While using AODV, sensor node 2 and 5 utilized the most energy to keep updating its routing table.

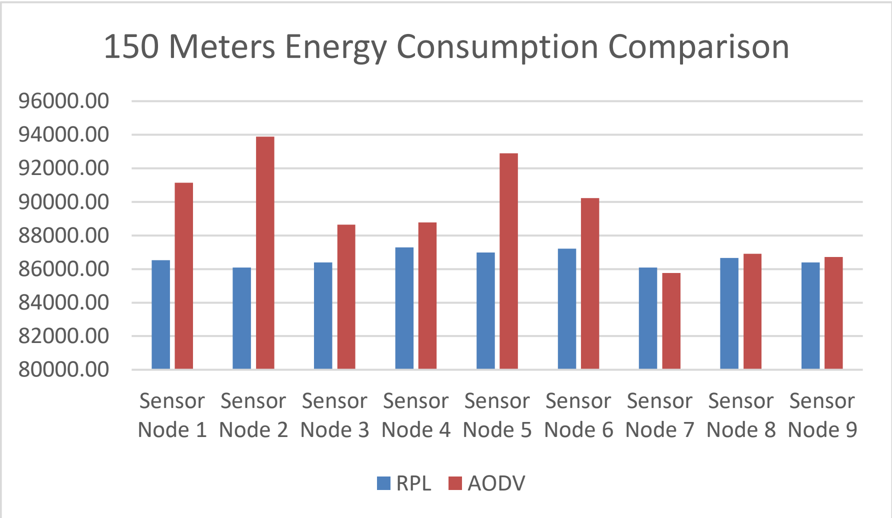

Fig. 12. 150 meters energy consumption comparison

3.2.4 Simulation with range of 200 meters

This simulation consists of 9 wireless sensor nodes that were placed 200 meters between each other. This simulation was simulating on how packet data being transferred from sensor node 1 to the server.

Sensor 1 has no other wireless sensor node that in its range to consider its neighbor. Thus, sensor node 1 has no option to choose to transfer packet data to the WLAN gateway as shown in Figure 13.

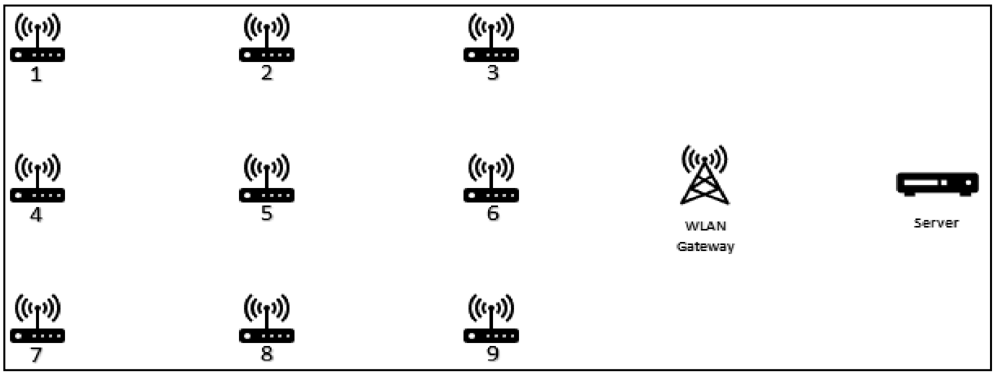

Fig. 13. Packet transfer route in 200 meters range

Table 6 below shows the result for 200 meters range packet transfer.

Table 6
200 meters range packet transfer result

Observed Result	AODV	RPL	Energy Difference [AODV-RPL]	Energy Difference Percentage
Energy Consumption (mJ)	770100.00	787480.16	-17380.17	-2.21 %
Energy Consumption Rate (mJ/min)	6417.50	6562.33	-144.83	-2.21 %

Based on the graph in Figure 14, when using AODV, sensor 1 attempted to send data packets causing it to consume more energy than the others. While using RPL, energy consumed were uniformly greater than AODV trying to establish connection without any attempt to send packet data without established connection.

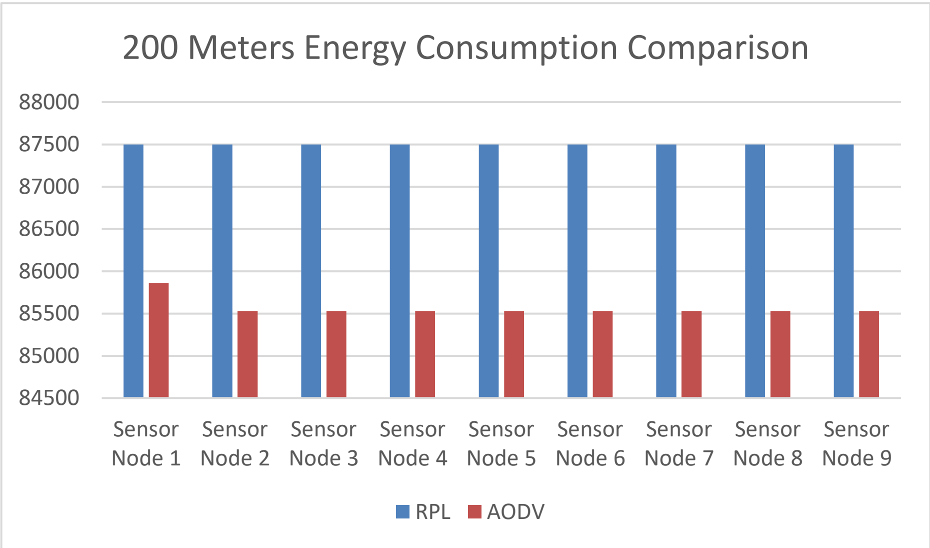

Fig. 14. 200 meters energy consumption comparison

3.3 Simulation Results Analysis

All the energy consumption rate from each simulation is collected as shown in Table 7. The total of energy consumption rate in 2 hours duration shows a 0.03% difference where AODV consumed larger amount of energy per minute than RPL. The results include the energy consumption rate of the sender node, the route node, the possible route node, and the standby node.

Table 7
Energy consumption rate result (2 hours)

Energy Consumption Rate	AODV (mJ/min)	RPL (mJ/min)	Energy Difference [AODV-RPL] (mJ/min)	Energy Difference Percentage (mJ/min)
Basic Topology	2873.52	2876.41	-2.89	-0.10 %
50 Meters Range	6439.81	6504.66	-64.85	-1.00 %
100 Meters Range	6740.88	6523.66	217.22	3.33 %
150 Meters Range	6707.90	6497.16	210.74	3.24 %
200 Meters Range	6417.50	6562.33	-144.83	-2.21 %
Total	29179.61	28964.22	215.39	0.03 %

In a topology where each node has greater number of neighbours, AODV consumed 1% smaller amount of energy. In a condition where the sender node must choose between several paths, AODV consumed around 3.24% to 3.33% amount of energy larger than RPL. During a situation where all the nodes were on idle mode, AODV consumed 2.21% smaller amount of energy than RPL.

4. Conclusions

The result of this research shows that there are advantages and disadvantageous for each routing protocol that can contribute to the Green IoT. For example, AODV routing protocol can work with a lower amount of energy in a place where the number of wireless sensors is well populated, where it has many neighbour nodes, and in a condition where the wireless nodes will be in idle mode for a long period of times, like in warehouse where sensor nodes need to be close to each other to be more precise when locating a subject and idle for a long time when not in use. On the other hand, RPL routing protocol works well with less energy when the wireless sensor is strategically placed to cover a specific region for each of them, like in a production line for a factory.

The routing protocol is still evolving, influenced by the requirements of a specific environment. Researchers are still studying to enhance the current routing protocols. One day, there will be a new routing protocol that may suit greater number of IoT environments as the technologies continue to evolve. The benefit of saving resources without sacrificing performances is an opportunity the industry can never ignore. Not only the costs of the resources are reduced, but a healthier environment can be achieved by reducing carbon dioxide emissions, thus, help to retain cleaner air for future generations.

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