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Sink position analysis of energy efficiency in Wireless Sensor Network (WSN) using routing Stable Election Protocol (SEP)

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Abstract — Wireless Sensor Network (WSN) is a wireless network that involves sensors in the network. The sensor node on the WSN will collect data information from the environment around the sensor. However, each sensor node has storage capacity, processing power, communication range, and battery life limitations. The use of energy consumption from these factors is the main problem because each sensor node uses its power consumption from the battery. Stable Election Protocol (SEP) is a type of routing protocol on WSN that uses the clustering method. SEP has a function to extend the time interval before the first node dies. This research was carried out on the SEP protocol with alive node parameters, total initial energy, and stability. This study indicates that on a network that uses 100 nodes with sink positions (0, 100), two nodes are still alive and several nodes still alive in several sink positions that use 200 nodes. For networks where there is still a lot of energy reduction in the sink position (0, 100) with the network using 100 nodes and for networks using 200 nodes, the reduction energy is mainly in the sink position (100, 100). The highest stability period is in the sink position (50, 50) for networks using 100 nodes, and for networks using 200 nodes, the highest stability period is in the sink position (100, 50).

Keywords – Wireless Sensor Network (WSN), Stable Election Protocol (SEP), Alive Node, Total Network Initial Energy, Stability Period

I. INTRODUCTION

The increasing development of telecommunications technology today is in sensor technology such as Wireless Sensor Network (WSN). WSN technology monitors environmental conditions by using sensors equipped with batteries as a power source. WSN has developed through various updates such as systems in the health sector, innovative home monitoring systems, the military, and others [1][2].

WSN is a technology that consists of several sensor nodes whose task is to monitor and collect data from the environment around the sensor node. Then the data is sent to the sink or base station as a processing center. Sensor nodes in WSN have sensing, processing, storage, and radio capabilities. Sensor nodes' ability can be optimized, and these sensor nodes will be connected with wireless and distributed network technology to form a wireless sensor network or WSN. One of the protocols in WSN is the Low Energy Adaptive Clustering Hierarchy (LEACH), where each node in LEACH is provided with the same initial energy so that it has the same probability of becoming a Cluster Head (CH). Still, the LEACH protocol is not aware of heterogeneity in terms of energy at each node, where this heterogeneity can increase network lifetime. Another proposed approach is the SEP protocol. The SEP will be aware of heterogeneity in terms of energy because the nodes are equipped with different initial energies. So that in, the selection of CH based on the initial energy at each node can increase the network life, especially by increasing the stability period or time interval before the death of the first node [3][4].

SEP is a type of routing protocol on WSN that uses the clustering method. Clustering is dividing each node into a cluster with CH as the head. In clustering, it is divided into two types of nodes, namely CH nodes and sensor nodes. CH is tasked with collecting information data from sensor nodes, and then the data is transmitted to the sink by CH. SEP has a function to extend the time interval before the first node dies. In SEP, there are two types of nodes, namely normal nodes and advanced nodes or advanced nodes. Advanced nodes have a higher energy level, so advanced nodes have a greater chance of becoming CH than normal nodes. On the other hand, normal nodes have lower energy levels than advanced nodes in the network [5][6].

The research was conducted using a MATLAB simulator simulation based on the background described above. Simulations will be carried out using different variations of nodes using the SEP Protocol. This research will analyze alive node parameters, total network energy, and stability Period.

A. Previous research

Research [7] discusses the effect of nodes' sink position on network performance by using the direct diffusion method to determine energy consumption, packet delivery rate, end-to-end delay, and network routing load criteria. Direct diffusion is one of the protocols developed for communication in wireless sensor networks. This research was carried out in a simulation with the NS2 simulator and used a varying number of nodes, 50, 100, and 300, which were randomly distributed in an area of 100 x 100 m2. The study was carried out in a simulation using NS2. This study used three sensor environment scenarios: sensor node 50 is considered a sparsely distributed environment. Sensor node 100 is considered customarily distributed, and sensor node 300 is considered densely distributed. In this study, six sink nodes are used and are assumed to have unlimited battery life. The test was carried out with three scenarios: the sink node in the middle, at the corner, and random. In each method, 20 times. This study shows that the number of sink nodes impacts energy consumption, but the number of sink nodes positively impacts end-to-end delay and packet delivery rate.

Research [8] will analyze the performance of the LEACH, SEP, and TEEN protocols. This research was conducted by simulation using the MATLAB simulator application. The simulation will be carried out using 100 nodes distributed in an area of 100 x 100 m and for sinks located at (50, 100) with a packet length of 4000 bits. This study applies the LEACH, SEP, and TEEN protocols. This study shows that the SEP protocol produces a higher stability period than the LEACH and TEEN protocols. In SEP, the optimal CH selection is, on average, 10, while in the LEACH and TEEN protocol, the optimal CH selection is 5 [8].

Research [9] will discuss the optimal amount of CH in WSN using the SEP protocol. This research was conducted by simulation using the TinyOS simulator application. The study will use the SEP protocol with various nodes used 25, 50, 75, 100, 125, 250, and 500, which are randomly distributed over an area of 70 x 70 m. This research was conducted to know the optimal CH on the WSN network. In transmitting data to a sink where the data is obtained from cluster members, the CH will consume higher energy than the sensor nodes of the cluster. The results obtained in the research, optimal CH with 2, 4, 5, 6,13, and 17. The optimal amount of CH is obtained in the network with nodes 50, 75, 100, 125, 250, and 500 because it consumes the minimum energy [9].

B. Wireless Sensor Network (WSN)

Wireless Sensor Network (WSN) consists of several sensor devices called sensor nodes placed randomly in a specific area where they have their energy power. The sensor node has the task of monitoring physical and environmental conditions to collect data and information in the form of temperature, vibration, movement, humidity, and pressure from the environment around the sensor node. After the sensor node collects data and information, it will send it to the sink or base station. Sensors in wireless sensor networks can perform sensing, data processing, and wireless communication. But each sensor node has limitations and challenges such as storage capacity, processing power, communication range, and battery life. Each sensor node has limitations in several ways, one of which is energy to maintain a lifetime. Energy consumption can be reduced by using hierarchical-based routing methods or grouping sensor nodes into communication clusters [2] [4][8]. The Wireless Sensor Network uses the IEEE communication protocol standard.[10] [11]. One type of IEEE protocol is IEEE 802.15.4. IEEE 802.15.4 is a Wireless Personal Area Network (WPAN) protocol used for radio wave (RF) standards. This protocol uses three frequency bands, namely 868-8686.8 MHz for Europe, 902-928 MHz for America, and 2, 4 GHz is used globally, with each frequency having a data rate of 20 Kbps, 40 Kbps, and 250 Kbps [12] [13].

C. Stable Election Protocol (SEP)

Stable Election Protocol (SEP) is a protocol for heterogeneous networks. In SEP, the normal and advanced nodes are randomly deployed. Suppose normal nodes are deployed in the majority far away from the base station. In that case, the nodes will consume more energy in transmitting data to the base station, resulting in less stability period and throughput. SEP uses routing clustering and extends the time interval before the first node dies [14]. SEP is a LEACH protocol that was developed in which. This protocol uses cluster-based routing and provides stability to the WSN network. Implementing SEP clustering does not consider various types of transmission in the WSN network, such as intra-cluster transmission, inter-cluster transmission, and cluster head-to-sink transmission. SEP will view all the same transmission categories and allocate the same energy for each transmission [15]. In SEP, there are two types of nodes, namely normal nodes and advanced nodes or advanced nodes. Advanced nodes have a higher energy level, so advanced nodes have a greater chance of becoming a cluster head than normal nodes. Normal nodes have lower energy levels compared to advanced nodes in the network. SEP in WSN uses a distributed method in selecting the cluster head by considering the energy level at each node in the wireless sensor network [16][17][18]. This is described in Figure 2.

In each round, the cluster head is selected. The nodes distribute in a certain area. First, the numbers 0 and 1 are generated by nodes. Then finally, it is compared with the threshold value. If the value is smaller than the threshold, the node will be selected as a cluster head by using Equation 2.1 [4].

$$T(s_i) = \begin{Bmatrix} \frac{p}{1 - p\left(r \bmod \frac{1}{p}\right)} & \text{if } s_i \in G \\ 0 \text{ other view} \end{Bmatrix} \quad (2.1)$$

Where s_i is the number of nodes, b is the percentage of desired cluster heads, r is the round value, and G is the number of nodes that have not become cluster heads.

$$P\,(\text{Normal}) = \frac{p}{1 + m.\alpha} \quad (2.2)$$

The probability calculation on normal nodes to be cluster heads using Equation 2.2. P is the optimal probability for each node to become a cluster head in the wireless sensor network in the SEP cluster head, selected randomly based on the possibility for each node. Where m is the fraction of the total number of nodes (n) and α (alpha) is the additional energy factor [16][18].

$$P\,(\text{Advanced}) = \frac{p}{1 + m.\alpha}\,(1 + \alpha) \quad (2.3)$$

The calculation of probability at the advanced node to be cluster head using Equation 2.3. P is the optimal probability for each node to become a cluster head in the wireless sensor network in the SEP cluster head, selected randomly based on the probability for each node. Where m is the fraction of the total number of nodes (n) and is the additional energy factor (alpha) [16][18].

D. Energy

Energy is one of the parameters used in this research simulation. Of the several problems on the WSN network, energy is the main problem because each sensor node uses a battery for its power. Hence, the energy reserves of each sensor node are limited. Energy consumption is one factor that affects the age of the network. In this research simulation, several parts of the energy parameters are used, namely:

a. ETX is the amount of energy required to transmit data per bit.

b. ERX is the amount of energy required to receive data per bit.

c. EFS is the energy required to transmit signals in an open area.

d. EMP is the energy required to transmit diarrhea signals with a barrier tone.

e. EDA is the energy used for data transmission in an aggregated manner [19].

In SEP, we describe the simulation model into a wireless sensor network with nodes heterogeneous in their initial amount of energy. There are two types of nodes. They are advanced nodes equipped with an initial energy of E_0 (1 + α), and the normal node has initial energy of E_0. On the other hand, the total energy in heterogeneous networks will change, calculated by equation [20]. Let m be the fraction of the total number of nodes n, which are equipped with α times more energy than the others. When the value of α is 0, then the simulation has a homogeneous environment. In this simulation, the value of E_0 is 0,5 Joule based on previous research [3].

$$\begin{aligned} Etotal &= n.\,(1 - m).\,E_0 + n.m.\,E_0.\,(1 + \alpha) \\ &= n.E_0.(1 + \alpha.m) \end{aligned} \quad (2.4)$$

Where E_0 is initial energy, n is number of nodes, m is total nodes advance, α is alpha.

E. Lifetime Node

The node lifetime is the time it takes each node from the simulation start or from being turned on until it runs out of power. Network lifetime is the time it takes from the beginning until all nodes die out of power, the network lifetime can be known from the number of rounds made by the network until all nodes die [21].

II. RESEARCH METHOD

This study will analyze the performance of the SEP routing protocol using the Alive node parameter, total energy, and stability period based on the sink position. This simulation uses a sink placed in the middle and at the edge of the research area. The number of nodes used in the simulation is 100 and 200, randomly distributed in an area measuring 100 x 100 m. This research was conducted by simulation in MATLAB. Fig.1 to Fig.4 is an illustration of distribution nodes which the position of the sink in the center and edge area. We use the Voronoi diagram to see the coverage of each cluster.

Table 1. Simulation Parameter

Simulation Area	**100 x 100 m**
Initial Energy (E_0)	0.5 J
A	1
Eelec (E_{TX}, E_{RX})	50 nJ/bit
Efs	10 Pj/bit/m2
Eamp	0.013 pJ/bit/m4
EDA	5 nJ/bit
Probability (P)	0.1
m (Node Advance)	0.2
Round	3000
Sink Position (X, Y)	(0, 50), (0, 100), (50, 50), (50, 100). (100, 50), (100, 100)

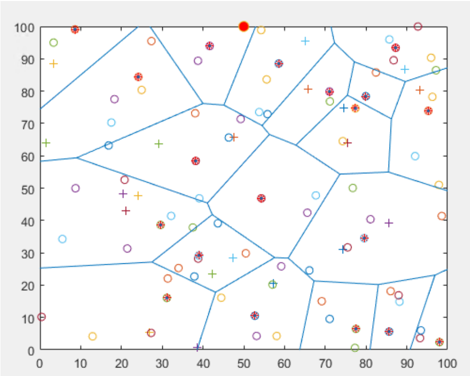

Fig.1. Distribution of 100 Nodes in the Sink Position at the Edge of the Area

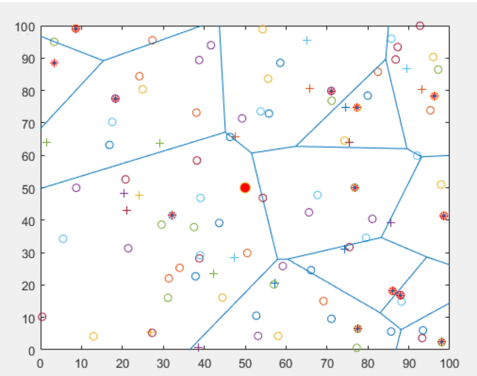

Fig.2. Distribution of 100 Nodes at the Sink Position in the Center Area

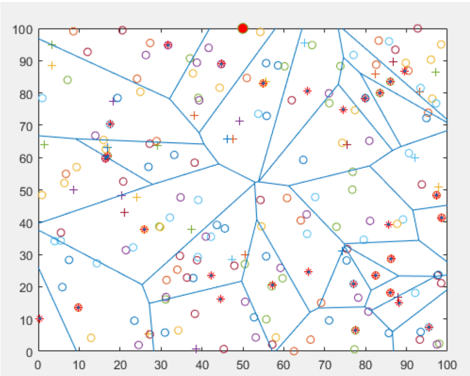

Fig.3. Distribution of 200 Nodes at the Sink Position at the Edge of the Area

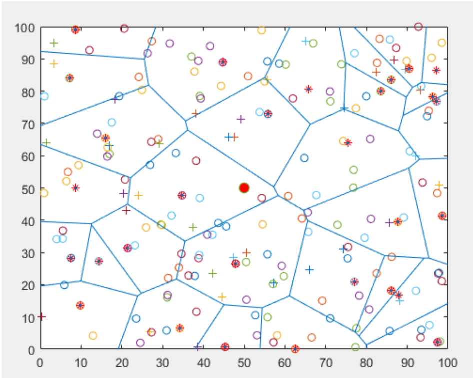

Fig.4. Distribution of 200 Nodes at the Sink Position in the Center Area

III. RESULT

A. Alive Node 100

In this section, the surviving nodes on the network will be discussed using 100 nodes with 0.2 or 20 (m) advanced nodes distributed over an area measuring 100 x 100 m and a total of 3000 rounds.

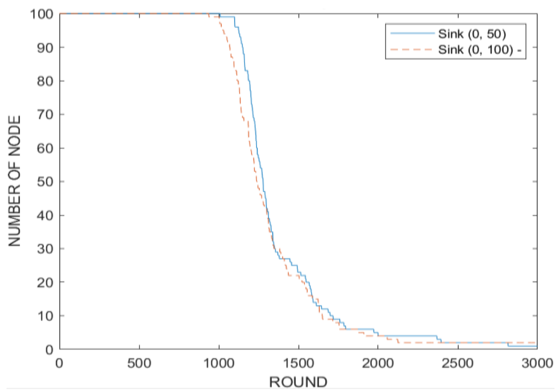

Fig.5. Alive Node 100 with Sink Positions (0, 50) and (0, 100)

Figure 5 shows the number of nodes that are still alive in each round or round on the network. It can be seen from the picture above that the node is still alive at 100% until the 900th cycle, but when the 937th cycle is in the sink position (x =0, y = 100), the node begins to die. While at the sink position (x = 0, y = 50), the first node death occurs during the 1008th round. The death of the node will increase as the number of rounds in the network increases. When the round is above 2000 nodes that are alive in both sink positions below ten nodes, and when round 3000 is at the sink position (0, 100), there are still two nodes that are still alive while at the sink position (0, 50) only one node is still alive.

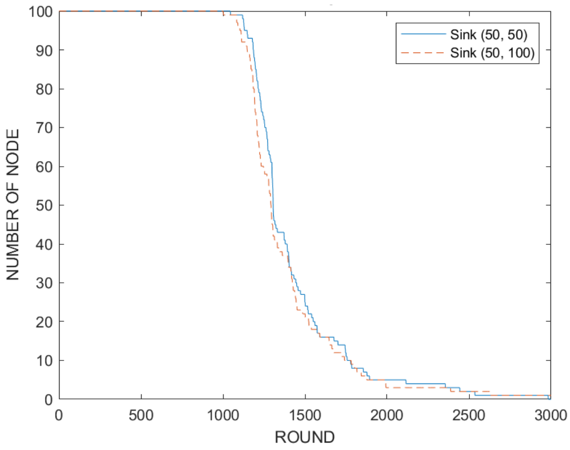

Fig.6. Alive Node 100 with Sink Positions (50, 50) and (50, 100)

Figure 6 shows the number of nodes still alive in each round or round on the network. The nodes in both sink positions can survive up to 1000 rounds from the graphic above. The sink position (x = 50, y = 100) produces a period of stability or nodes. The first death occurred during round 1001. While the sink position (x = 50, y = 50) resulted in a period of stability, or the first node died during round 1045. In this experiment, the time interval before the death of the first node increased by 44 rounds or increased by 4 %. The sink position (x=50, y= 50) resulted in the highest stability period of all the tested sink positions on a network using 100 nodes. Still, at a sink position (x=50, y=50), the network became unstable after experiencing the death of a node because the cluster formed is not optimal. At the sink position (50, 100), energy is more efficient because in the network with this sink position, there is still one node alive until the round runs out, while at the sink position (50, 50), all nodes are dead. Previous studies stated that the sink position at the edge of the propagation beam of packet delivery was in the same direction. In contrast, the sink position in the middle of the propagation beam was not in the same direction.

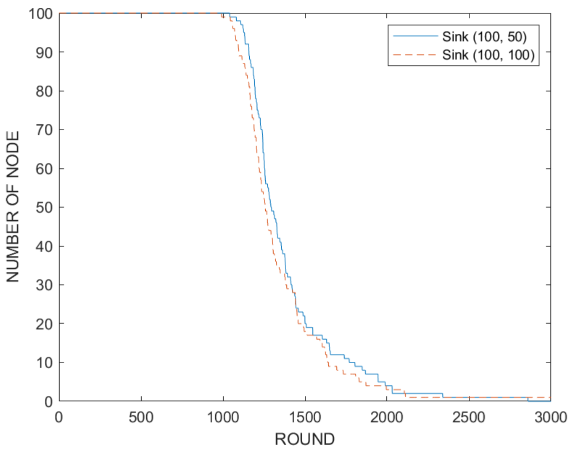

Fig.7. Alive Node 100 Sink Positions (100, 50) and (100, 100)

Figure 7 shows the number of nodes still alive in each round or round on the network. From the picture above, the first node dies at around 990 for the sink position (x = 100, y = 100). Meanwhile, at the sink position (x = 100, y = 50), the first node dies during the 1041st round. The death node will increase as the round increases due to the reduction of energy in the network. The round is above 2000 nodes in sink positions below ten nodes.

B. Alive Node 200

In this section, we will discuss the surviving nodes on the network using 200 nodes with 0.2 (m) advanced nodes or 40 nodes distributed over an area measuring 100 x 100 m and a total round of 3000.

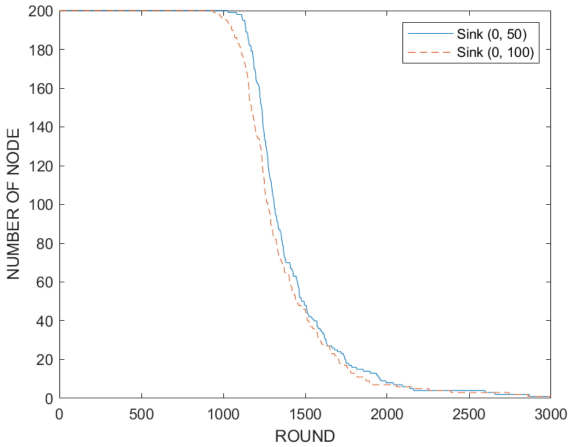

Fig.8. Alive Node 200 Sink Positions (0, 50) and (0, 100)

Figure 8 shows the number of nodes still alive in each round or round on a distributed network of 200 nodes scattered randomly. The nodes in both sink positions can survive up to 900 rounds from the picture above. But when the round enters 940 at the sink position (x = 0, y = 100), the node dies first. Meanwhile, at the sink position (x = 0, y = 50), the first node dies during the 1029th round. When the round is above 2000, the fewer nodes live, the better the two sink positions used.

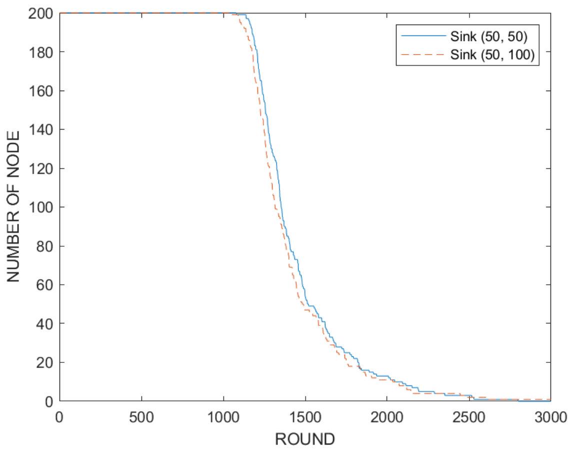

Fig.9. Alive Node 200 Sink Positions (50, 50) and (50, 100)

Figure 9 shows the number of nodes still alive in each round or round on the network. From the picture above, the node can survive up to 1030 rounds. At 1035 round the first node dies occurs for the sink position (x = 50, y = 100). Meanwhile, at the sink position (x = 50, y = 50), the first node dies during the

1080th cycle. The sink position (50, 50) results in a higher node lifetime than the sink position (50, 100).

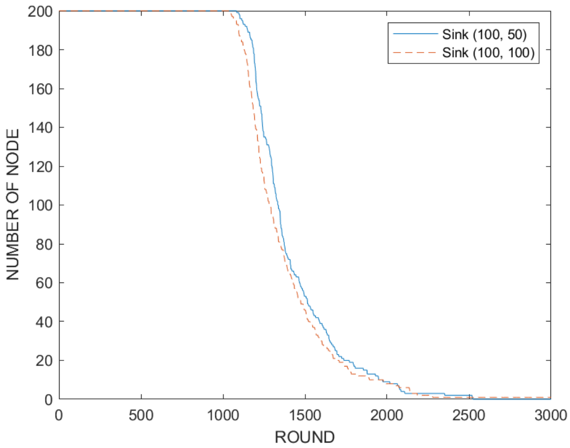

Fig.10. Alive Node 200 Sink Positions (100, 50) and (100, 100)

Figure 10 shows the number of nodes still alive in each round on the network by the sink positions (100, 50) and (100, 100). It can be seen from the picture above that the first node dies occurs at round 1035 for the sink position (x = 100, y = 100). Meanwhile, in the sink position (x = 100, y = 50), the first node dies during the 1083rd round. Every time the number of rounds increases, the reduction nodes in the network will continually decrease.

C. Total Node Energy 100

This section will discuss the total energy generated by 100 nodes and energy reduction in each round.

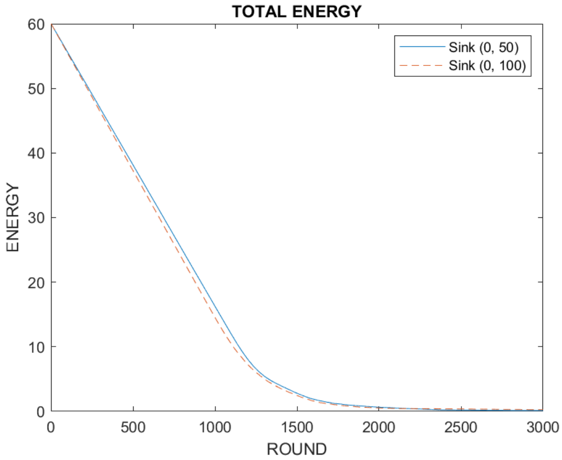

Fig.11. Total Energy of 100 Nodes with Sink Position (0, 50) and (0, 100)

Figure 11 shows the total initial energy in the simulated network. The total initial energy can be calculated using equation (2.4) where the number of nodes used affects the initial total energy in the network, the more nodes used, the greater the total initial energy. In this simulation, the initial energy of the network is 60 J, using 100 nodes and among them there are 20 advanced nodes or nodes that have more initial energy than normal nodes. Figure 11 shows the results that using the same protocol but with a different sink position affects the reduction energy, it can be seen in the initial rotation that the reduction energy runs linearly at both sink positions, but in rotations above 500, the difference begins to appear. At the sink position (0, 100) the energy in the network begins to decrease with increasing rounds than at the sink position (0, 50).

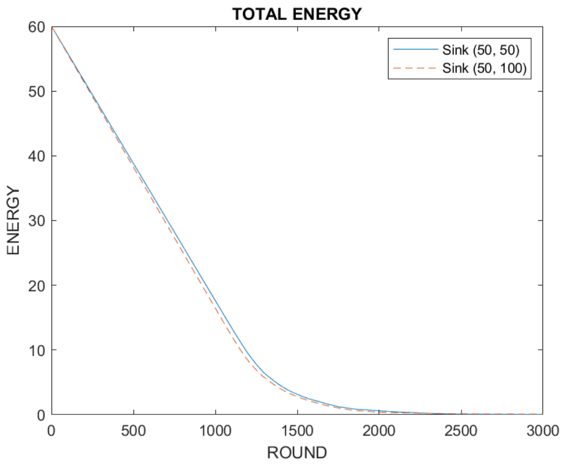

Fig.12. Total Energy 100 nodes Sink Position (50, 50) and (50, 100)

Figure 12 shows the total initial energy at both sink positions running linearly. Still, when the rotation is around 600, the energy sink position (50, 100) decreases from the sink position (50, 50). Finally, when the rotation is above 1600, the energy runs linearly in both sink positions because the energy in both sink positions is already below 1.

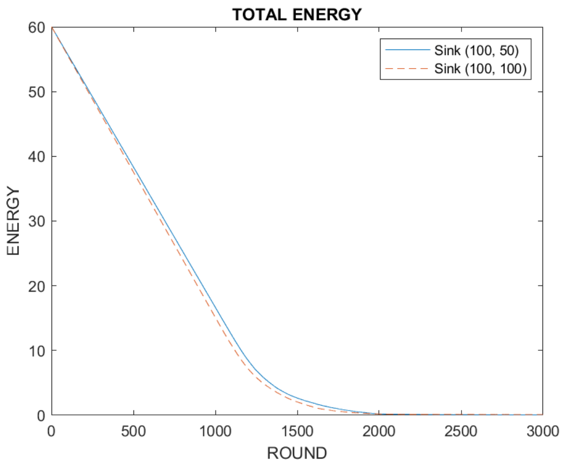

Fig.13. Total Energy 100 nodes Sink Position (100, 50) and (100, 100)

Figure 13 shows the results that using the same protocol but with a different sink position affects the reduction of energy in the network. It can be seen in the initial rotation that the reduction energy runs linearly in both sink positions. Still, in rotations above 500, the difference begins to appear. At the sink position (100, 100), the energy in the network decreases with increasing rounds from the sink position (100, 50).

D. Total Node Energy 200

This section will discuss the total energy generated by the 200 nodes and the energy reduction in each round.

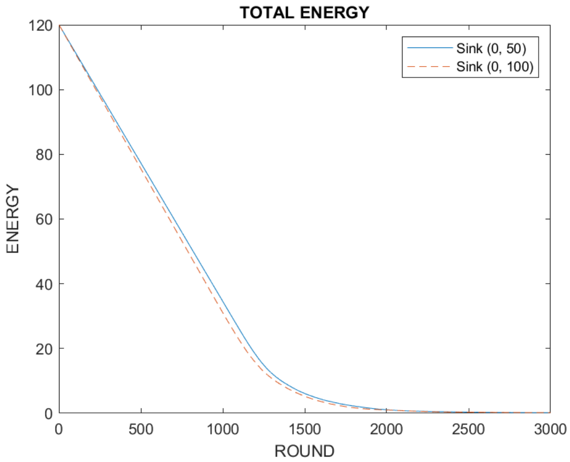

Fig.14. The total energy of 200 nodes Sink positions (0, 50) and (0, 100)

Figure 14 shows the total initial energy in the simulated network using 200 nodes. In this simulation, the initial energy of the network is 120 J, using 200 nodes, and among them, there are 40 advanced nodes or nodes that have more initial energy than normal nodes. Figure 14 shows the results that using the same protocol but with a different sink position affects energy reduction. It can be seen in the initial rotation that the reduction energy runs linearly at both sink positions. Still, in rotations above 500, the difference begins to appear. At the sink position (0, 100), the energy in the network starts to decrease with increasing rounds than at the sink position (0, 50) because the sink position (0, 100) is located in the upper corner so that the node s requires more energy to transmit data to sink. When the rotation is above 2000, the energy runs linearly in both sink positions because the reduction energy in both sink positions is already below 1.

Figure 15 shows the total initial energy in the simulated network using 200 nodes. Among them, there are 40 advance nodes distributed over an area of 100 x 100 m with the initial energy used of 0.5 J and alpha or additional energy of 1. This simulation calculates the initial energy 120 J network and the initial total energy using equation (2.4). It can be seen at the beginning of the energy cycle at both sink positions running linearly. Still, at about 600 rotations, the energy at the sink position (50, 100) decreases more than the energy from the sink position (50, 50).

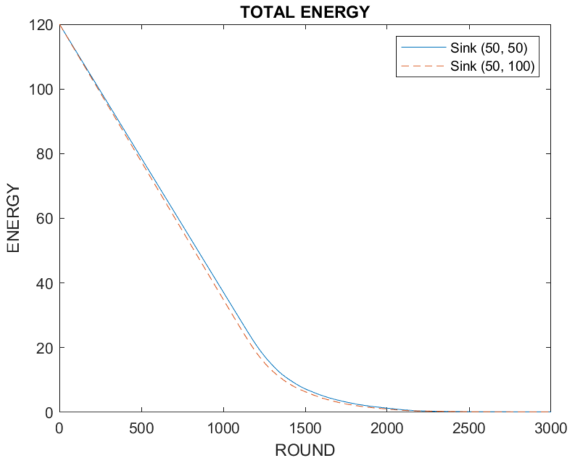

Fig.15. The total energy of 200 nodes Sink positions (50, 50) and (50, 100)

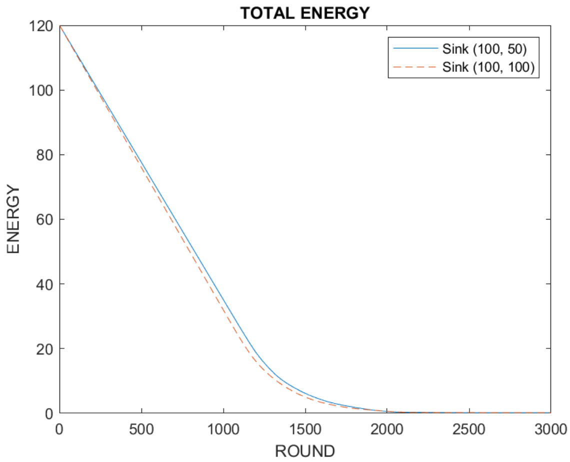

Fig.16. The total energy of 200 nodes Sink positions (100, 50) and (100, 100)

Figure 16 shows that using the same protocol but with a different sink position affects the reduction of energy in the network. In the initial rotation, the reduction energy runs linearly at both sink positions. Still, at a rotation above 500, the difference begins to appear. At the sink position (100, 100), the energy in the network decreases with increasing rounds than at the sink position (100, 50).

E. Node Stability Period

The stability period is the time it takes from the start of the network running until the death of the first node. This simulation produces a period of stability, as shown in Figure 15. The sink position in the center of the area (50, 50) results in a higher stability period of 1045. This stability period is higher than the other sink positions, and on a network that uses 200 nodes, the stability period occurs. At the sink position (100, 50) by producing a stability period of 1083. The higher or the number of times the network travels until the network experiences the death of the first node.

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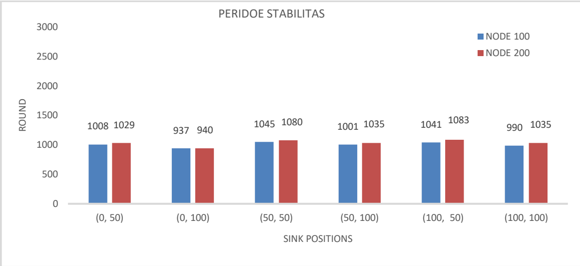

Fig.17. Stability Period

IV. DISCUSSION

Wireless Sensor Network (WSN) is a wireless network that involves sensors. The sensor node on the WSN will collect data information from the environment around the sensor. However, each sensor node has storage capacity, processing power, communication range, and battery life limitations. Energy consumption is the main problem from these factors because each sensor node uses its power consumption from the battery. Stable Election Protocol (SEP) is a type of routing protocol on WSN that uses the clustering method. SEP has a function to extend the time interval before the first node dies. This research was conducted on the SEP protocol with the alive node parameters, total initial energy, and stability periods. This study indicates that two nodes are still alive on a network that uses 100 nodes with sink positions (0, 100), and several nodes that are still alive in several sink positions use 200 nodes. For networks where there is still a lot of energy reduction in the sink position (0, 100), with the network using 100 nodes and networks using 200 nodes, the reduction energy is mostly in the sink position (100, 100). The highest stability period is at the sink position (50, 50) for a network using 100 nodes, and for a network using 200 nodes, the highest stability period is at the sink position (100, 50).

V. CONCLUSIONS

In this research, a comparative study of sink positions on a WSN network using the SEP protocol has been carried out with a distribution of 100 nodes and 200 nodes. The number of nodes used in the network affects the total initial energy of the network and the stability period. Normal nodes with initial energy E0, and advanced nodes with initial energy E0 (1 +) where E0 = 0.5 J, = 1 and m = 0.2, are used as parameters in this study. The resulting performance of the SEP protocol, the sink position, affects the period of stability and energy efficiency. From the simulation results that have been carried out, the sink position with coordinates (y=50) has a higher stability period than the sink position with coordinates (y=100). The sink position with coordinates (y=100) is more efficient for energy than the sink position in the middle (y=50). This condition is because the sink is positioned on the edge. With 100 nodes and 200 nodes, there are still nodes that live up to around 3000. And the propagation of packets to the sink is in the same direction, while at the sink position in the middle, the propagation beam is not in the same direction. The sink position is placed on the sensor network's edge, considering energy efficiency from the results obtained. If the sensor network considers the stability period, the sink position is placed in the middle of the area.

REFERENCES

[1] M. Dr. Ir. Prihadi Murdiyat, "Mengenal Wireless Sensor Network, Solusi Alternatif Mendeteksi Bencana," *1 Januari*, 2019. .

[2] E. M. Reagan *et al.*, "Analisis Perbandingan QoS Routing Protokol Pada WSN Menggunakan LEACH, TEEn dan SEP."

[3] G. SMARAGDAKIS and I. M. A. BESTAVROS, "SEP : A Stable Election Protocol for clustered heterogeneous wireless sensor networks," no. May 2014, pp. 1–11, 2004.

[4] F. F. Kusumastuti, I. Wahidah, and R. Mayasari, "Analisis Perbandingan Konsumsi Daya dan Masa Hidup Jaringan pada Protokol Routing LEACH dan HEED di Wireless Sensor Network," *Conf. Inf. Technol. Inf. Syst. Electr. Eng.*, pp. 57–64, 2016.

[5] S. Iqbal, S. B. Shagrithaya, G. P. Sandeep Gowda, and B. S. Mahesh, "Performance analysis of stable election protocol and its extensions in WSN," *Proc. 2014 IEEE Int. Conf. Adv. Commun. Control Comput. Technol. ICACCCT 2014*, no. 978, pp. 744–748, 2015, doi: 10.1109/ICACCCT.2014.7019189.

[6] R. E. Izzaty, B. Astuti, and N. Cholimah, "Sistem Komunikasi Multihop SEP dengan Dynamic Cluster Head pada Jaringan Sensor Nirkabel," *Angew. Chemie Int. Ed. 6(11), 951–952.*, pp. 5–24, 1967.

[7] R. Kocaoglu, A. Erggzen, and E. Erdal, "Effect of Sink Node Position on Performance in Direct Diffusion Based Sensor Networks," *UBMK 2019 - Proceedings, 4th Int. Conf. Comput. Sci. Eng.*, pp. 217–222, 2019, doi: 10.1109/UBMK.2019.8907008.

[8] I. Journal, "An Efficient Protocol for Reducing Energy Consumption in Wireless Sensor Networks."

[9] M. Bouraoui and A. Meddeb, "Optimal number of cluster heads for random topology WSNs using the stable election protocol," *GSCIT 2015 - Glob. Summit Comput. Inf. Technol. - Proc.*, 2015, doi: 10.1109/GSCIT.2015.7353323.

[10] K. K. Lapangan, "Standard IEEE." .

[11] M. Rps, R. Propagation, M. A. Amanaf, E. S. Nugraha, and D. Kurnianto, "Analisis Simulasi Model COST-231 Multiwall Pathloss Indoor Berbasis Wireless Sensor Network pada Aplikasi Absensi Mahasiswa dengan Tag RFID Analisis Simulasi Model COST-231 Multiwall Pathloss Indoor Berbasis Wireless Sensor Network pada Aplikasi Absensi M," no. September, 2018, doi: 10.17933/bpostel.2018.160102.

[12] D. Anggraini, "ANALISIS DAN SIMULASI WIRELESS SENSOR NETWORK (WSN) UNTUK KOMUNIKASI DATA MENGGUNAKAN PROTOKOL ZIGBEE ANALYSIS AND SIMULATION OF WIRELESS SENSOR NETWORK (WSN) FOR DATA COMMUNICATION USING ZIGBEE PROTOCOL."

[13] "Analisa Efisiensi Energi Algoritma Routing Low-

Energy Adaptive Clustering Hierarchy (LEACH) Pada Wireless Sensor Network (WSN) Menggunakan MATLAB," vol. 1, no. 2, pp. 1–9, 2014.

[14] K. Ge. F, "Sistem Komunikasi Multihop SEP dengan Dynamic Cluster Head pada Jaringan Sensor Nirkabel," *Angew. Chemie Int. Ed. 6(11), 951–952.*, 1967.

[15] T. Jinpa and B. V. R. Reddy, "M-SEP: A variant of SEP for WSN," *Adv. Intell. Syst. Comput.*, vol. 385, pp. 45–56, 2016, doi: 10.1007/978-3-319-23258-4_5.

[16] A. Juwaied and L. Jackowska-Strumiłło, "Analysis of cluster heads positions in stable election protocol for Wireless Sensor Network," *2018 Int. Interdiscip. PhD Work. IIPhDW 2018*, pp. 367–370, 2018, doi: 10.1109/IIPHDW.2018.8388392.

[17] X. Sun and L. Zhang, "Improvement of SEP Protocol Based on Energy Consumption and Residual Energy," *Proc. - 2019 12th Int. Symp. Comput. Intell. Des. Isc. 2019*, pp. 60–63, 2019, doi: 10.1109/ISCID.2019.10096.

[18] Y. Mishra, A. Singhadia, and R. Pandey, "Energy Level Based Stable Election Protocol in Wireless Sensor Network," *Int. J. Eng. Trends Technol.*, vol. 17, no. 1, pp. 32–38, 2014, doi: 10.14445/22315381/ijett-v17p206.

[19] F. S. Syukri, A. Rakhmatsyah, and S. Prabowo, "Analisis dan Simulasi Clustering Node Menggunakan Algoritma LEACH," vol. 4, no. 3, pp. 4614–4622, 2017.

[20] B. Mostafa, "FUZZY LOGIC APPROACH TO IMPROVING STABLE ELECTION PROTOCOL FOR FUZZY LOGIC APPROACH TO IMPROVING STABLE ELECTION PROTOCOL FOR CLUSTERED," no. July 2013, 2014.

[21] C. Fu, Z. Jiang, W. Wei, and A. Wei, "An Energy Balanced Algorithm of LEACH Protocol in WSN," *Int. J. Comput. Sci. Issues*, vol. 10, no. 1, pp. 354–359, 2013.