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Extend Wireless Sensor Networks Lifetime which use Cluster-Based Routing Protocol, Namely Leach

Case Study: Integrated Polyclinic Regional College-Huye Campus (Area of Focus: Wireless Sensor Network)

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Abstract:- Wireless Sensor Network (WSN) is a spatially distributed sensors that can monitor environmental and exchange that information with each other over wireless medium. Due to their energy restrictions, their limited storage capability, and positioning in hostile environments, WSNs are vulnerable to various routing attacks. Sinkhole attack is the main issue in the said wireless sensor network which permanently disable sensor node by draining nodes battery power and drop all packets and prevent it to reach the base station. Cluster-based routing protocols are developed to undertake this problem, and the Low Energy Adaptive Clustering Hierarchy (LEACH) is one of the best-known protocols of this type. It is very important to secure the communication between nodes and prevent against different attacks especially in cluster based WSN that run LEACH routing protocol.

Therefore, this paper proposes an algorithm for extending the lifetime of Wireless Sensor Network which uses a clustering-based routing protocol namely LEACH for its routing operation in IPRC-Huye Campus. The proposed algorithm indicates the random election of normal nodes and then flags the dead nodes at each epoch and then increment accordingly. The cluster head(CH) election is done by calculating the ratio of optimal election probability and the modulation of rounds. The dissipated energy is now obtained based on the energy data aggregation and the distance between nodes.

Above all, the simulation result is shown for the proposed algorithm which is proven to be efficient compared with the existing one, namely, LEACH, in terms of minimum computational complexity and high energy efficiency. Moreover, the algorithm was numerically analyzed using MATLAB.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) have been a focal point of research and development for several decades, driven by the need for cost-effective and efficient solutions for monitoring and controlling physical environments remotely. Wireless Sensor Network (WSN) consists of large number of low-cost, resource-constrained sensor nodes with the ability to sense information from the surrounding and send to the base station(BS.

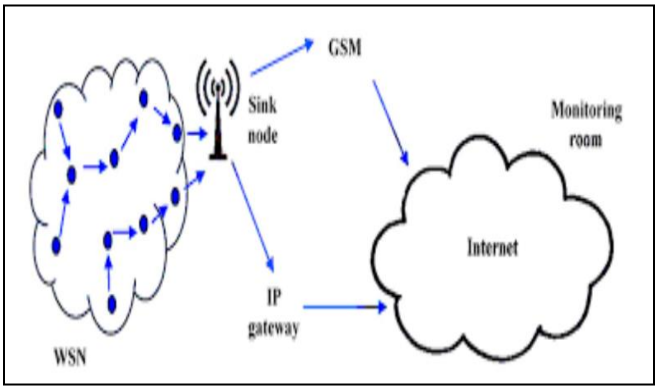

Fig 1 WSN Distribution

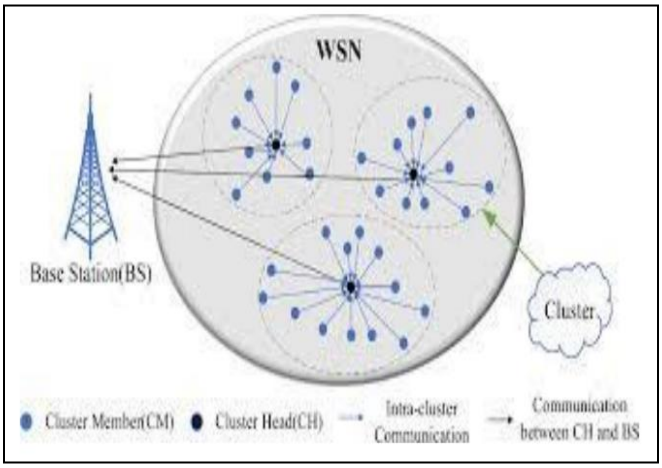

Fig 2 Clustering Wireless Sensor Network

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The development of an extended the WSN ‘s lifetime that uses LEACH protocol is a complicated and intriguing task. It involves a trench apprehension of the needs of IPRC Huye Campus WSN, the impact of quick energy drainage on the lifetime of the network due to various threats such as sinkhole reduce gradually the performance of the network, and the complexity of the algorithm needed to solve the problem. In this study a comparative study technique was followed to analyze the connection between the forecasted variable and criterion variable(dependent variable).Many were found from each single in the sample ,one mark for every variable .This study approach were appropriate and matching to our study since the researcher had to gather based on current situation of WSN of the campus to increase lifetime.

II. BACKGROUND OF STUDY

The research background of WSNs can be traced back to the late 1990s and early 2000s when the proliferation of microsensor technology and advancements in wireless communication paved the way for their exploration and development Hossam Mahmoud Ahmad Fahmy (2016).Early research in WSNs primarily focused on fundamental issues such as energy efficiency, routing protocols, and data aggregation techniques. Energy efficiency was a critical concern due to the limited power resources of sensor nodes, which are often powered by batteries or energy harvesting mechanisms. Researchers explored techniques to minimize energy consumption at different layers of the network protocol stack, including the physical, MAC, routing, and application layers Waltenegus Dargie(2010).Routing protocols played a crucial role in WSNs to enable efficient data delivery from sensor nodes to sink nodes or base stations.

Traditional routing protocols such as LEACH (Low-Energy Adaptive Clustering Hierarchy) and SPIN (Sensor Protocols for Information via Negotiation) were developed to address the unique characteristics and constraints of WSNs, such as node mobility, network topology changes, and energy conservation by Holger Karl (2007). Today, WSN research continues to evolve with a focus on addressing emerging challenges such as security and privacy concerns, scalability issues, interoperability among heterogeneous sensor nodes, integration with emerging technologies like Internet of Things (IoT) and edge computing, and the development of self-organizing, self-healing WSN architectures capable of adapting to dynamic environmental conditions Abdulrahman Yarali, PhD(2020).However, the decentralized nature and limited security features in WSNs make them vulnerable to a variety of attacks, including sinkhole attacks. A sinkhole attack is a type of network-layer attack in which a malicious node, or a "sinkhole," attempts to attract network traffic by falsely advertising itself as an optimal route to the base station. This attack is particularly harmful because, once the malicious node successfully attracts traffic, it can disrupt the network by Dropping packets, Altering or delaying packets , Energy drain and so on. IPRC-Huye has introduced this technology in different domain such as in detecting water tanks level in the campus, greenhouse management and other workshops that uses different sensor to provide different real-time data for the campus Nsabiyumva willy ,2015).

III. RESEARCH GAPS

The LEACH (Low-Energy Adaptive Clustering Hierarchy) protocol is a well-known protocol for wireless sensor networks (WSNs) that uses clustering to improve energy efficiency. However, as research on LEACH has evolved, various gaps and challenges have emerged, suggesting areas for further research.

- *Energy Efficiency in Large-Scale Networks:*

LEACH struggles with energy efficiency and scalability when applied to large-scale networks with many nodes. In LEACH, cluster heads are chosen randomly without considering node residual energy or proximity to other cluster heads, which can lead to unbalanced energy consumption.

- *Security Vulnerabilities:*

LEACH was not designed with security as a primary concern, making it susceptible to attacks like eavesdropping, replay attacks, and node compromise, which can compromise data integrity and network resilience.

- *Mobility Support:*

LEACH assumes static sensor nodes and does not support mobile nodes, which limits its applications in scenarios like vehicular ad hoc networks or animal tracking.

- *Load Balancing and Cluster Head Longevity:*

The random selection of cluster heads can lead to uneven load distribution, causing some nodes to deplete their energy faster than others. This imbalance can reduce network lifetime and reliability.

- *Energy Overhead in Cluster Formation:*

The frequent re-clustering in LEACH introduces significant energy overhead due to control message exchange, which can be counterproductive for network lifetime.

IV. METODOLOGY

- *Methods of collecting data: Tools/Instruments*

Data collection is the process of gathering and measuring information on variables of interest in a systematic way, allowing you to answer research questions, test hypotheses, and evaluate outcomes. In general, data collection aims to ensure the information is accurate, reliable, and relevant to the subject of study. In this study, the researcher used a questionnaire as research instrument and analyze the secondary data. Approaching people with a questionnaire is the best way to collect both qualitative and quantitative data from respondents.

- *Data Analysis*

Data analysis is the process of examining, cleaning, transforming, and interpreting data to extract meaningful

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insights, answer research questions, or support decision-making. It's a crucial step in turning raw data into actionable information. Data analysis is expected to offer clarity on the topic of the study and the respondants'perceptions, as well as increase readers understanding of the topic and temper their interest in this portion of the research. SPSS were used to analyses data and present the results using data analysis tools used in scientific analysis (Burns ,2022).

- *Data Processing*

Data processing is the act of converting raw data into a usable form through a series of systematic operations. The goal is to transform data into information that can be easily interpreted and used for decision-making. Data processing was mainly done though MATLAB as a simulation tool.

- *MATLAB*

All the network topologies were simulated with MATLAB. Moreover, it was backdoored to facilitate changes in network with the pre-available protocols. MATLAB is short for MATrix LABoratory and it revolves around vectors and matrices. MATLAB additionally addresses algebraic and differential equations, which are quite relevant in linear algebra.

It is a powerful tool for creating 2D and 3D imagesMATLAB offers visually appealing graphic capabilities. This is, in my opinion one of the easiest languages to write mathematical programsAt last, it is programming language as well. Others include signal processing, image in addition to optimization that can be download from the MATLAB via its tool boxes (Chidiebere, 2017).

➤ *Research Design*

Research design is the structured plan for conducting a research study. It outlines the methods and procedures for collecting, analyzing, and interpreting data, ensuring that the study effectively addresses the research question or hypothesis. A well-defined research design maximizes the validity and reliability of the results, making the findings more credible and actionable. The experiments of this research were accomplished based on the algorithm.

The output from experiments were compared with control samples. Sample input data were used to test change in the outputs. The correlated research was to variables of new result at the end. Hence, we do not have continuous data, random data sample were assumed. The study was conduced in Integrated Polyclinic Regional College-Huye Campus as case study because it was the best place which has enough and appropriate infrastructure.

➤ *Ethical Considerations*

The ethical consideration will be useful to safeguard the data collected within this research. Research ethics are likely a limited set of requirements imposed on researchers to be truthful and respectful with all people their study affected by or the results report. Stricter ethical codes are codified with Researcher typically. It will respect the values of people researching with. Except that data was only helping me to do the academic work and aid my contribution in quality of education. Personal data were guaranteed confidential and none of the respondents was accused based on his/her statement.

➤ *Conceptual Framework*

Conceptual framework (or theoretical framework) is a structure which can hold or support many things to interpret and explain them. It is a theoretical base that enables researchers, scholars or professionals to conceptualize and organize their research so one can present it within the specific field or discipline.

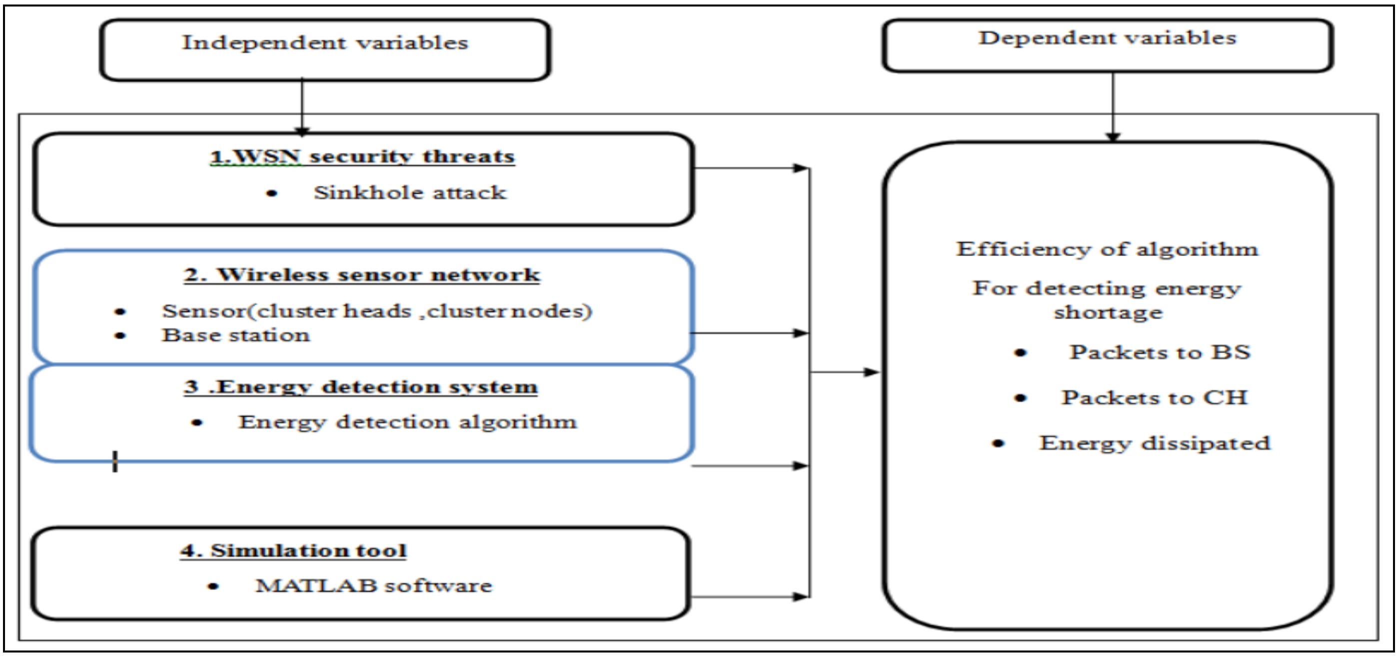

Fig 3 Conceptual Framework

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➢ *Improved LEACH Model*

This diagram indicate the data flow of an extended algorithm for dissipation of energy in wireless sensor networks. It have many of steps as shown in the figure 4.

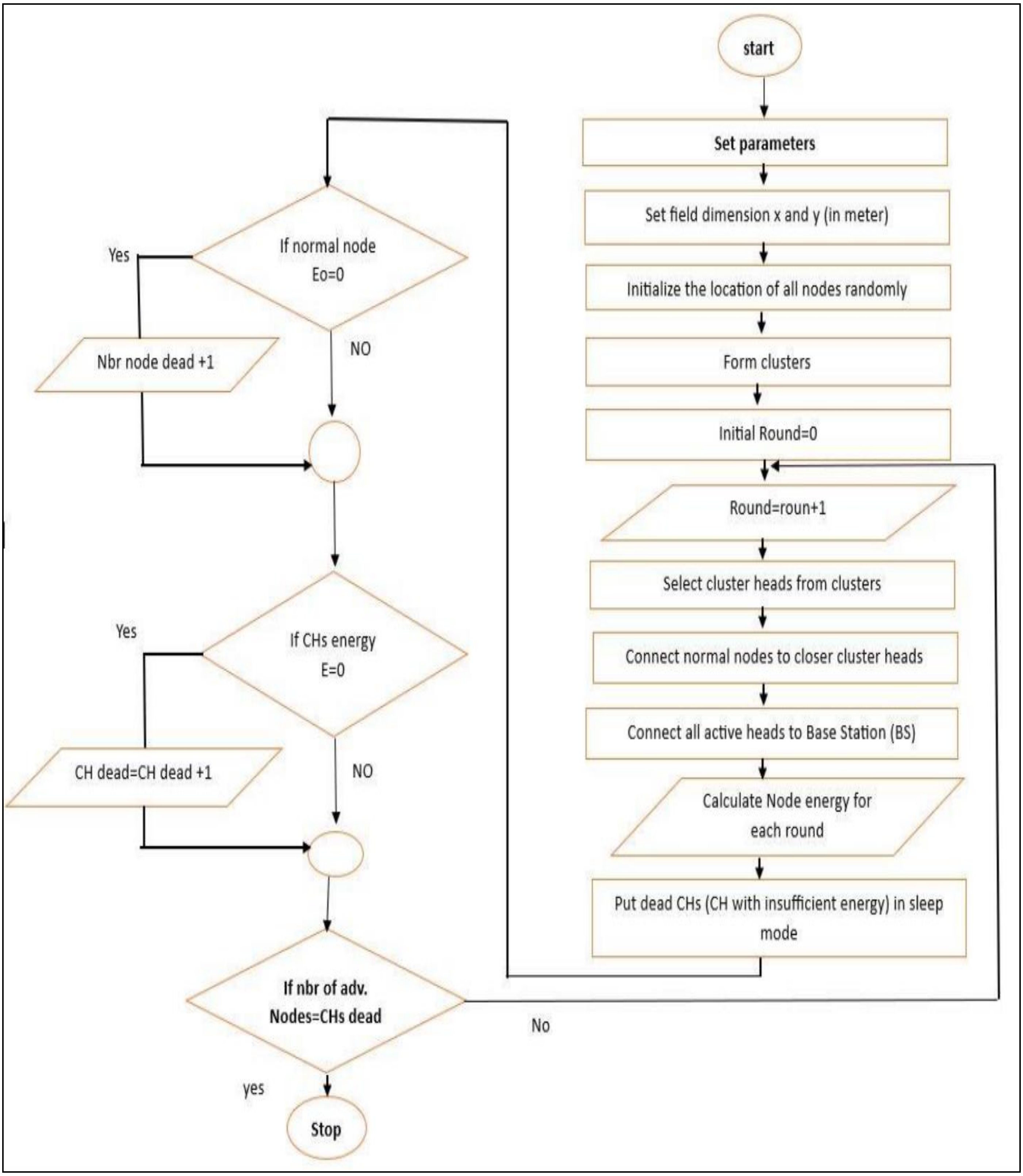

Fig 4 Data Flow Diagram.

➢ *Random Nodes Distribution*

During the creation of the field dimension, it is composed by of 30 nodes as shown in figure (5). The normal nodes and dead nodes are distributed randomly and the algorithm will form the clusters, elect cluster heads.

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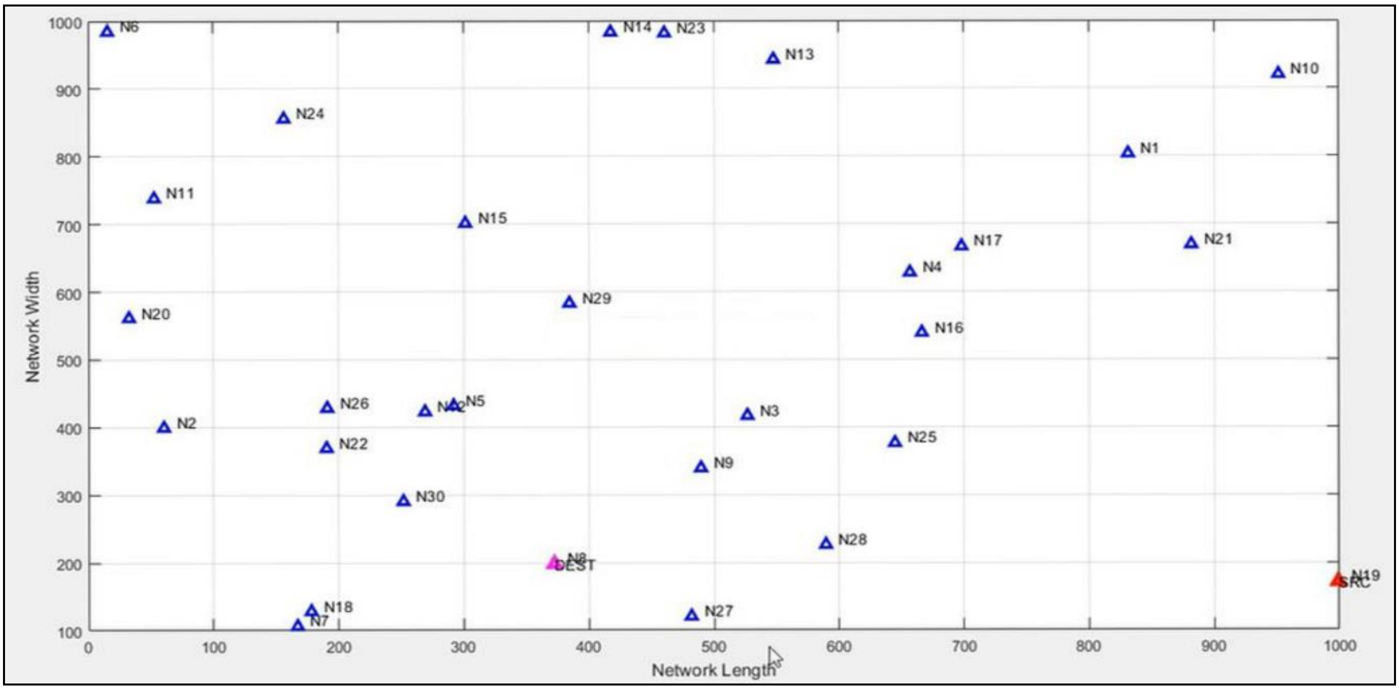

Fig 5 Random Nodes Distribution

➤ *Cluster Formation*

Clustering involves managing a limited number of logical groups composed of physical network nodes while the network operates. Clusters represent the logical groups. During the initial formation of the cluster, it can identify compromised nodes and remove them. The primary defense for secure clustering is the elimination of at-risk nodes during the cluster setup. The clustering process aims to minimize energy consumption for all sensors. Clusters are established based on the physical proximity of the nodes.Data transmission from a cluster to a base station is carried out by a Cluster Head (CH). In this configuration, energy consumption is relatively minimal. The use of clustering facilitates the rapid identification of routes since only the cluster heads communicate with the base station. The diagram below depicts how communication occurs within the cluster. It involves single-hop communication from node to cluster. The structure of the wireless sensor network consists of 30 sensor nodes that are connected to a single base station. These sensors are organized into three distinct clusters. This network design enables the sensors to use less energy while sending data within the network.

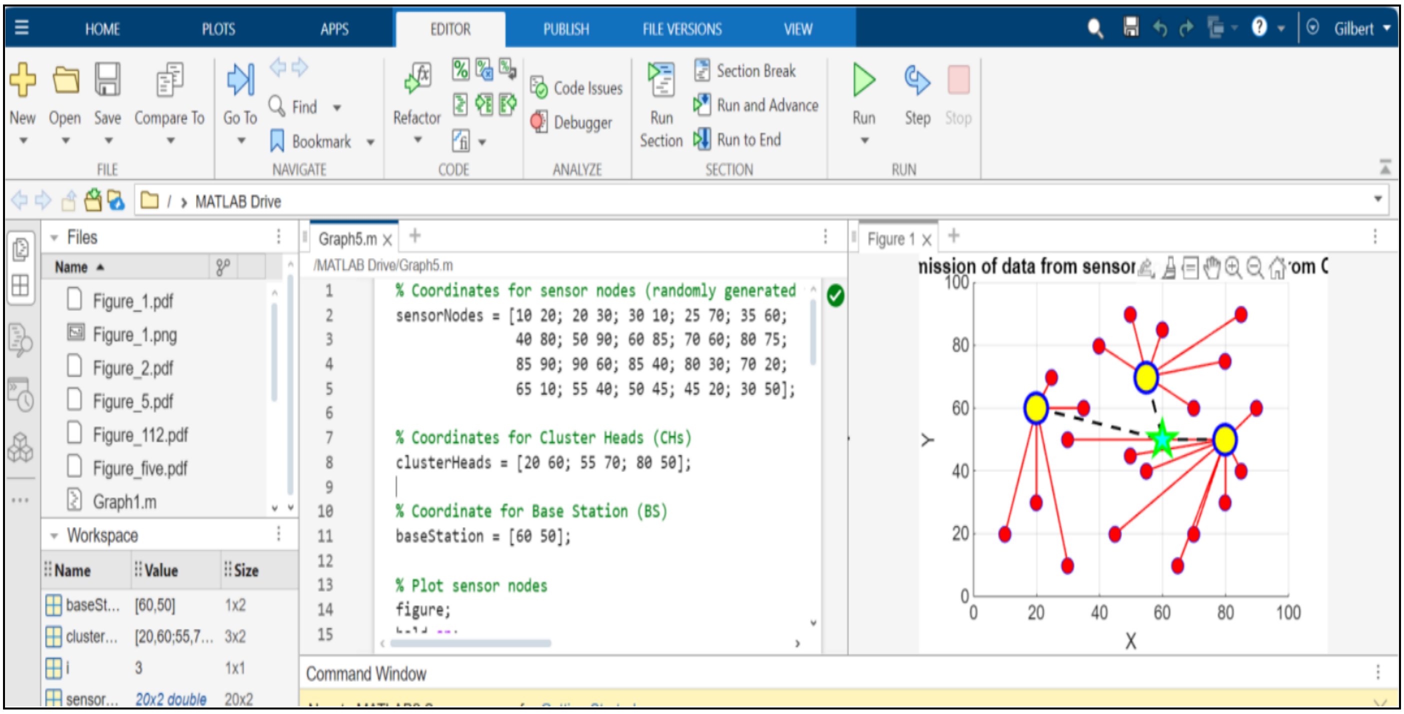
Fig 6 Cluster Formation

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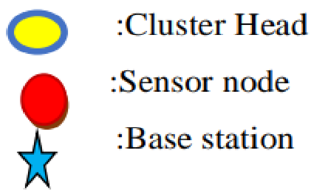

➢ *Extended Algorithm*

The proposed new adaptive algorithm is based on operating in rounds with three phases each:(1)sensor nodes clustering (2.)Cluster head election and (3)Calculation of energy dissipation.

- *Sensor Nodes Clustering*

In this phase, nodes are distributed randomly and organized themselves into clusters based on initial energy of each node as indicates in figure (5).

- *Cluster Heads Election*

In this phase, every node chooses a random number between 0 and 1 and compares it to doorway t(n) and if n<t(n), the node becomes a Cluster Head. In every round, the chosen CHs disseminate an advert message to all nodes in network of their new status. Based on the message received, every non-cluster head node can find out to which cluster it belongs to according to the received signal strength. Each node in cluster is allocated a fixed time slot by using time division multiple access protocol (TDMA).

- *Calculation of Energy Dissipation*

Since the main source of energy dissipation rely on CHs and Base Station communication, the importance of LEACH is to rotate CHs in order to avoid the quick drainage of energy for CHs.This approach increase the network lifetime. The energy dissipation is calculated in this way: Total_Energy(i)=S(i). E; temp_rand= (p/ (p*mod (r, round(1/p)))) *S(i). E/Total_Energy. Where temp_rand is the temporary round; p is the optimal election probability of node to become cluster; mod is S(i) is the nodes; E is the energy.

```
start
1.  Set parameters
2.  Set field dimension x and  y maximum (in meter)
3.  Set  x and y coordinates of the sink
4.  Set Sink to x and sink to y;
5.  Set number of nodes in field;
6.  S(i) represent nodes
7.  P is optimal election probability of node to become cluster PHASE 1.;
8.  Eo is the energy model (all values in Joules) and initial energy;
9.  ETX is the energy of transmission;
10. ERX is the energy at reception;
11. Eelct is the energy election which is equal to ETX and ERX;
12. Efs is Transmit amplifier type;
13. Emp is the amplifier;
14. EDA is energy data aggregation;
15. M is values for Heterogeneity percentage of nodes than are advanced;
16. a is alpha
17. G is the croup of nodes
18. Rmax is the maximum number of rounds
19. inputs number of nodes;
20. input the length of network;
21. input the width of network;
22. For ∀ S(i)
23. Calculate Do=sqrt(Efs/Emp);
24. Group of normal nodes is zero;
25. Initialize random election of Normal Nodes
26. If(temp_rndo>=m*n+1)
27. The energy of each node is S(i). E=Eo;
28. End if
29. Initialize clusterHead (CH)node to 0;
30. counter for CHs per round;
31. initialize cluster to 1;
32. calculate CH per cluster;
33. calculate number of dead nodes;
34. calculate the number of dead advanced nodes;
35. count for bit transmitted to base station and to cluster Heads
36. count for bit transmitted to base station and to cluster Heads per round
37. checking if there is a dead node
38. If node energy(S(i). E) <=0
39. Dead=dead+1;
40. Else If node energy(S(i). ENERGY==1)
41. Dead_advanced=dead_a+1;
else
42. If (S(i). ENERGY==0)
43. Dead_normal=deadn+1;
44. End if
45. Calculate Totol energy(i)=S(i).E;
46. election of cluster Head; PHASE 2
47. If (temp_rand<= (p/ (p*mod (r, round(1/p))))) *(S(i). E/Total_energy)
48. countCHs=countCHs+1;
49. packets_TO) _BS=packts_TO_BS+1;
50. PACKETS_TO_BS(r+1) =packet_TO_BS;
51. calculation of Energy dissipated PHASE 3
52. initialize Distance;
53. If(distance>do)
54. Calculate energy for each node[S(i). E=S(i). E-((EXT+EDA) *(4000)
    +Emp*4000*(distance*distance*distance*distance))];
55. Else
56. If(distance<=do)
57. Calculate energy dissipated [S(i). E=S(i). E-((EXT+EDA) *(4000)
+Efs*4000*(distance*distance))];
58. Endif
59.End
```

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- *Algorithm2.Sinkhole attack and energy lifetime extension*

This algorithm focuses on energy efficiency for increasing network lifetime that run on LEACH protocol in cluster based WSN. It is starting by the initial parameters, energy of normal nodes E0=0.5J, environment size 100m x 100m, number of node 100, maximum number of round RMAX=4000, data aggregation energy.

EDA=5*0.000 000 001; active cluster head and sleep cluster head are elected randomly, optimal election probability of node to become cluster p=10%, energy model for transmission and reception ETX=ERX=50*0.000 000 001.

The step number one was to set the location in random way, then choose the strongest node as acting as CH after that will choose active CHs and put the remain particular node in dead mode. For every round, will compute the node energy dissipated by detecting 1st energy dissipated in its round then edit all nodes of energy, all former procedures will iterate the most of CHs are died.

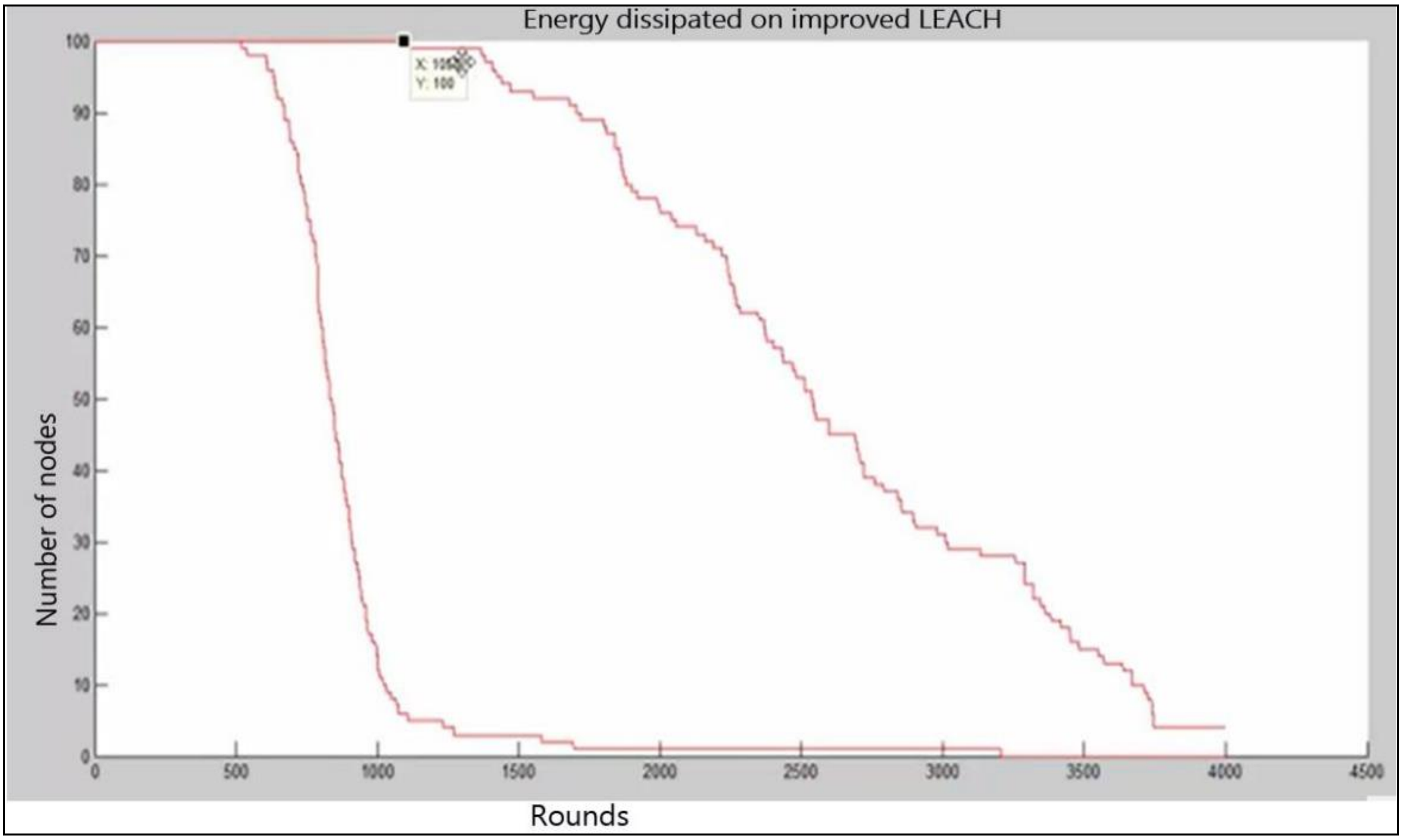

Fig 7 Energy Dissipation by Rounds Comparison

The simulation results as shown on graph1 indicates the energy dissipated per round on ordinary LEACH is too quick in 4000rounds.The graph2 indicates that the energy dissipation improved LEACH is lasting dramatically. The simulation indicates that the energy dissipation has increased almost about 300% which a good results for algorithm efficiency. This gives a good performance as the network lifetime longer than before.

V. CONCLUSION

In summary, the main objective of this project was to raise the lifetime of WSN using cluster-based routing protocol namely LEACH. As discussed in the previous chapter, we developed an algorithm that effectively extends the lifetime of the WSN on the campus. Ultimately, we found that existing algorithms are not effective and their energy efficiency is significantly lacking. Furthermore, we conclude that the proposed algorithm successfully increases the lifetime of the campus's wireless sensor network.

RECOMMENDATION

- *IPRC-Huye Campus.*

The developed algorithm extends the network's lifespan. I suggest that IPRC-Huye Campus adopt this algorithm for their wireless sensor network to impove its performance.

- *Future Researches*

This research was carried out solely at the IPRC-Huye campus. Future researchers should explore the other campuses in Rwanda as well as other institutions that implement wireless sensor networks. They may focus on improving security protocols and look into expanding the algorithms related to machine learning and artificial intelligence.

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