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Integrating the Syracuse Algorithm with K-MEAN: A Comprehensive Approach to Energy Optimization in Wireless Sensor Networks

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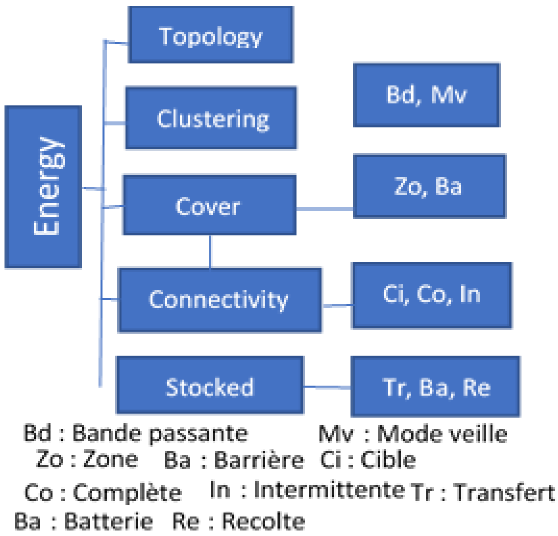
Abstract: ***In deploying a sensor network in a challenging environment, it is crucial to consider energy consumption to ensure an extended network lifespan. Since the inception of sensor networks, researchers have proposed various energy-saving solutions outlined in the introduction. In our study, we introduce a novel approach for cluster formation and positioning of clusters and base stations to minimize energy consumption in implementing clusters using the K-MEAN algorithm. Through simulation, we demonstrate that the Syracuse-WSN algorithm significantly outperforms the traditional K-MEANS algorithm in conserving energy consumption.***

Keywords: Energy, K-MEAN, Syracuse, WSN, SHEM

I. INTRODUCTION

The significance of Wireless Sensor Networks (WSNs) [1], [2] is widely acknowledged in various fields today. A wide variety of sensor types, such as pressure, position, vibration, flow, humidity, light, ultrasound, accelerometers, gyroscopes, and temperature, are readily available [4].



[Fig.1: Energy Management in Wireless Sensor Networks[1]]

These sensor nodes can capture, process, and wirelessly transmit data related to various environmental factors, including vibration, temperature, humidity, water or air quality, soil composition, pressure, noise, light, and specific characteristics of an element like size, weight, location, direction, and speed [24] [27]. These networks typically consist of tens to thousands of unattended wireless nodes, which can be easily deployed in diverse environments with specific node functions [16][17][18][25]. The sensor nodes are typically battery-powered [6][7], and it is often challenging to recharge or modify nodes with limited battery life [8][9][10].

Therefore, energy conservation is a critical consideration to ensure the sustainability of these networks. The energy management in WSNs can be outlined as depicted in Figure 1.

In wireless sensor networks (WSNs), network clustering is a widely used technique for energy replenishment. However, traditional clustering methods have limitations as they do not consider the self-organizing and dynamic topology inherent in WSNs [3][5][21][22][28][29]. These limitations can lead to an uneven distribution of cluster heads, impacting the overall energy consumption of the network. For example:

- Hierarchical Low Energy Adaptive Clustering (LEACH) [23][30][31][32], [24] is a hierarchical clustering-based protocol that organizes the network into clusters using both distributed and centralized schemes. Cluster heads are chosen based on their receiving signal strength and rotate after each round to distribute the energy consumption across the network evenly.
- Hybrid Energy Efficient Distributed Clustering (HEED) [26] improves upon LEACH, particularly in the election of cluster heads (CH), by not using a random approach for CH selection. The cluster formation is based on a hybrid combination of two parameters.

One parameter depends on the residual energy of the node, and the other parameter is the intra-cluster communication cost. In HEED, elected CHs have relatively high average residual energy compared to member nodes.

- The TEEN protocol is a hierarchical clustering protocol known as Threshold-sensitive Energy-efficient Sensor Network. It employs a multi-level hierarchical concept to place sensors in clusters, each managed by a Cluster Head (CH). The sensors send their detected data to their respective CH, which aggregates the data and forwards it to the next level CH, ultimately reaching the sink. The main idea behind the TEEN network architecture is based on hierarchical clustering, where nodes form clusters and this process continues until reaching the sink.

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- The K-means algorithm addresses the gap left by traditional algorithms and has three main steps:

- Initialization: The algorithm initializes cluster formation with the WSN. If a WSN has n nodes divided into k clusters, k out of n nodes are randomly selected as CHs. Each of the remaining nodes determines its nearest CH based on Euclidean distance.

- Assignment step: After assigning each node to one of the k clusters, the centroid of each cluster is calculated. In a two-dimensional space, the centroid of a cluster is calculated as a virtual node located at the center position of the cluster.

- Center registration step: Once the clusters are formed, an ID number is assigned to each node in a cluster based on the distance from the centroid, with a smaller number assigned to the closest node. The ID number of a node indicates the order in which it will be chosen as CH.

- The K-means algorithm is used in Wireless Sensor Networks (WSN) for cluster formation. The following algorithms are discussed in the literature:

- FC-KMEANS: Proposed in [11], FC-KMEANS allows clustering by fixing some cluster centers based on real conditions, while seeking the most appropriate cluster centers for the rest and the best distribution of data between clusters.

- ISBFK-means: In [12] [13], ISBFK-means, based on influence space, is introduced. The influence space divides the dataset into several small regions before implementing K-MEANS.

- GBK-means: Described in [14], GBK-means involves cluster centers competing to attract the largest number of similar targets or entities to their cluster. The centers constantly adjust their positions to minimize distances with the maximum possible data, relative to other cluster centers. This algorithm is named the game-based k-means algorithm (GBK-means).

- GAK-means [15]: This work presents a unique combination of K-means and an improved genetic algorithm (GA) to reduce energy consumption and extend network lifetime. The GA-K means aims to minimize energy consumption by determining the optimal number of cluster heads (CH) using an improved genetic algorithm (GA), where the number of CH also indicates the number of clusters in the network. Additionally, [19][20] provides the limit of K-mean.

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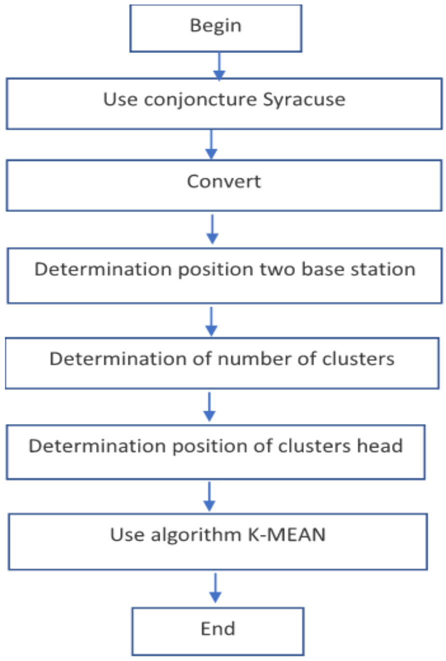
II. PROPOSED METHODOLOGY



[Fig.1: Block Diagram]

III. ALGORITHM

Algorithm 1: The main principles of our algorithm for a fixed network

a. Use of the Syracuse conjuncture

b. Convert the length of the field into an integer

c. Determination of the position of the two base stations relative to the size of the field

d. Determination of the number of clusters based on the number of sensors to deploy

e. Determination of the possible positions of the Heads clusters

f. Application of the K-MEAN algorithm

g. The CHs communicate with the two central base stations.

Algorithm 2: the Syracuse equation

The authors of [8] emphasize that "determining the sufficient number of guards to cover the entire art gallery is an NP Hard optimization problem". We use the Syracuse equation to determine the number of clusters and clusters heads.

$$f(x) = \begin{cases} \frac{x}{2}, & si\ x\ est\ pair \\ 3x+1, & si\ x\ est\ impair \end{cases}$$

We will modify this algorithm with the following expression:

$$f(x) = \begin{cases} \frac{x}{2}, & si\ x\ est\ pair \\ (3x+1)/2, & si\ x\ est\ impair \end{cases}$$

Algorithm 3: Determining the number of clusters or cluster-head N is the number of sensors to be deployed on the ground.

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```
Function syracuse(N):
Begin
   u = N
   n=0
   While (u! = 1) do
 If (u%2) ==0 :
u = u//2
Else
u = (3*u+1)//2
endif
n=n+1
   endwhile
   return n
end
```

Algorithm 4: Determining the position of the two base stations based on the size of the terrain

```
N is the length of the deployment terrain
Function search (N: integer)
Begin
 max_time=0;
 for n from 1 to N do
flight_time= syracuse(n)
if flight_time>max_time then
max_time:=flight_time;
Nmax:=n;
Endif
     endfor;
return(Nmax)
End
```

Algorithm 5: Determination of possible positions of cluster heads based on the number of sensors to deploy.

```
(N number of sensors to deploy)
Tps_vol=[]
for nb in range(2, tps_vol_syracuse(N)):
if (tps_vol_syracuse(nb) not in tps_vol):
tps_vol.append((nb, tps_vol_syracuse(nb)))
       endif
endfor
```

IV. RESULT AND DISCUSSION

A. Parameter of Simulation [25]

Parameter	Value
Initial energy	2J
E_{elec}	50nJ/bit
E_{amp}	0.0013pJ/bit/m^2
Data packet size	4000 byte
Energy taken for aggregation (Epa)	5nJ/bit/signal

The transmitter consumes:

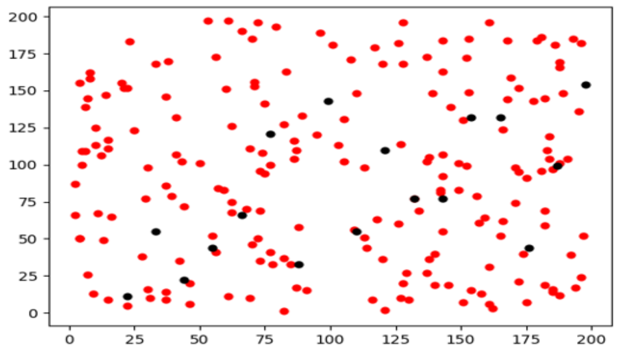
$$E_t(k,d) = E_{elec} * k + E_{amp} * k * d^2$$

and the receiver consumes:

$$E_r(k) = E_{elec}(k) = E_{elec} * k$$

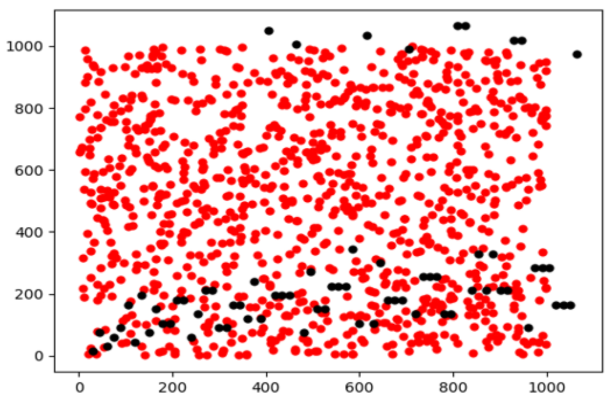
B. Simulation

We utilized multiple terrain sizes to display diverse base station positions while maintaining a consistent number k of clusters based on the number of sensors. When deploying 200 sensors, the positions of the cluster heads are determined as depicted in the diagram below (figure 2). These positions seem to be distributed in such a way that they cover the entire terrain.



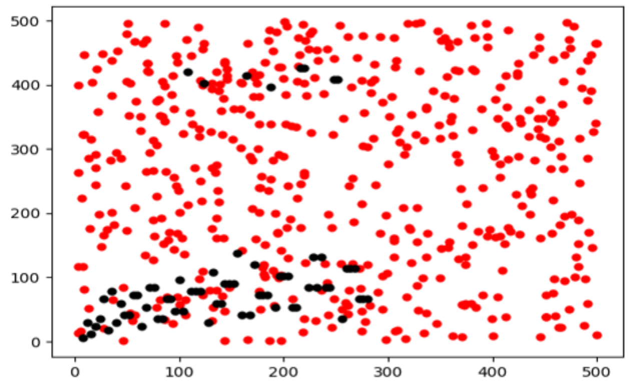
[Fig.2: Deployment of 200 Sensors]

For several 1000 sensors to deploy, we obtain the positions of the cluster heads according to the following diagram in Figure 3.



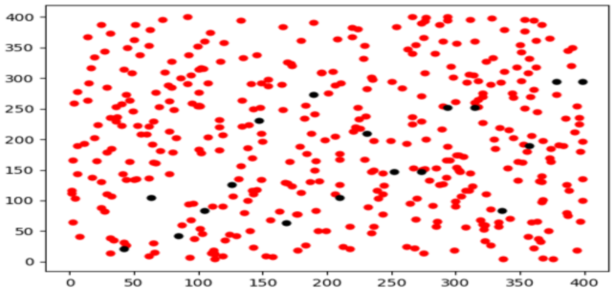
[Fig.3: Deployment of 1000 Sensors]

These positions show sparse areas and do not seem to be a good alternative. For some 500 sensors to deploy, we obtain the positions of the cluster heads according to the following diagram Figure 4.



[Fig.4: Deployment of 500 Sensors]

This configuration seems to give the same result as for a thousand. For several 400 sensors to be deployed, we obtain the positions of the cluster heads according to the following diagram figure 5.



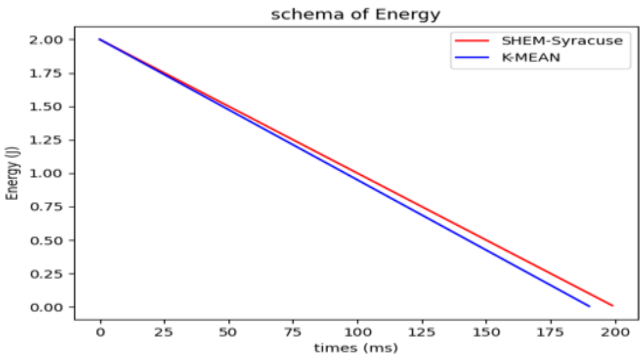
[Fig.5: Deployment of 1000 Sensors]

This diagram encompasses the entire 200-unit terrain, which appears beneficial for avoiding sparsely populated areas.

We plan to use an average of 200 to 400 sensors to compare energy consumption between our Syracuse-WSN algorithm and the K-MEAN algorithm.

C. Analysis of Energy Consumption

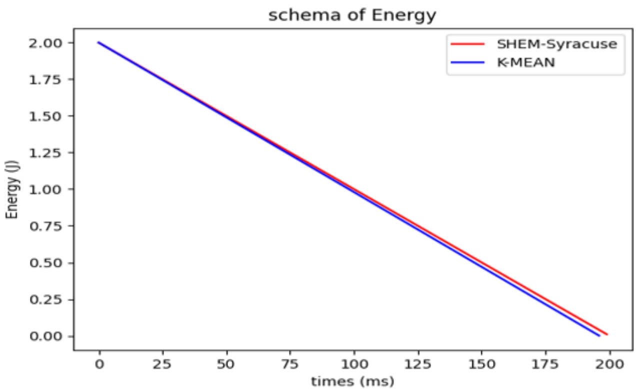
- Using 200 sensors, and comparing our algorithm to the basic K-MEAN algorithm, we obtain the following Figure 6.



[Fig.6: Schema of Energy]

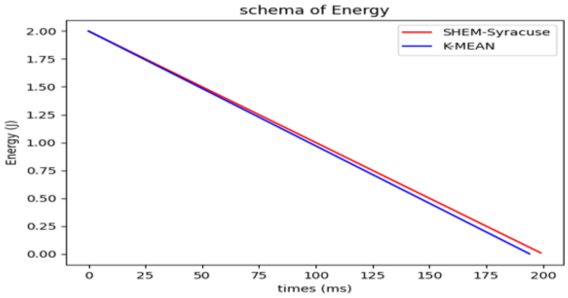
The data indicates that our algorithm is more energy-efficient than K-MEAN.

When we replicated the study with 300 sensor nodes, the resulting diagram demonstrated our solution's superior energy management capabilities compared to K-MEAN (Figure 7).



[Fig.7: Schema of Energy]

- We will repeat the test using 400 sensor nodes to compare energy management between our solution and the K-MEAN solution.



[Fig.8: Schema of Energy]

Through the figure below (Figure 8), we find that our algorithm manages energy consumption better by giving a longer network lifetime than K-MEAN.

V. CONCLUSION

Our Syracuse-WSN algorithm enhances the energy efficiency of sensor networks, utilizing the K-MEANS algorithm to determine the optimal number of clusters. This improvement is achieved by forecasting cluster formation through mathematical calculations based on the number of nodes to be deployed and by specifying the positions of the two base stations. In addition, our algorithm enhances K-MEANS by identifying potential positions for the cluster heads. Simulation results demonstrate that our algorithm outperforms the K-MEANS algorithm in terms of energy consumption, as it eliminates the need for excessive energy expenditure in searching for and forming cluster heads.

APPENDIX

It is optional. Appendixes, if needed, appear before the acknowledgment.

ACKNOWLEDGMENT

It is optional. The preferred spelling of the word "acknowledgment" in American English is without an "e" after the "g." Use the singular heading even if you have many acknowledgments. Avoid expressions such as "One of us (S.B.A.) would like to thank ... ." Instead, write "F. A. Author thanks" Sponsor and financial support acknowledgments are placed in the unnumbered footnote on the first page.

DECLARATION STATEMENT

I must verify the accuracy of the following information as the article's author.

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