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Evaluation of energy consumption in selected clustering techniques using experimental approach

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Abstract
This study focuses on wireless sensor networks, which play a vital role in modern life. A key challenge in these networks is energy consumption, which is examined in this research. Three clustering techniques were evaluated using networks with 150 and 250 nodes. The performance of these techniques was compared based on different velocities (m/s) and the percentage of energy depletion in the network. The findings indicate that among the three methods, the Fuzzy clustering technique proved to be the most energy-efficient.
Keywords: Energy Consumption, Clustering, K-Means, Fuzzy, SOM.

INTRODUCTION

Wireless sensor networks are widely used in the modern industrial era to monitor various environmental and physical conditions, such as pressure and temperature. These networks operate by transmitting data collaboratively through the system to a central location (Sasikumar & Khara, 2012). Their significance is undeniable, as they are implemented in diverse applications, including parking lots, automated doors, construction sites, industrial environments, and security systems. For instance, farmers utilize wireless sensor networks to monitor field temperatures, while prisons employ them for surveillance. The wireless sensor networks are also used by businesses settings such as in industrial context for testing the quality, monitoring defective products; in retail by observing the customers and so on.

The primary objective of wireless sensor networks is to detect specific events or estimate physical parameters. They play a crucial role in both civilian applications, such as healthcare and agriculture, and military operations, including target tracking and fire hazard detection (Prabhu & Sophia, 2011).

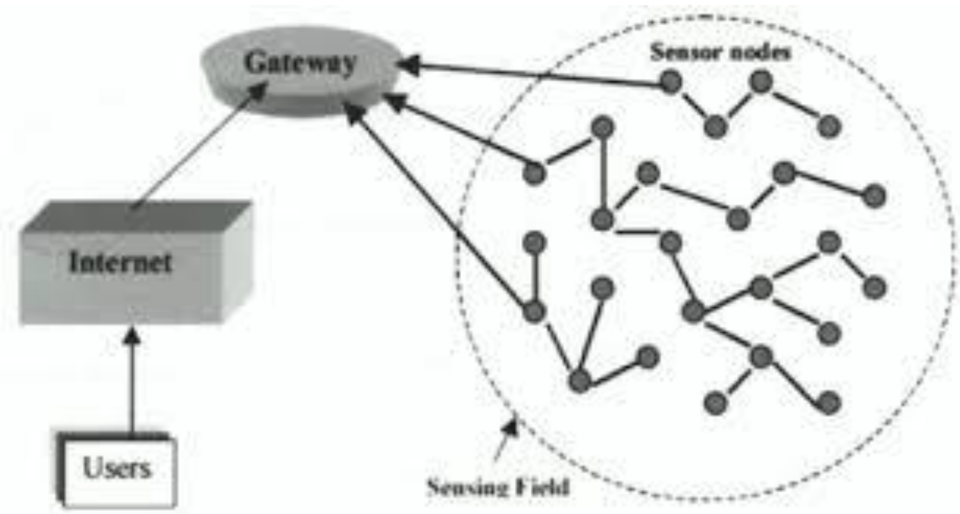

Figure 1: Wireless Sensor Network

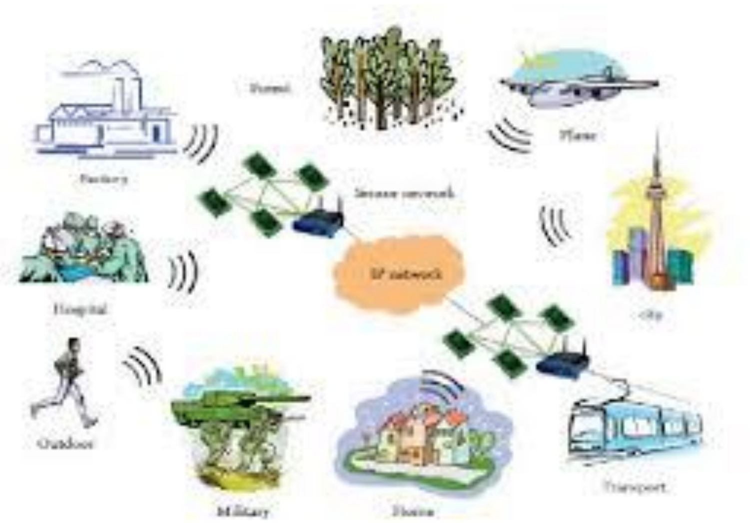

Figure 2: Wireless Sensor Network Uses

Wireless sensor networks come in various types, categorized based on their specific applications. These networks also differ in how they utilize resources, particularly energy. In general, they gather data and transmit it to a single or multiple sink nodes (Lindh & Orhan, 2009). While most sink nodes are stationary, some may need mobility when integrated with mobile devices such as cell phones. In such cases, optimizing communication costs and network overhead becomes a crucial challenge, prompting efforts to develop efficient solutions tailored to network requirements.

Traditionally, wireless sensor networks are characterized by low cost, energy constraints, small autonomous nodes, and distributed deployment for sensing or monitoring. Multi-hop routing is commonly employed for data communication and transmission (Kori & Baghel, 2013). The typical architecture of a wireless sensor network includes source nodes and sink nodes. Source nodes generate data using various sensors, such as those for radiation, humidity, or temperature, while sink nodes collect this data. Additionally, intermediate nodes may assist in transmitting information between source and sink nodes. Network design plays a significant role in determining the system's efficiency, robustness, and processing capabilities. Different network architectures impact data routing and overall performance. For instance, in highly dense wireless sensor networks, selecting an appropriate topology is essential to meet operational requirements. A commonly used sensor network topology is outlined below.

Clustering

To minimize energy consumption, a clustering and node redundancy approach has been extensively analyzed. In the clustering method, sensor nodes are grouped into clusters based on a specific division strategy (Thangavelu & Pathak, 2014). This approach helps optimize resource utilization and enhance network efficiency.

K-Means Based Wireless Sensor Network

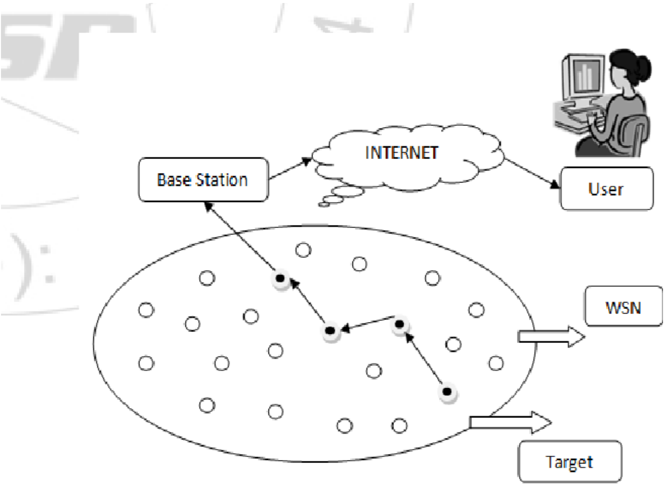

Figure 3: K-Means based Network

Fuzzy Method Wireless Network

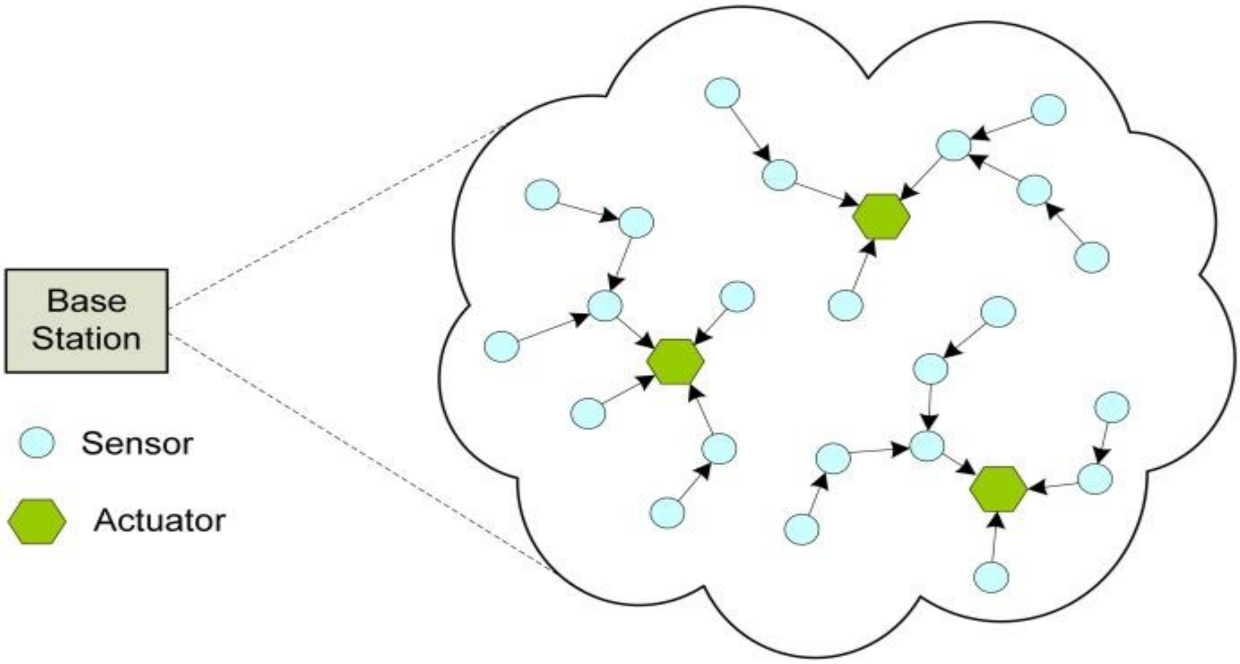

Figure 4: Fuzzy Method Wireless Network

SOM Wireless Sensor Network

In a clustering approach, the cluster head serves as the leader of each cluster, responsible for aggregating and transmitting collected data to the base station (Enzinger, 2012). One key advantage of clustering is its ability to minimize data duplication by transmitting only relevant information. This approach also reduces overall data transmission, thereby lowering resource consumption. An efficiently designed clustering system enhances network stability and extends its lifespan by decreasing network traffic and optimizing energy usage.

Energy Consumption

Energy consumption occurs in all phases of the protocol, beginning with the election of cluster heads. Following this election phase, data transmission takes place, where sensor nodes send their collected data to their respective cluster heads. During this process, energy is expended in both receiving and transmitting data (Orhan & Lindh, 2010). A comparison between HCR and LEACH reveals that networks with a higher number of cluster heads consume less energy compared to those with fewer cluster heads. This is because distributing the workload among more clusters reduces the overall transmission burden on individual nodes, leading to improved energy efficiency.

SIMULATION RESULTS

In this study, we utilized networks with 150 and 250 nodes to compare the energy consumption of various clustering techniques, including Fuzzy Clustering, Self-Organizing Maps (SOM), and K-Means. The results were analyzed based on the relationship between velocity (measured in m/s) and the percentage of energy decay in the wireless sensor network. To evaluate cluster characteristics, several key metrics were considered, including the number of single-node clusters, cluster size variance, maximum cluster size, and average cluster size. The findings are summarized in the following table.

Table 1

Simulation Results

S. No	Parameter	Value
1	Clustering Technique	K-Means, Fuzzy, SOM
2	Update time	2 Sec
3	Sink velocity	50-450 m/s
4	Update distance	50 m
5	Network length	1500 * 1500 m^2
6	No. of Nodes	150 and 2500
7	No. of Clusters	20

The simulation results indicate that average cluster size is affected by network density and the transmission range of sensor nodes. An optimal network should be appropriately sized—neither too small, as it would be cost-inefficient, nor too large, as it could become difficult to manage, leading to increased transmission delays and message collisions. The analysis was conducted separately for networks with 150 and 250 nodes to assess their performance under different clustering techniques.

Table 2

Comparison of Energy Consumption for 50 Nodes of Three Clustering Technique

Velocity m/s	% Decay Rate of Energy		
	K Means	Fuzzy	SOM
50	1.2	1.3	1.9
100	2.3	2.7	2.9
150	3.6	4.1	4.1
200	5.1	4.9	5.1

250	6.1	5.3	6.1
300	7.2	6.1	6.7
350	7.8	6.3	6.9
400	8.2	7.1	7.3

The table above presents a comparison of energy consumption for a cluster technique based on 50 nodes. The results indicate that the energy decay rate increases with higher velocities (m/s). For instance, in the K-means-based cluster network, the energy decay rate starts at 1.2 for 50 m/s and rises to 8.2 at 400 m/s. In the Fuzzy cluster network, the decay rate starts at 1.3 for 50 m/s and increases to 7.1 at 400 m/s. For the SOM-based network, the decay rate is 1.9 at 50 m/s and increases to 7.3 at 400 m/s. Overall, the comparison reveals that the Fuzzy cluster technique is the most efficient in terms of having the lowest energy decay rate among the three networks.

Table 3

Comparison of Energy Consumption for 100 Nodes of Three Clustering Technique

Velocity m/s	% Decay Rate of Energy		
	K Means	**Fussy**	**SOM**
50	1.3	1.6	2.2
100	2.6	2.6	3.2
150	3.5	3.3	4.3
200	4.8	4.5	5.1
250	5.9	5.3	6.2
300	7.0	5.9	7.3
350	7.2	6.1	7.5
400	7.6	6.7	8.2

The comparison of energy consumption for 100 nodes across three cluster techniques is presented. The results indicate that at 50 m/s, the K-means energy decay rate is 1.3, which increases to 7.6 at 400 m/s. For the Fuzzy technique, the energy decay rate is 1.6 at 50 m/s and rises to 6.7 at 400 m/s. For SOM, the decay rate starts at 2.2 at 50 m/s and increases to 8.2 at 400 m/s. Overall, the comparison between the 50-node and 100-node setups reveals that the Fuzzy technique is the most effective, as it exhibits the lowest energy decay rate at various velocities.

CONCLUSION

The aim of this study was to compare three types of wireless sensor networks, namely K-means, Fuzzy, and SOM. The experiment was conducted using networks with 50 and 100 nodes. The results indicate that, among the three clustering techniques, the Fuzzy method demonstrated superior performance with a lower percentage of energy decay compared to the other two approaches. Based on these findings, the study recommends the adoption of the Fuzzy method for energy-efficient network operation.

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