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A Data Transmission Scheme Using K-Means and Fuzzy Logic for IOT Sensor Based Forest Fire Detection System

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ABSTRACT

Forest fires are natural disasters and effective mitigation of these fires require early warning systems. Deployment of sensors that are robust against environmental conditions, collection of sensor data in an energy efficient manner and at real time at the central server, and accurate detection of fire's existence are all critical elements for implementing such systems. In this paper, we focus on second issue which is energy efficient routing of sensor data in a Internet-of-Things (IoT) sensor network that is deployed for forest fire detection. A Fuzzy-based Cluster Head selection technique for WSN in detecting forest fire is presented. In the proposed scheme, the nodes are divided into clusters using K-means clustering and then the cluster heads are determined by using a fuzzy logic scheme. Unlike traditional parameters, distance from the centroid and the remaining energy levels are used as parameters to select the cluster head. Simulation tool is used to implement the proposed technique. The simulation results suggest that the proposed cluster head selection approach outperforms the existing schemes.
Key words : Forest Fire, Fuzzy Logic, IoT, K-means, WSN

1. INTRODUCTION

Forest fires are natural disasters that cause widespread economic, ecological, and environmental harm around the globe. Therefore, prevention of forest fires or mitigation of these fires by taking effective measures are important to avoid such harms. Conventionally, forest fires are spotted using watchtowers, which are ineffective since they rely on human surveillance. Several forest fire detection approaches, including satellite image processing methods, optical sensors, and digital camera-based systems have been adopted in the current literature. However, there are various disadvantages, including inefficiency, power consumption, latency, accuracy, and implementation cost. Deployment of Internet-of Things (IoT) sensor nodes such as temperature, smoke, light, or humidity sensors in a large forest area, which appears to be one of the most effective forest fire detection systems [1],[2].

IoT Sensor Networks (ISN) are used for essential applications in distant and unsupervised situations. In the ISN, sensor nodes detect information, process it, and send the processed data to the sink or destination node. A base station (BS) or a central node monitors and controls all of the nodes [3],[4]. IoT nodes favor energy-efficient approaches because of their limited energy and the need for using them for a long time once they are deployed over a forest region which might pose difficulty for accesibility. Due to a lack of energy sources, it is difficult to keep the IoT sensor nodes charged. Hence, it is critical to make effective use of these nodes. IoT nodes send and receive signals from one another all the time while consuming energy. Clustering is one of the approaches for energy efficient transmission of sensor data towards central node because it conserves energy by limiting communication to a few nodes, extending the network lifespan [5]. Cluster creation in a dynamic environment is a critical problem in hierarchical routing because it affects energy dissipation [6],[7]. In this paper, we propose to use K-means and Fuzzy Logic based data transmission for IoT sensor nodes. Specifically, the major contribution of this paper is as follows:

1. The clustering concept can be used to manage frequent contacts between IoT nodes deployed for forest fire detection. These nodes are clustered using K-Means machine learning algorithm.

2. Among the cluster members, we apply Fuzzy Logic to choose the cluster leader. Fuzzy logic is a decision-making approach that employs more than one parameter. The battery level and distance from the centroids are used in this article. If the battery is less than half full, the node will not vote in the election. The goal of this strategy is to extend the node's lifespan.

The rest of the paper is structured as follows. Section II explains the overall system model used for IoT sensor nodes deployed in a forest for fire detection. Proposed methodology is presented in Section III. Simulation model and results are given in Section IV. The paper is concluded in Section V.

2. SYSTEM MODEL

For forest fire detection, the IoT sensor nodes can be deployed to monitor physical or environmental factors such as temperature, humidity, light, smoke, and so on. A typical ISN is made up of hundreds or even thousands of sensor nodes that are linked together and communicate with one another over a wireless channel. Compared to conventional forest fire detection methods, use of ISNs include advantages such as precision, adaptability, cost effectiveness, and simplicity of installation [8].

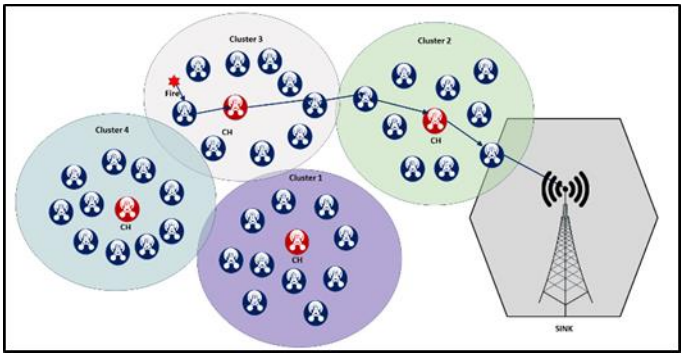

Figure 1: Clustering and cluster heads in a IoT sensor network deployed for forest fire detection

We consider a generalized scenario of IoT sensor network as in Figure 1, which can be deployed in a forest for early detection of fire. We assume that sensor nodes are immobile. One of the sensor nodes is chosen as a Cluster Head (CH) in order to reduce the communication cost among source and destination (central node or monitoring station) nodes [9]. The sensor nodes are separated into levels on the basis of battery level and distance from the centroid. One of the nodes in each cluster is then selected as the CH. The CH then receives data from other source nodes and delivers it to the CH at the next level [10],[11]. As a result, the node with the most considerable residual energy is the CH at a given level. The scheme, however, is sophisticated, and higher-level CH's require more energy than lower-level CH's. The probability of choosing the CH is calculated using Fuzzy logic [12].

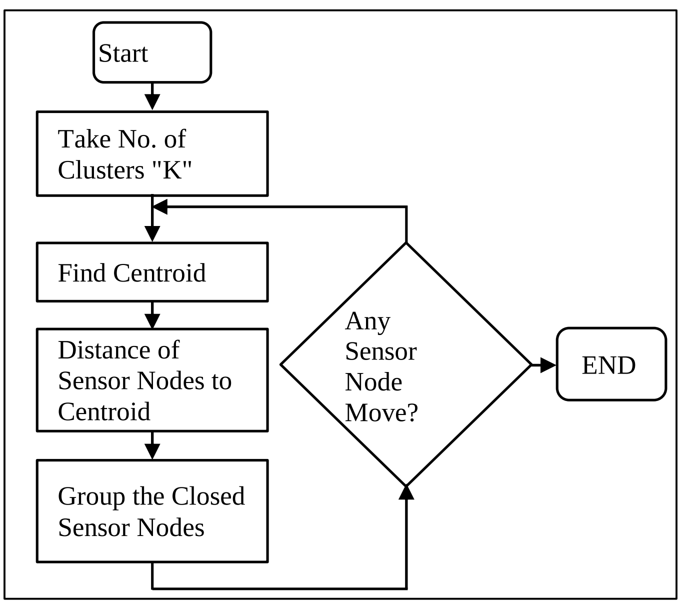

Figure 2: Flowchart of the K-means algorithm for cluster formation

3. PROPOSED DATA TRANSMISSION MODEL FOR FIRE DETECTION

Our approach for transmitting sensed data towards central node utilizes two methods: K-means in machine learning and Fuzzy Logic. The term clustering can be utilized to manage frequent communication between nodes. To partition sensor nodes into clusters, K-means machine learning approach is utilized. It is a technique for automatically dividing data into smaller clusters or subsets. It groups data with statistically comparable characteristics together. An element can only belong to one cluster. The value that represents the cluster is the cluster center [13]. The flow chart of the K-Means clustering algorithm is given in Fig. 2. At starting, the algorithm takes the number of clusters "K." Then, "K" points are randomly selected for centroids. Based on centroids, the sensor nodes are grouped together. In the next step, central points are chosen to indicate the new centroids. The sensor nodes grouped themselves according to the new centroids, and this process keeps iteration until no change in the group occurs. The K-Means algorithm follows the expected maximization to address the problem. There are E steps that involve allocating the data points to the nearest cluster, and M steps that calculate the centroid of each cluster. The objective function "J" is given as,

$$J = \sum_{i=1}^{m} \sum_{k=1}^{K} \omega_{ik} \left\| x^i - \mu_k \right\|^2 \qquad (1)$$

where $\omega_{ik} = 1$ for data $x_i$if it belongs to cluster K; otherwise, $\omega_{ik} = 0$ and μ_k is the centroid of x_i's cluster. The distances from centroids are calculated using

$$dist = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2} \,. \qquad (2)$$

The K-means algorithm's operating mechanism begins with the selection of k items at random to represent the centroid or mean of the center point of each cluster. The remaining items are assigned to the clusters with which they are most comparable, based on their distance from the cluster mean values. The average value of each cluster is then computed, and the fresh cluster centers and object center distances are checked once again. The algorithm is shifted indefinitely until there is no change.

The Fuzzy logic is a strategy that employs more than one parameter to determine which node in a cluster is the cluster leader. The battery level and the distance from the centers are used in this article as shown in Table 1. If the node's battery is less than 50% charged, it will be unable to participate in the selection. The goal of this strategy is to extend the life of that node.

Parameter	Cluster Head Election Percentage		
	Description	***Range***	***Percent***
Distance	Distrance from centriod	0 – 100	50 %
Battery	The ramaining battery level	51 - 100	50 %

Table 1: Criteria for selection of cluster head in Fuzzy Logic step

4. SIMULATION MODEL AND RESULTS

A Matlab based simulation tool is used to simulate and obtain the result of the proposed method. The proposed technique is simulated and experimented for network size of 100 sensor nodes that are shown in Fig. 3. In the first phase, the sensor nodes are grouped into clusters by employing the K-means clustering method. Consequently, CHs are elected based on Fuzzy logic algorithm with two fuzzy descriptors such as remaining battery level, distance to centroid of clusters. Every sensor is illegible to participate if its battery level is higher than 50%, otherwise, it can not participate. Fig. 4 represents clusters in different colors, cluster heads, sensor at fire location and base station (monitoring station). As two fuzzy metrics have been considered, two main rules have been applied. The distance from the cenroid is obtain by using (1). In this experiment, 100 sensor nodes are uniformly deployed over the area of (x=-10000, y=-10000) and (x=10000, y=10000). The base station is located at the center (x=0, y=0). For battery level, a simple energy model from 0% to 100% is considered.

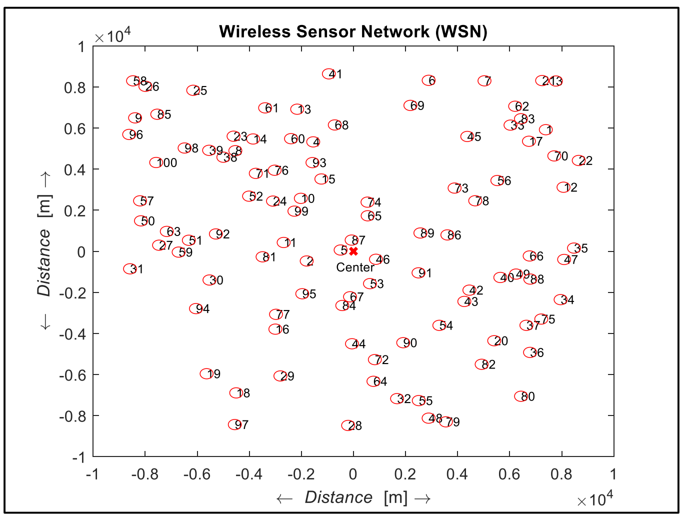

Figure 3: A Snapshot of distribution of sensor nodes

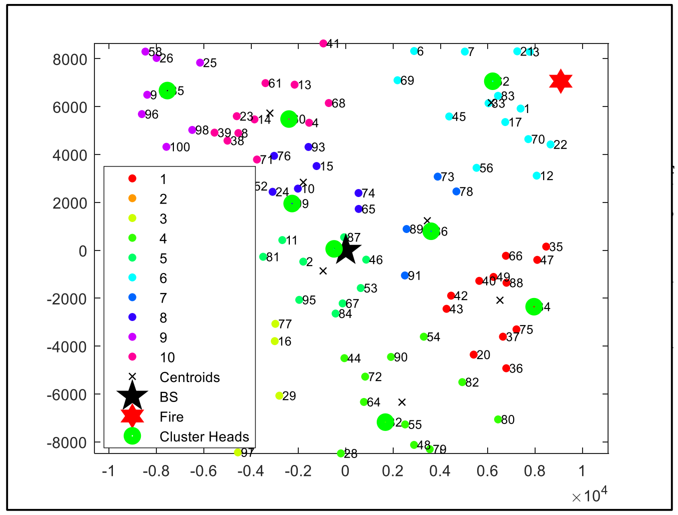

Figure 4: A Snapshot of distribution of sensor nodes after K-means clustering

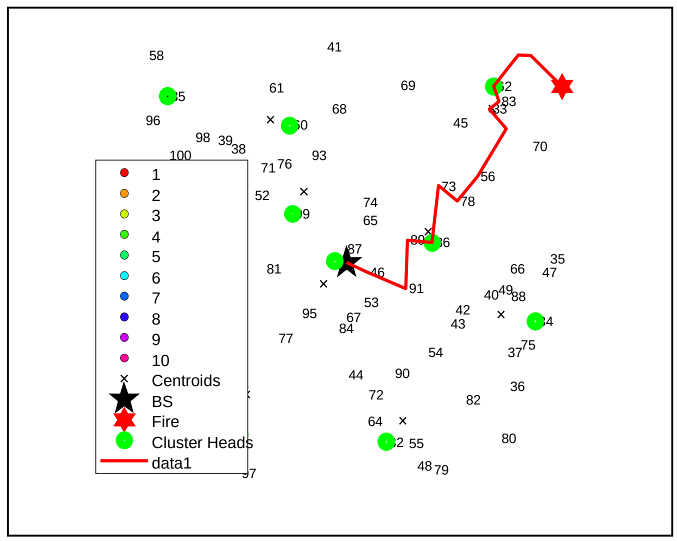

Figure 5: A Snapshot of the data transmission route after applying proposed scheme

Figure 5 shows the simplest possible route from the detected fire position to the BS. Once a fire is detected nearby any sensor node in a cluster, the sensor node sends the signal to the CH of that cluster. The CH head then follows the route to BS by using the nearest short path rule. The Monte Carlo simulation was repeated 1000 times to obtain the best possible route and average battery consumptions of the nodes involved in data transmission. The results are given in Figure 6 which represents the battery consumption for sensor nodes 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100. Figure 6 clearly indicates that the proposed technique saves a considerable amount of energy when compared with the LEACH method [14] and No-Clustering method. Specifically, the savings in energy become more significant when the number of sensor nodes deployed is increased. For instance, with 90 sensor nodes the energy consumptions are nearly 35%, 65%, and 95% for the proposed technique, LEACH, and No Clustering methods, respectively. The proposed technique uses clustering and CH selection, which reduces the battery and provide better efficiency.

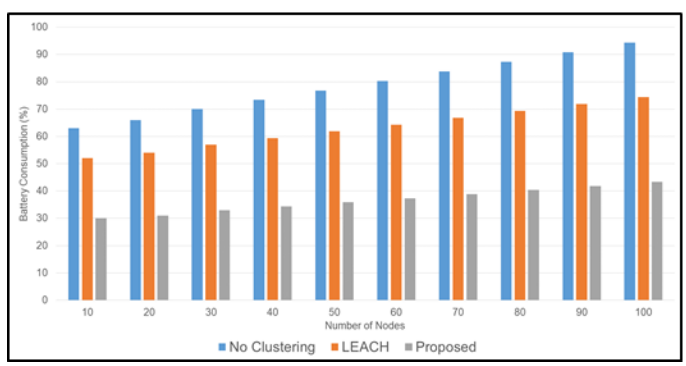

Figure 6: Comparison of energy consumptions

4. CONCLUSION

In this article, we have proposed a data transmission scheme for IoT sensor node deployment based forest fire detection system. Energy level is a critical factor for the deployed nodes in a forest region, because the nodes can be deployed once and they cannot be easily reached for maintenance. Therefore, we have considered a hybrid method relying on K-means machine learning method for cluster formation and Fuzzy Logic method for cluster head selection. Once the cluster and cluster heads are determined, the sensed data can be forwarded towards central base station in the IoT sensor based forest fire detection system. The results showed that proposed method is effective in terms of saving energy level of the nodes involved in the data transmission.

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