FPGA Based Forest Fire Detection using Neural Network

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***Abstract*— Wireless Sensor Network (WSN) plays crucial in emerging field in different circumstances like woodland, military, surveillance, and so forth. The significant issue of WSN is restricted in energy supply which drives affect on the network lifetime and delay in transmitting the information starting with one detecting hub then onto the next. To beat the above issue, Neural Network (NN) was proposed. This paper concentrates on recognizing the timberland fire with no false detection and to increase the life time of the system. Cluster Head was made through K-means clustering algorithm which extends the life time of the system. The recreation of the proposed technique is done utilizing Model Sim Altera 6.4a Starter Edition and is actualized using FPGA. Energy Efficient algorithm is utilized for vitality improvement of the system.80% of accuracy was obtained while implementing through Neural Network tool.**

Keywords—Energy Efficient Algorithm; Field Programmable Gate Array (FPGA); K-means clustering algorithm; Neural Network; Wireless Sensor Network (WSN).

I. INTRODUCTION

Clustering method is the efficient tool for data analyzing process and it is widely used for pattern recognition, feature extraction, data segmentation, etc. this method is based on the statistical model identification and it gives the overview of learning based clustering neural network like SOM, neural gas, LVQ, etc [1].The main impact of WSN is usage of limited energy resources and the power source of the battery is not able to replaceable. Hence, energy aware routing algorithm is proposed and is based on the clever strategy of cluster head selection, residual energy of cluster head and intra cluster distance for cluster formation. This algorithm improves the energy efficiency during data routing process and achieves the linear time complexity [2].A new technique was proposed to enhance the learning capabilities and reduce the computation intensity of the competitive learning using K-means clustering algorithm. Back propagation learning method was used and the K-means clustering algorithm was applied to the trained data set to reduce the amount of samples in the neural network by automatically select the optimal set of samples which results in the accuracy and computation time [3].

WSN mainly depends on the networks life time in which Dynamic Power management approach in wsn reduce the energy consumption in sensor nodes, after the deployment and designing of the network. To overcome this an intelligent tool like neural network was used in the energy efficient approach of WSN due to its distributed storage, data robustness, parallel distributed computation, etc. the output of neural network leads to lower communication cost, and energy conservation and improves the networks life time [4].Neural Network was proposed and it was tested with an application. The neural network implementation was done through Spartan 3. The weight matrices and the biasing functions are generated through Matlab and the network is verified using Verilog in Xilinx ISE [5].

The critical issue of WSN is to collect the various information's due to the limited energy resources. This can be overcome by a new centralized adaptive Energy Based Clustering protocol through the application of Self organizing map neural networks (called EBC-S) which can cluster sensor nodes, based on multi parameters; energy level and coordinates of sensor nodes which enable us to form energy balanced clusters and equally distribute energy consumption [6].The energy consumption of the network is monitored and the information about the energy status can be noted by sensing nodes and it is performed by energy efficient routing in WSN which maximize the networks life time. Cluster head is selected by learning algorithm in neural network by routing and data transmission [7].WSN is one among the ad-hoc network, where the sensor nodes are small in size and have limited resources due to the reduction in battery consumption. Dynamic clustering was proposed in which the sensor nodes are clustered before the data transmission which extends the life of the network and avoid the probability of pits which increases the packet delivery time and decreases the packet loss rate [8].

A method of neural network was proposed with multi sensor that is applied to the data processing which is detected by various sensors that are designed to enable low power and higher precision in WSN. A comparison is made with the crisp values and the proposed method maintains the high accuracy level despite fluctuations in the sensor values that decreases the number of false detection and provides the accurate detection [9].Hierarchical Protocols are proposed to reduce the energy utilization and increases the networks life time, the sensor nodes are clustered by using a new technique called neural network and residual energy is used as a factor for selecting the cluster head. Radial basis function network

model is used for cluster-head selection problem. The proposed algorithm is compared with LEACH and LEACH-C based on energy efficiency and the improvement of networks life time [10].The neural system takes the contribution as detected information through which measures the fire discovery and this can be connected for substantial number of utilizations [11].The proposed technique depended on nourish forward neural system which fulfils the prerequisite of sensor information. Since FNN affects the speed and accuracy of detection and this can be overcome by WSN algorithm and the solution is applied to FPGA circuit for high performance.

In this paper, neural network was created by interfacing sensor with ADC and the clustering techniques are used for detecting the forest fire accurately. The structure of the paper is organized as follows. Section II discusses about the proposed method. Section III, IV discusses the result.

II. PROPOSED METHOD

The proposed method consists of 4 main blocks

- Sensor Inputs
- Neural Network
- WSN Algorithm
- Optimization.

The block diagram of the proposed method is described in the Fig. 1.

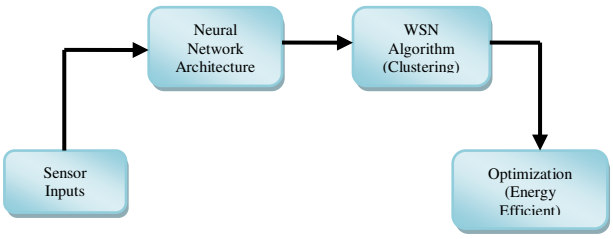

Fig. 1. Proposed Method

A. *Sensor Inputs*

The Inputs of the proposed model contains the environmental information's of detecting forest fire. In order to detect the forest fire various sensors have used which collects the information's through its sensing ability. In the proposed model, temperature, Humidity, Carbon-monoxide sensors are used. Temperature Sensor-LM35 is used to detect the variations of temperature in forest. It is well-suited for remote applications, low-cost due to wafer level trimming and it operates from 4V to 30V.

Humidity Sensor or hygrometer is used to measure the moisture content and the air temperature. It is smaller in size which posses fully calibrated and gives digital output. It performs the low power consumption.

Carbon-monoxide sensor-MQ7 is suitable for sensing the CO concentration in air. This sensor measures the CO gas concentration from 20 to 2000ppm. This sensor possess high sensitivity and faster response which posses analog signal as sensor output. The environmental information's are collected based on these sensors and it is converted into digital signal through ADC and then the digital signals are send to the neural network architecture.

B. *Neural Network*

An Artificial Neural Network was interconnected with various groups of nodes that perform collective information similar to the neurons in the human brain. Neural Network consists of 3 layers:

- Input Layer
- Hidden Layer
- Output Layer

Neural Network consists of various numbers of nodes in the input layer, hidden layer, and output layer. The nodes in the each layer are independent with one another. Fig. 2 describes the block of Neural Network.

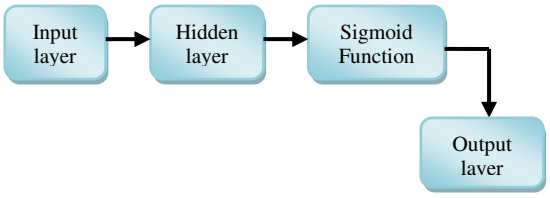

Fig. 2. Neural Network

The input layer gets the digitalized values from the sensor inputs through ADC converter. The input layer consists of number of nodes which is got multiplied with the corresponding weight of the sensor nodes and it is fed as input to the hidden layer. The output of the hidden layer gets multiplied with its weights and then it is summed up and then it passed through the activation function (i.e.) threshold value which is before the output layer. If the values from the hidden layer are greater than the threshold limit then the output will be positive or else it will be negative. Fig3 shows the flow of Neural Network Architecture.

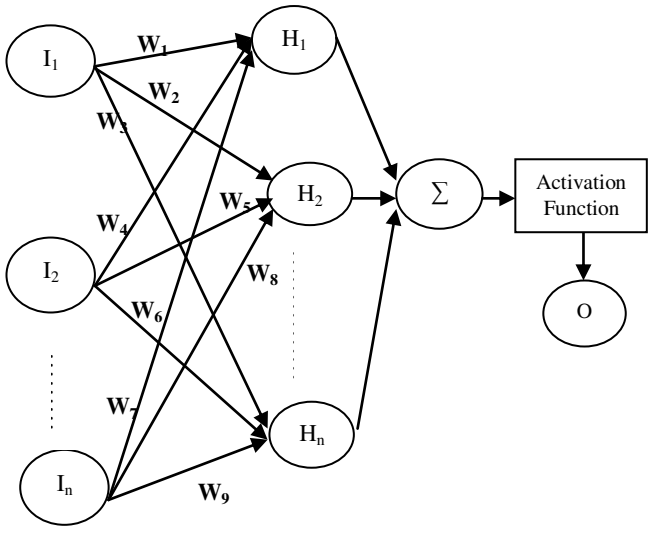

Fig. 3. Flow of Neural Network

The Artificial Neural Network was possessed by certain parameters:

- The neural network contains number of input layer, hidden layer and output layer which are independent to each other. The inputs of the network are obtained from the sensors and from the input layer the values are passed to the hidden layer and then output layer. Since the values of the network passed from input layer to hidden layer it is referred as Feed Forward Neural Network.
- The most important parameter of the neural network is updating the weights for the network interconnection. The weights can be obtained in matrix form and the weight matrices can be updated through MATLAB.
- The condition of the paper is to detect fire or not. Hence, in case of activation function Hard Limit Activation Function is used between the hidden layer and the output layer.

i) Architecture of Neural Network

In the architecture the inputs are obtained from sensor network and stored in the RAM and the weights are generated through MATLAB. On initializing the counter the inputs from the RAM and the corresponding weights from the RAM are get multiplied and the resultant values are summed up repeatedly in order to obtain the output.

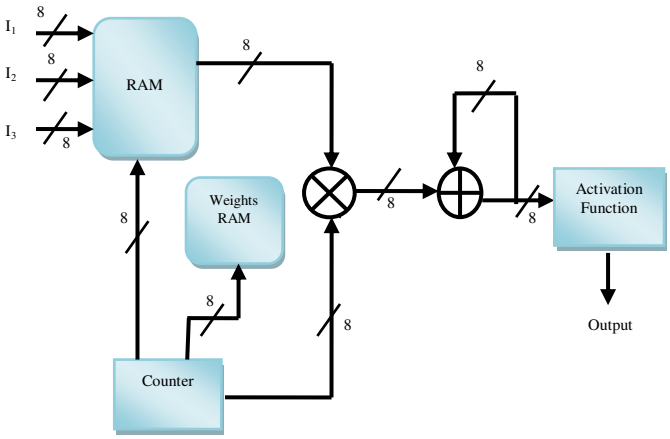

Fig. 4.Neural Network Architecture

The outputs are then passed into the activation function of the neural network. If the output of the neural network is greater the threshold value then the output is declared as fire detected or else the fire is not detected.

ii) Weights

Here the weights matrices for the hidden layer and the output layer are calculated through MATLAB.

$$\text{Weight} = \begin{bmatrix} w_{11} & w_{12} \\ w_{21} & w_{22} \end{bmatrix} \quad (1)$$

iii) Hard Limit Activation Function

Neural network have different activation functions. Since the output of the network is either 0 or 1, hard limit activation function is used.

$$\text{Hard Limit,} \qquad y_j = f(u) = \begin{cases} 1 & if\ f(u) \geq 0 \\ 0 & if\ f(u) < 0 \end{cases} \quad (2)$$

Through this activation function neural network output is obtained whether there is fire or not.

C. Clustering Algorithm

In WSN Algorithm, Clustering Algorithm is used through this cluster head has been created with the output of the neural network. Clustering process is a set of objects partitioned into subsets also known as Clusters. Clusters involve the groups that have a short distance between the subsets, dense areas of the data space with specific statistical distributions. The clustering technique used in the proposed system is k- means clustering algorithm.

i) k-means Algorithm

The *k*- means algorithm is a clustering algorithm related to the *k*-means algorithm and the medoid shift algorithm. K-medoid is more robust than K-means in the presence of noise and outliers. The K- means algorithm is summarized in the following steps:

Step1: Randomly select the cluster head from the set.
Step 2: Find the minimum distance by means of Manhattan distance of each data point in the set.
Step 3: Take arithmetic mean of the data in each cluster and declare it as the next cluster head.

$$\left|(x_1 - x_2)\right| + \left|(y_1 - y_2)\right| \quad (3)$$

Step 4: Repeat Step 2 and 3 till the cluster remains same. Fig.5. shows the flow of Clustering Algorithm.

D. Optimization

In the proposed system the energy optimization is done through the following equation. The energy required to transmit the data and to receive the data can be calculated using

$$E_{trans}(k,d) = E_{elec} * k + E_{mp} * k * (d)^p \quad (4)$$

$$E_{recv}(k,d) = E_{elec} * k(d)^p \quad (5)$$

where, k – Size of message being received and transmitted
d – Distant of nodes
p – Path loss
E_{mp}- Energy of multi path loss

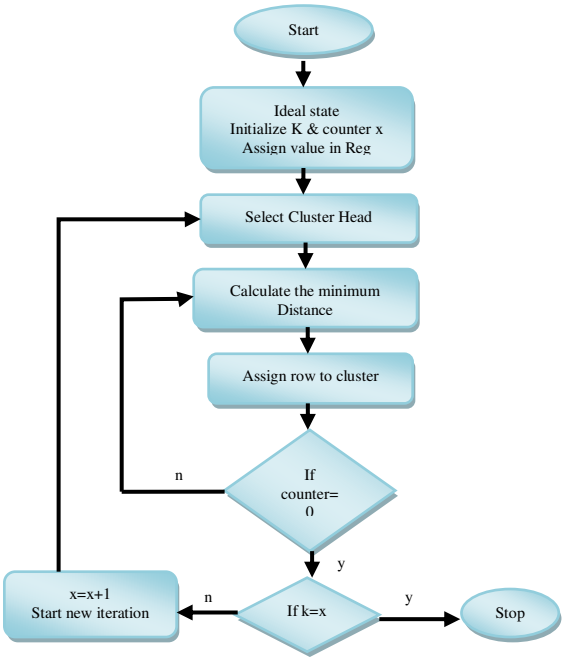

Fig. 5.Clustering Algorithm

III. Results And Discussion

The Verilog HDL code was generated and is re-enacted utilizing Model Sim Altera 6.4a starter Edition and it is implemented through Spartan 3E. Initially, the readings of inputs are sensed through the various sensors of Temperature sensor, Humidity sensor, and Carbon-monoxide sensor. The values from the sensors are in analog values which are converted into digital signals through ADC converter in ModelSim Alter 6.4a starter Edition. These values are stored in the ROM Memory. Fig. 6. shows the Sensor Digital Output from Spartan 3E.

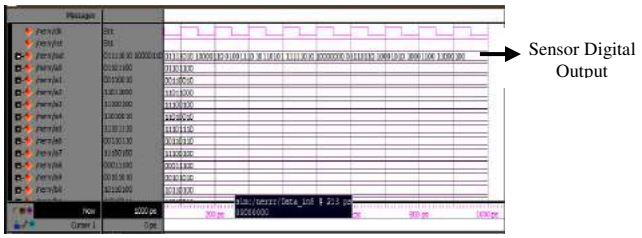

Fig. 6. Simulation waveform for Digital outputs

Alternatively, the weights of the neural network are calculated using NN tool in MATLAB. From the NN tool the weights are calculated which is in the matrix format and these weights are stored in the ROM Memory. On initializing the counter the values of sensor from the ROM Memory get multiplied with its corresponding weight and provide the output.

Fig. 7. Output of Fire Detection

The output is based upon the Hard Limit Activation Function (i.e.,) if the output of the neural network is greater than 0, based upon the function it is declared that fire is detected or else the fire is not detected. Fig.7 & 8 shows the simulation result of fire detected or not.

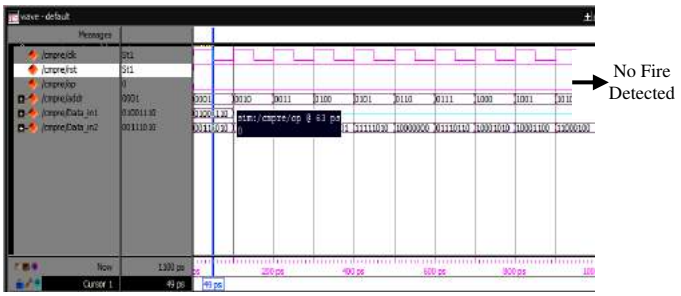

Fig. 8. Simulation waveform of Fire Detected as 0

Based on the values of the neural network outputs clustering process is done, through which the cluster head is created. By making cluster head as the initial step further steps are proceed for clustering process, cluster head is created as 1 and 0. Fig.9 shows the creation of Cluster Head 1.

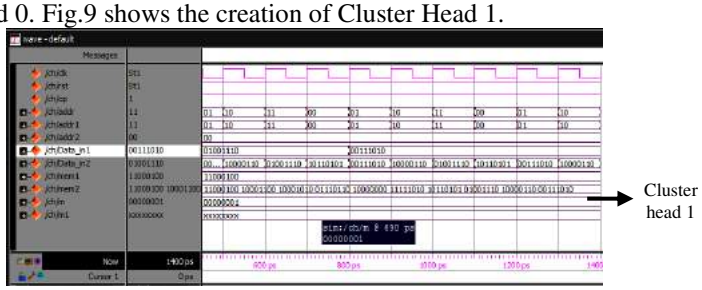

Fig. 9. Cluster Head 1

If the values from the neural network are greater than 1, then the values is clustered under Cluster Head 1 otherwise the values are clustered under Cluster Head 0. Fig.10 shows the waveform of cluster head 0.

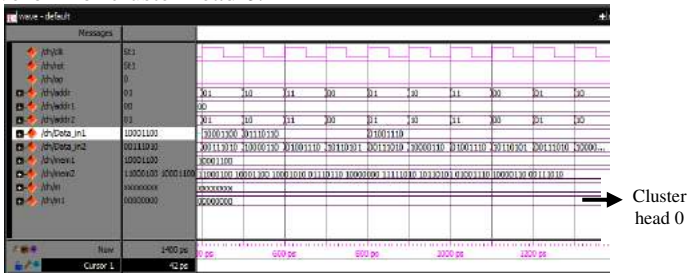

Fig. 10. Waveform of Cluster Head 0

The RTL view of the proposed work is shown in Fig. 11. Device utilization summary for the proposed block in FPGA is shown in Table I.

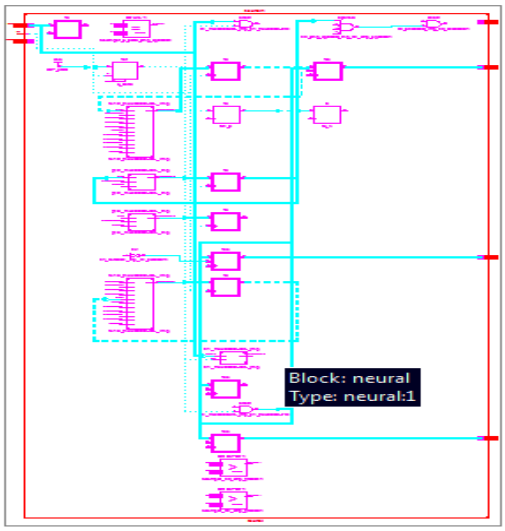

Fig.11. RTL view of the proposed block

TABLE I. DEVICE UTILIZATION SUMMARY

Logic Utilization	Used	Available	Utilization
Number of Slice Flip Flops	45	4,896	1%
Number of 4 input LUTs	26	4,896	1%
Number of occupied Slices	32	2,448	1%
Number of Slices containing only related logic	32	32	100%
Number of Slices containing unrelated logic	0	32	0%
Total Number of 4 input LUTs	26	4,896	1%
Number of bonded IOBs	45	172	26%
Number of BUFGMUXs	1	24	4%

IV. CONCLUSION

The proposed model clearly shows the fire detection in the forest through the neural network method. The fire is detected accurately through the clustering algorithm. This architecture posse's low power and high precision output through the sensing values of the sensors. The simulation result shows the detection of forest fire through Model Sim Altera 6.4a Starter Edition and the implementation is done through the Spartan 3E FPGA kit. The implementation is done in 4.284ns.Detection method through neural network improves its accuracy by data processing of several sensors and its variation and in NN tool the accuracy was detected as 80% and energy is optimized.

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