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Clustering and Event Detection in Wireless Sensor Networks

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Abstract: Lifespan of Wireless Sensor Networks is directly dependent on battery life of tiny electromechanical devices i.e. Sensors. Sensors are limited with non rechargeable batteries so it is required to use their energy efficiently to strengthen them which results that network can remain usable over the maximum time. This paper will present collective work of our previously proposed clustering algorithms Mutual Exclusive Distributive Clustering (MEDC) protocol, Mutual Exclusive Hybrid Energy Efficient Distributed Clustering (MEHEED) and change point detection for fire detection application. This works assumes that sensors are homogeneous; resultant every sensor is having equal capacity of becoming cluster heads. Two parameters taken for evaluation of clustering protocols are number of sensor nodes and range of communication. Results have been taken on different values of parameters to show improved performance also shown which values give negative effects on performance.
Keywords: Clustering Protocol; MEDC; MEHEED;Change Point Detection

I. INTRODUCTION

Wireless sensor Networks are one of famed research leaning upward field. WSN had applications in various fields which include bio-medical, target detection in military, regular weather forecasting etc. Wireless Sensor Networks are networks of tiny electro mechanical devices. Sensors communicate via RF signals with one or more powerful sinks called base stations (BSs) [3]. Sensor Networks have some requirements which are shown in figure 1. Among them one of the crucial requirements is Network Lifetime. The reason of criticality of this requirement is limited battery power of sensors. Intense research has been carried to save battery life; clustering is one of from this. The first clustered sensor network was proposed by author lin [16] This proposed clustered network architecture has three advantages one of which is bandwidth utilization at its maximum, second is bandwidth sharing and third advantage is to make network robust. Concept of Clustering is extended by author Heinzelman in 2000 who has proposed first clustering protocol [17]. Clustering is grouping method of sensors to reduce cost of communication and to save battery life [1]. Clustering is a energy saving mechanism in WSN through which, number of group member can save their energy by communicating their information to cluster head only instead if transmitting to far located base station. Clustering is more or less hierarchical network where cluster heads can be cluster member for next leveled cluster heads[2]. The cluster heads perform data aggregation and information forwarding [6, 11, 12]. Clustering is having advantages of energy saving, more scalability, less load, more robustness, data aggregation/fusion, load balancing and, improved network lifetime and latency reduction [15]. Clustering protocols can be differentiated on number of parameters like some protocols may work in centralized way or some may be distributive, other criteria could be power base, location aware, multilevel and multi-hop inter-cluster communication etc. Centralized algorithms are those in which the base station allocates the cluster heads to sensors. Base station is having whole responsibility cluster heads rotation [13]. In Distributed algorithms cluster heads get choose on basis of mutual selection process among sensor nodes; no center authority ever exists. Power base clustering algorithms decide cluster heads on ground of residual battery life of sensor. Multi-hope inter cluster communication is feature in which information can communicated with the help of intermediate relay node. Some clustering protocol works with sensors which have Location awareness with the help of GPS. Multilevel clustering is representation of hierarchy of cluster heads. Table 1 is shown feature survey of existing clustering protocols. Section II in this paper will present gist of our previously proposed work MEDC and MEHEED along comparison with HEED protocol. This Section Present experimental results MEDC and MEHEED on different values parameters. Simulated result also present performance degradation in some specific cases. Section III will introduce change point detection and show experimental evaluation for fire detection application.

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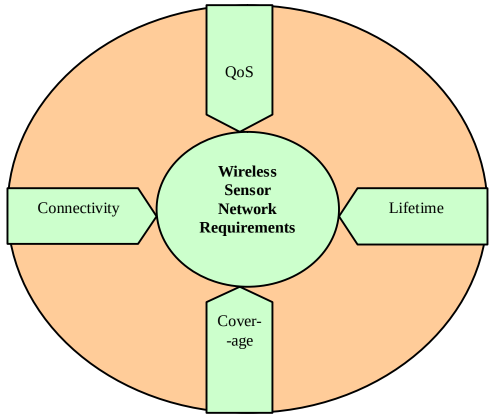

Figure 1-Wireless Sensor Network Requirements

Table 1- Feature Survey of Different Clustering Protocols

Clustering Protocol	Centralized	Distributive	Multi hope Inter cluster communication	Location Awareness	Power Base	Multilevel Clustering
LEACH[5, 17]		√				
HEED[7]		√	√		√	√
LEACH-C[14]	√			√	√	
TEEN[9]		√			√	
PEACH[8]		√		√		
SHORT[10]	√					
EEUC[11]		√	√			
DHAC[4]		√				√
EECF[20]		√	√		√	
PADCP[21]		√	√		√	
SEECH		√			√	

II. CLUSTERING

A. Network Model Assumption

Sensor nodes are of homogeneous type means they have the same capabilities and resources like battery power etc.
Sensor nodes are stationary deployed in local region for monitoring and the data sink is located far from the sensing field.
Network is formed of location unaware sensor nodes; nodes does not having any capability like GPS
Sensory data is aggregated at different levels and sent to data sink generally called base station at regular period of time
A different identifier will be used for each sensor node. Communication is done on symmetric links. Communication can be bidirectional.

B. Radio Model Equations

Sensors energy is dissipated on transmission and receiving activity along with sensing. If any sensor want to transmit t bits to a node located at distance d. Then energy dissipation is calculated by equation 1 [1,19]. Transmission Energy Dissipation

1) Etx (t) =t* Eelec. + Etx_amp (t, d) (1)
Etx_amp (t, d) = t*d^2*Efs (2)
Etx_amp (t, d) = t*d^4*Emp (3)

Where Etx represent transmission energy will be calculated from electron energy (Eelec) and amplification energy (Etx_amp). Amplification energy consumption also varies depending on free space communication or multipath communication equations 2 and 3 are shown. Free space energy and multipath energy consumption is represented as Efs and Emp respectively. If any sensor node is receiving t bit from any sensor node then energy dissipated for t bits is represented as Erx

Receiving Energy Dissipation

$$Erx(t) = t * Eelec \quad (4)$$

C. MEDC

Mutual Exclusive Distributive Clustering protocol is proposed in paper [15]. The protocol works on the basis of mutual exclusion algorithm of distributed networks. Cluster heads are chased under a range of communication on basis of their remaining energy. Sensors which are having maximum residual energy under the particular range of communication they will be elected as cluster heads. This is an iterative protocols having three steps in each iteration. New cluster heads will be selected from a new iteration as energy of previous cluster heads will be degraded due to data aggregation and long communication. In start of iteration step 1 will starts with iteration under range of R_f. Queue will maintained by each sensor for received advertisement. In Step 2 sensors send OK message to only those sensors that are having residue energy more than its own. If a sensor got advertisement of other sensors those are having power less than or equal to its own power then it will wait up to some period of time. In step 3 each sensor will look up its own status. If sensor had not sent OK message to any other sensor that means presently itself is having higher residue battery power over R_f. So it will send a declaration message of becoming cluster head to every sensor under range R_f. There will be only one cluster head that's having highest residue energy no other sensor is allowed to be cluster head [15]. MEDC protocol is communication based distributive clustering protocol. All sensors within R_f will participate in communication. MEDC protocol has been evaluated for different parameter. And result of MEDC had been compared on corresponding parameters. It has been evaluated that MEDC is working better than HEED on most of parameters.

D. MEHEED

MEHHED protocol is extension work of our proposed MEDC protocol [15]. MEHEED protocol is combination of MEDC and HEED protocols. MEDC protocol was working on the parameters of residue energy Eresidual and range of communication on the other side HEED protocol considers three factors one of them is Chprob second is Snbr and third is range of communication. The proposed MEHEED protocol will take first parameter same i.e. Chprob and second parameter will be Eresidual instead of Snbr, the third factor is same for all three protocols here i.e. Range of communication.

The idea to change the second parameter is; instead of considering previous calculated Snbr which was dependent on remaining energy of starting level, why not to consider Eresidual that have been recalculated after each iteration. Benefit of this idea will be that recent updated value i.e. Eresidual will also reflect energy detrainment of previous cluster heads.

So decisions will be more accurate. MEHEED protocol adopts benefit of both protocols. When it take first decision sensor's Chprob will be checked, which is calculated in first phase.

If Chprob come out equal to one that it will select that particular sensor as cluster head, rest all computations will be simply skipped. if it is not equal to one in that case part of MEDC algorithm works out and selects cluster head which is having maximum residual energy. MEHEED protocol will works in two phases. First phase will be of initialization and calculations phase is as like HEED. In first phase first of all sensors under the range of communication are queued.

On basis of this queue, Communication cost and Eresidual will be calculated. After that, Chprob will be calculated on basis of residual energy and predefined Cprob as like of HEED protocol. Second phase will decide the cluster head and the cluster members under clusters. Second phase will decide which sensor will be cluster head.

This decision firstly depends on Chprob after that this decision will depend on the Eresidual unlike HEED, in which second factor was Snbr. If and sensor node is having Chprob is equal to one that it will be directly declared as cluster head and sensors under its queue will be cluster members for this. In this case further computations will be skipped both computation time and energy will be saved. In case if there is no sensor node under a range of communication have met first selection criteria then selection will be done according to MEDC protocol i.e. on basis of remaining energy.

Table 2 has compared and summarized different working parameters of these proposed two protocols along HEED clustering protocol

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Table 2- Comparisons of Working Factors

HEED	MEDC	MEHEED
1. Ch_{prob} 2. Snbr (cost) 3. Range of Communication	1. Eresidual 2. Range of Communication	1. Ch_{prob} 2. Eresidual 3. Range of Communication

E. Experimental Evaluation

Simulation on these protocols has been done on MATLAB. Simulation parameters are shown in table 3. Figure 2 to5 shows comparative analysis of MEHEED, MEDC and HEED protocols on different values of sensor count(n) and Range of Communication(Rc).

Table 3- Simulation Parameters

Parameters	Abbreviation	Values
Random field x axis	Xm	100 meter
Random field y axis	Ym	100 meter
Initial energy of sensor	eo	0.05 Joule
Total number of sensor	n	100,200
Transmission energy per bit	Etx	50*1.E-9 Joule
Receiving energy per bit	Erx	50*1.E-9 Joule
Free space energy per bit	Efs	10*1.E-12 Joule
Data aggregation energy per bit	EDA	5*1.E-12 Joule
Advertisement energy per bit	Eadv	50*1.E-12 Joule
Range of Communication	Rc	20,40,60,80 meters
Cluster Probability	Cprob	0.5

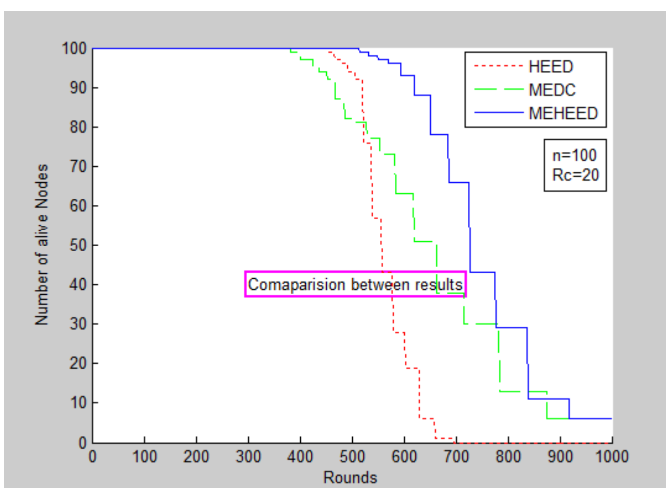

Figure 2- Comparative Results HEED, MEDC, MEHEED number of sensor=100 Rc =20

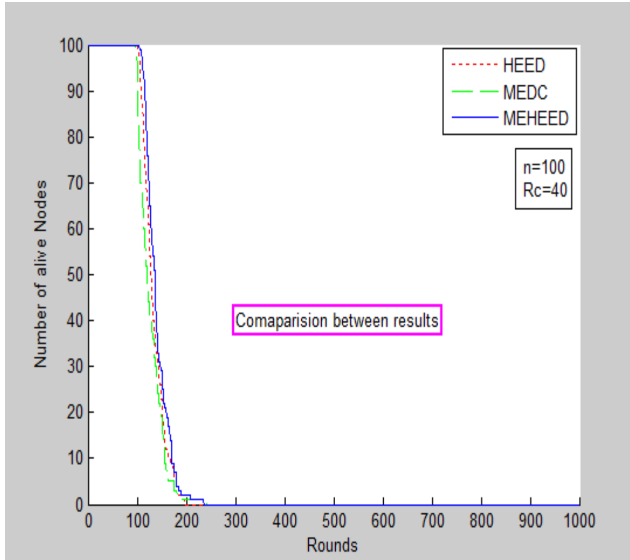

Figure 3- Comparative Results HEED, MEDC, MEHEED number of sensor=100 Rc =40

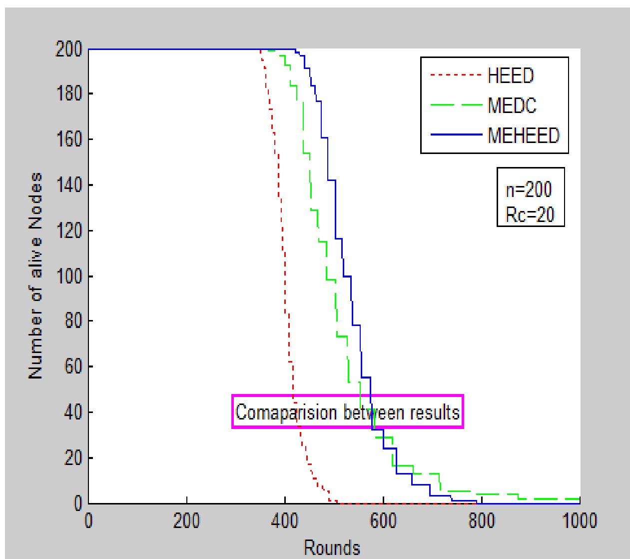

Figure 4- Comparative Results HEED, MEDC, MEHEED number of sensor=200 Rc =20

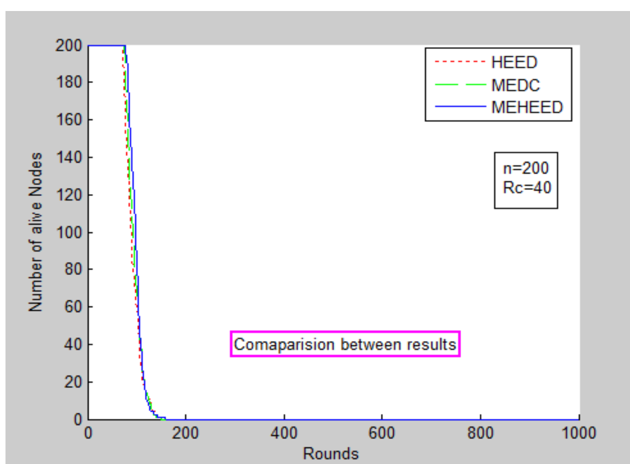

Figure 5- Comparative Results HEED, MEDC, MEHEED number of sensor=200 Rc =40

F. Results and Discussions

MATLAB results given in Figure 2 to Figure 5 experimental result how MEHEED perform. Network life time is measured as number of alive nodes per round. In results graph Y axis represents alive nodes and X axis represents rounds. Figure.2 is shown for comparative performance of MEHEED, MEDC and HEED on parameter n=100 and range of communication is taken as 20. Red arc represent performance of HEED, Green arc represent MEDC and Blue Arc is representing MEHEED Performance is again measured in terms network life time. Results in figure 3, Figure 4, Figure 5 are again performance analysis of MEHEED, MEDC and HEED by varying values of n and Rc (Range of communication) n is varied on two values 100 and 200. Rc is also varied by four values which are 20 and 40. From different analysis we concluded that MEHEED perform better infect from MEDC also but as parameter are changed graph of MEHEED come closer to MEDC further close to performance of HEED. At n=200 and Rc =40 all three graphs overlap each other. Reason for this decrement in graph of MEHEED; is increased cost of communication. When we increase n from 100 to 200 or Rc from 20 to 40 then their will be more no of sensors under range of communication to each other. More sensors under range more advertisements mean more cost of communication which result decrease in performance

III. EVENT DETECTION

Wireless Sensor Networks are deployed any of two reasons one of which is regular data gathering another is event detection sometimes called change point detection. Change point detection is having a number of applications in WSN. Change point detection is different from regular data gathering as in this cluster heads report to base station only in specific reasons. Change point detection can be carried by various techniques like fuzzy logic, neural network and Bayesian etc. Work presented here is solution to fire detection problem through fuzzy logic. Cluster heads are chased by any of clustering protocol we assume MEDC here. Chased cluster heads will aggregate sensed data received from cluster sensor members. Cluster heads will decide whether to report base station or not.

A. Experimental Evaluation

For experimental evaluation on fire detection work has been carried on FIS tool of MATLAB. Here for fire detection scenario consideration is; the sensors are motes that are sensing three parameters one is heat index, second is relative humidity and third parameter is Carbon Monoxide. We are assuming that sensors will sense the values and send sensory values to their cluster heads which are chased by MEDC clustering protocol. Cluster heads will aggregate the received data and for aggregation we are taking simple averaging rule. These three aggregated values will be inputted into fuzzy system of cluster heads. Fuzzy system will decide on basis of fuzzy rules and decide whether these values are concluding presence of fire. We are taking Mamdani FIS with three input variables and one output variables. FIS take inputs in crisp form and give output also in crisp form. But this mapping is totally based on fuzzy rules in turn also on membership functions. Here in fire detection FIS we had mapped three input functions to one output function. Three input variables heat index, relative humidity, carbon monoxide are inputted with crisp values. These values are fuzzyfied, mapped to fuzzy output with the help of rules and operators. For simulation purpose membership values are taken from data national weather services. Figure 6 is showing initial view of FIS editor with three input variables and fire probability is output variable. Figure 7 mbership function plotted over range [80 120] for Heat index input variable. We have taken four membership functions (mf) lower, moderate, high and extreme. Figure 8 is shown input variable Relative Humidity having four mfs extreme danger, danger, extreme caution and caution. Figure 9 represent membership function of carbon monoxide. Three mfs are taken named low, medium and high divided over range 0 to 100 parts per million (ppm). Figure 10 is showing membership function for output variable that is fire probability divided into over range 0 to 1. Figure 11 view of rule editor. Table 4 is showing results of Rule Viewer

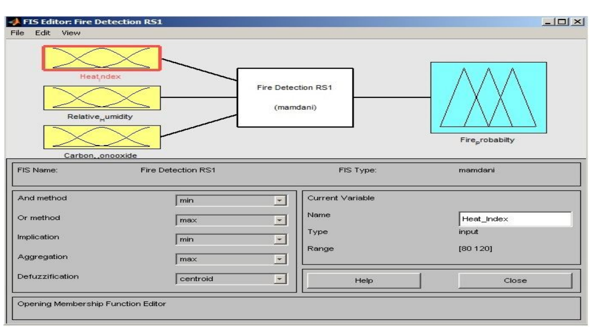

Figure 6- Initial View of FIS editor

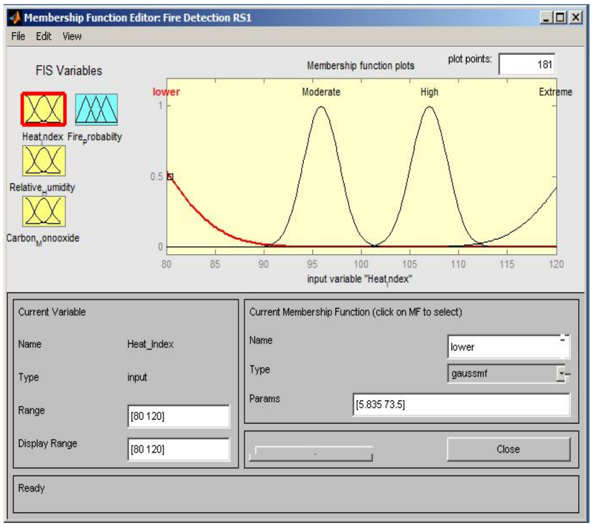

Figure 7- Membership Functions of Heat Variables

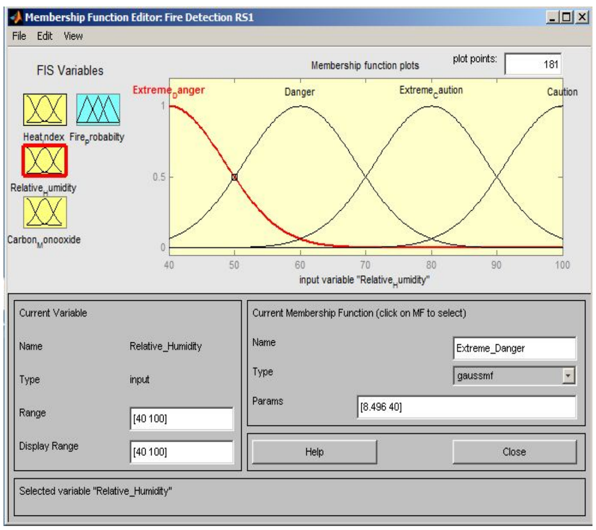

Figure 8- Membership Function of Relative Humidity

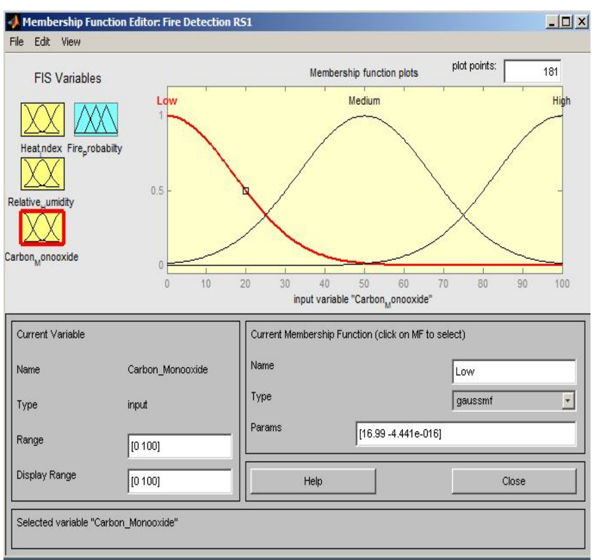

Figure 9- Membership Functions of Carbon Monoxide

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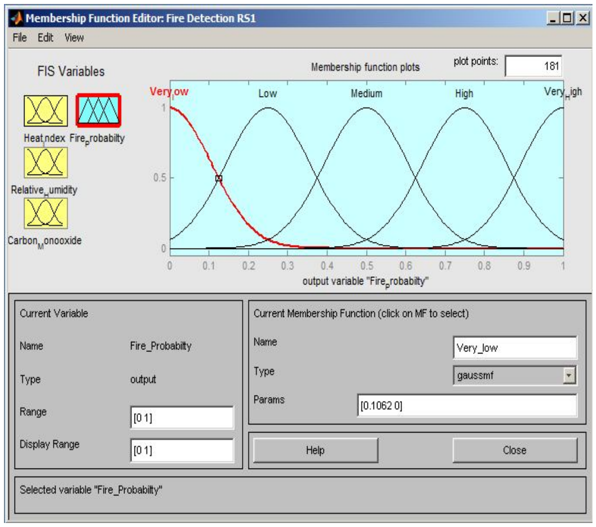

Figure 10- Membership Functions of output variable Fire Probability

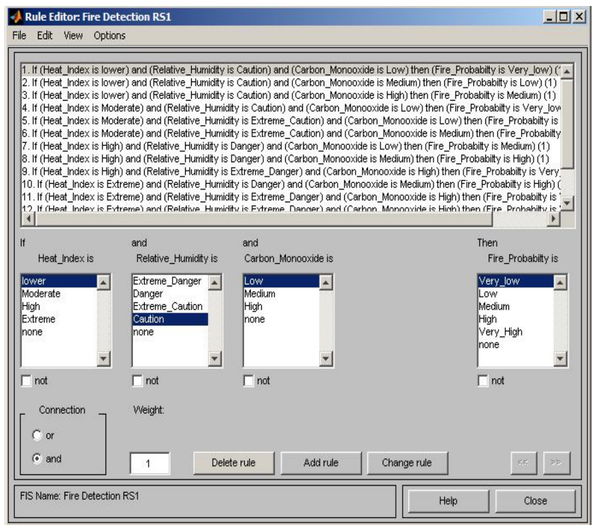

Figure 11- Rule Editor for Fire Detection

Table 4- Results of Rule Viewer

Input Variables			Output Variable
Heat Index °F	Relative Humidity (%)	Carbon Mono-oxide (ppm)	Fire Probability
85.54	82.3	48.8	0.281
100	70	50	0.482
90.8	59.9	64.5	0.498
110	40	60	0.724
120	50	90	0.85

IV. CONCLUSION

This paper had presented evaluation of previously proposed work MEDC and MEHEED. Evaluation is done on varying two parameters one is no of sensors over field and second one is range of communication of sensors. Experimental Evaluation has shown that MEDC working better than HEED; and MEHEED works even better than MEDC. But in some cases the performance is proximally similar for all; the reason effecting is more cost of communication as range of communication and number of sensors increases. It’s concluded that range of communication affect the performance in great impact. This is also concluded that Fuzzy logic can work for change point detection on cluster heads.

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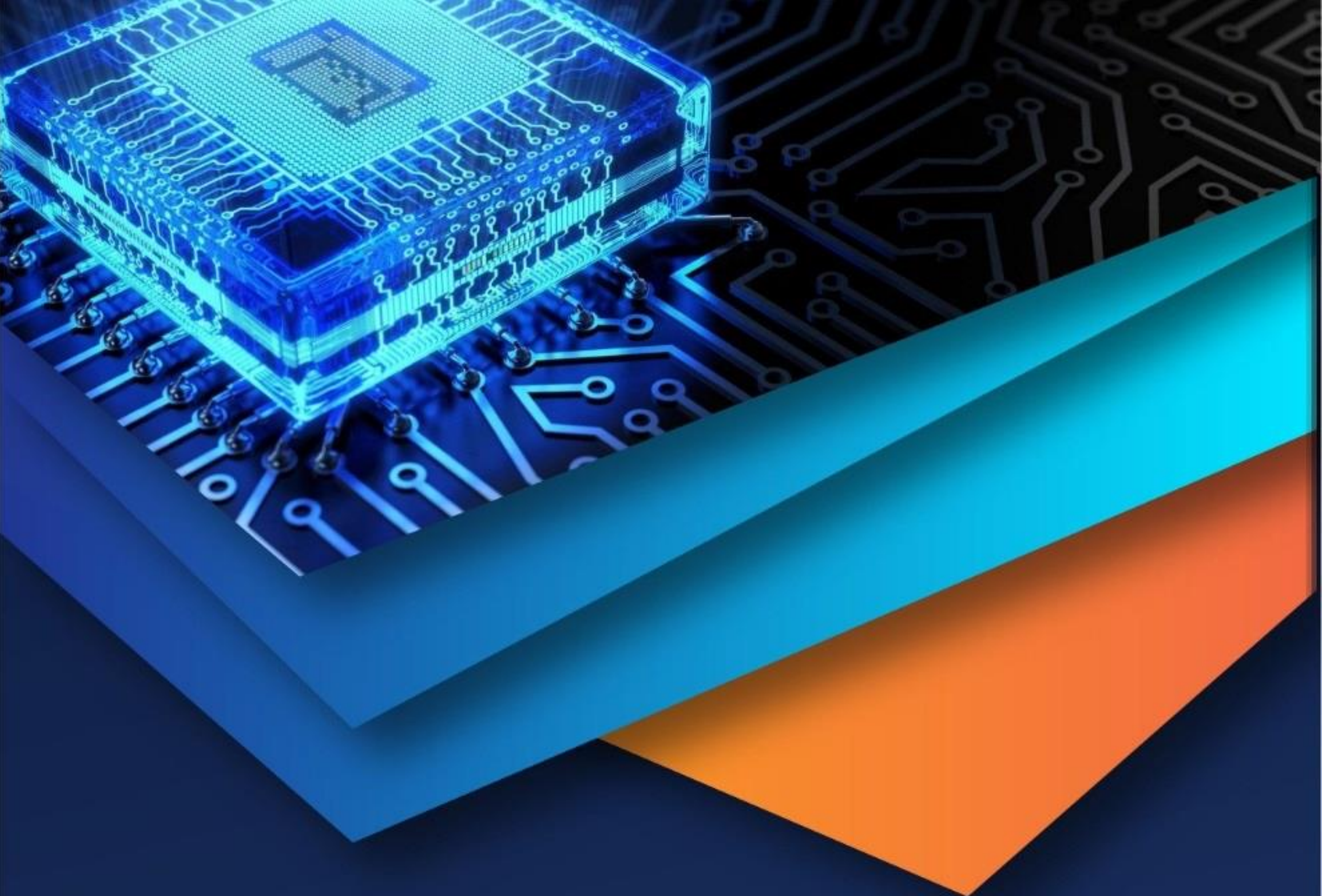

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