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Information Fusion and Change Point Detection in Mutual Exclusive Distributive Clustering

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Abstract

Wireless Sensor Networks in present world are not only aimed for sensing for regular data gathering, can also aimed to extract useful information i.e. Information Fusion. Information Fusion is sometime targeted for change point detection or it can be said for event detection in present scenario. This paper will present information fusion and change point detection merged with our previously proposed work i.e. Mutual Exclusive Distributive Clustering (MEDC). In this paper change point Detection is aimed for forest fire detection via fuzzy logic. MEDC protocol will perform clustering and after that, these cluster heads will use fuzzy logic to represent change point detection. Fire detection is considered here as application for change point detection. In this paper for simulation purpose, data is taken from National Oceanic and Atmospheric Administration [15] and Occupational Safety and health administration [4].

Keywords: MEDC, Change point detection, Fuzzy theory

1. Introduction

WSN is emerging field having various application approx in each field like medical, military, weather forecasting and many more[6,7]. In WSN, Sensors with limited battery power are challenged with major three tasks first is

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Sensing, second is Representing the sensed information and third is Transmitting/ Receiving. Among these three tasks transmission is most energy consuming task. According to research, for transmitting k bits to a distance d, the power requirement is proportional to d^2 or d^4 depending on free path or multipath [23]. So to reduce transmission cost for saving battery power is very important research area. Therefore suitable methods for clustering and information fusion should be developed so that transmission energy requirements could be reduced. Information Fusion is also dependable upon sensors configurations. Sensor configuration in WSN can be any of three types complementary, competitive, and cooperative [21] In Complementary type, the sensors do not depend on each other directly, One sensor views one part of the region, and another views a different part of the region, thereby giving a complete picture of the entire region. Second is Competitive type configuration, each sensor transmit independent own measurements of the same attribute or feature. In third type i.e. Cooperative type, two independent sensors are used to derive information that would not be available from a single sensor as in a stereoscopic vision system. Our proposed work is done for competitive sensors configuration. Various researches have been carried for clustering protocols and information fusion change point detection as distinct topics but neither of these had shown complete solution for theses all together .we had tried to present a combined solution which will solve all these targets. This paper will first represent MEDC clustering protocol and after that information fusion via MEDC protocol and final phase is change point detection via fuzzy logic. MEDC protocol will cluster the sensors, after that on cluster heads information fusion and change point detection will be done. This paper will represent MEDC protocol in Section II followed by information fusion and change point detection in section III with experimental results.

2. Related work

2.1. Clustering

Transmission of information is most energy consuming task, so to save transmission energy of many sensors; clustering will be done. Clustering is a concept in which in place of a group of sensors only the group head will transfer the information. Objective of clustering is to reduce the power requirement for communication to save battery life of sensors network [5, 6]. Clustering is a technique to group the sensors in which there will be a single cluster head and other sensors will be cluster members [5, 6]. From clusters, only cluster head will transmit aggregated information to base station instead of each sensor. Cluster members will communicate to near located cluster head only, not to the far located base station. Clustering is also more or less implementation of hierarchical network. In clustering, cluster member sensors will send their sensed information to the next level i.e. cluster head and after that, the cluster head will aggregate it and forward this information to the next level which may be the base station or head of cluster heads. The benefits of clustering are very clear increased scalability and lifetime of the network. Clustering protocols can be compared on various factors like centralized, distributive, power base, and location aware, multilevel and multi-hop inter-cluster communication. Some clustering protocols are compared on theses factors. *Centralized algorithms* are those the base station allocates the sensor which happens to be the cluster head for the cluster. *Distributed algorithms* sensors elect among them which sensor suitable to be the cluster head and also keep rotating their role of being the cluster head. *Power base clustering algorithms* are those algorithms which take care of the remaining battery life or remaining network life time of sensors. *Multi-hope inters cluster communication* termed for path traversed to send the sensed information. *Location awareness* in wireless sensor networks is the ability of sensors with the help of GPS to know the location of all the other nodes. *Multilevel clustering* shows the hierarchy in cluster heads means cluster heads are having their heads again. Some clustering protocols are discuss in paper example are like LEACH (Low Energy Adaptive Clustering Hierarchy [9]), HEED (Hybrid Energy-Efficient Distributed clustering) [10], TEEN ((Threshold sensitive Energy-Efficient sensor Network) [12]), PEACH (Power-efficient and adaptive clustering hierarchy protocol [12]), SHORT, EEUC (energy-efficient clustering protocol [11]), DHAC (distributive hierarchical agglomerative clustering [8])

2.2. Information fusion and Change Point Detection

Information Fusion is the process of collection of data and representing it in most usable form. Collection and processing of data is the fundamental issue in Wireless Sensor Networks. The objective of Information fusion is to

get most accurate data of observed phenomena, in minimum cost. . Information fusion can be categorized on basis of knowledge, level of data abstraction, purpose, parameters, type of data, and mathematical foundation etc. During Information fusion process information received from the different sensors needs to be combined in such a way that more or better information could be achieved [16]. Generally information fusion system would show resolution, accuracy, speed, intelligence, insight, pragmatism etc. [18]. Another characteristic of information fusion is that we can use it as a decision support system (DSS) as it fuses information of various types and present the result to the user as per his requirement and make decision making process more easier in comparison to an ordinary system [17].Data Aggregation is one more term which is frequently used in WSN. Data Aggregation is more or less subset of Information Fusion process. Information fusion is sum of data aggregation and filtering process. First level of Data aggregation is carried out on cluster heads. The Next data aggregation is done on base station it's a process of summarization of data that is coming from different sources [19]. Paper [25] had shown Tree based Data aggregation. Author had used Genetic Algorithm to fine best suitable route which balances the data load throughout the network and thus balances the residual energy in the network. Author had worked to search the energy efficient data collecting spanning trees.

Information Fusion can serve any of two purposes one is regular data gathering and the second is change point detection. Change point detection is identification of those measurements that significantly deviate from the normal pattern of sensed data. Change point detection also defined as observation of abrupt changes in the generative parameters of sequential data. Change point detection can be done via many approaches. One of them is Neural Network for example in the paper [26] presents detection with the method of learning neural network called self-organizing map (SOM), and uses Discrete Wavelet Transform (DWT) for data reduction. In paper [27] author had used recurrent neural networks (RNNs) for fault detection. This paper is the real-time implementation of a neural network-based fault detection which is implemented on TinyOS operating system. From the many more approaches used for change point detection one more is Dempster Shafter theory. In paper [28] Dempster Shafter theory is used to infer the context of multi sensor data fusion. This work has been focused on the inference to determine a particular situation or the cause of a specific situation. The paper [29] has used Dempster-Shafer theory of evidence and proposed a distributed reliable Structural Health Monitoring (SHM) protocol. For this research work, hierarchical approach is used, and it is assumed that the sensors are in cluster network they will sense the condition, after that cluster head collect and process the sensory measurements from the sensors and prepares a local report. One more approach Bayesian theory is highly suitable for change point detection. Most of work done is for images for example, in paper [30] work have been carried out for change detection in remote sensed images. The work done is based on the formulation of unsupervised change detection problem in terms of Bayesian decision theory [30]. The author worked with three algorithms Reduced Parzen Estimate (RPE), Expectation Maximization (EM) and Markov Random Field (MRF) to find the change detection. This paper presents the work with unsupervised learning methods in contrast of supervised learning methods. In [31] Bayesian inference is used for offline change point detection in synthetic apertures radar images. This paper had shown practical implementation with markov chain Monte Carlo (MCMC) method. A more or less similar term for change point detection is, *Outlier*. Different methods of outlier detection are discussed in [1]. In paper [32] rule based classifier based on naïve Bayesian algorithm is used to detect outlier in WSN security. This paper proposed an algorithm for training and test data set for detection as well as rectification of outlier and author had simulated this work on NS2. Paper [24] had shown Outlier detection by distributing sensors in different clusters. They had also distinguished event form error via Nearest Neighborhood method. But they had not considered any mechanism to show who will be cluster head and will transmit the information to base station. One more approach for change point detection is Fuzzy Logic that we are considering in more detail for our work.

2.3. Fuzzy logic

Fuzzy sets and logic were introduced by L. Zadeh in 1965. Fuzzy set theory is representation way of elements in universe which are ambiguous or vague. In a fuzzy set each element having graded membership in the real interval 0 to 1 or it could also be said, that elements can belong to a fuzzy set to a certain degree [7, 14]. This graded membership is represented by membership functions. Fuzzy inference is the mapping from a given input to an output using fuzzy logic. Fuzzy logic is having wide research area. One example is Fuzzy logic had applicability for

routing; paper [2] proposed generalized fuzzy logic based approach for energy-aware routing in wireless sensor networks. This paper had estimated the cost using FIS on behalf of existing parameters like transmission energy, remaining energy, queue size etc. Fuzzy logic is having great application work also in change point detection , in paper [3] authors had worked for Aircraft dry bays and engine compartment, where they had proposed fire detection system used a fuzzy inference system to detect a fire. In [13] author had shown great work for fire detection experimental for burning chair and burning oil. The work has also shown that using fuzzy values instead of crisp values improve the accuracy of event detection. They had also compared that detection via Fuzzy logic is more accurate than two well established classification algorithms. Fuzzy is also has applicability for change point detection in remote sensing images [20].

3. Clustering, Information fusion and change point detection of MEDC using Fuzzy logic

3.1. MEDC (Mutual Exclusive Distributed Clustering) [22]

MEDC is our proposed work presented in [22]. MEDC protocol works on principal of mutual exclusive protocol of distributed networks. Cluster heads will be chosen in mutual exclusive way over range of communication. Under a range of communication sensor that's having maximum of residue energy, only and only that will be cluster head. The protocol will run in iterations, each iteration follow three steps and cluster head will be again chosen in succeeding iteration. When iteration starts step 1 Sensors will advertise their remaining battery power to the sensors under range of R_f. All sensors will send and receive advertisement. A queue for incoming advertisements will be maintained at sensors. Step 2 will work as, that Sensors will check all incoming advertisements, after that all Sensors send OK message to only those sensors that are having residue energy more than its own. This step gives clarity that if any sensor is sending OK message to the any of other sensor that's having higher residue energy then, that means presently there is no chance for itself becoming cluster head within its R_f. 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 most likely TDMA slot. 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. 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 see the algorithm in paper [22].

3.2. Information fusion and change point detection in MEDC

Information fusion is extraction and representation of useful information. In WSN when sensors are configured as Competitive type, then it's needed to remove ambiguity of information. The reason of ambiguity is, as they are of competitive type sensors so they will sense same phenomena at same time. Now in our proposed MEDC protocol, after execution of step 3 that sensor will be taken as which is having highest remaining energy will send OK message to queued sensors which are having less remaining energy then its own [19]. So cluster head is having idea how many sensors are under it, from which cluster head will get sensed data. Cluster heads will gather information from their sensor members. Cluster head need to execute next step is Information Fusion. We suppose if cluster head is getting data from 2 or more sensors, then for representation and extraction of useful information, the cluster head will calculate mean. The reason why we are calculating mean is that sensors are Competitive configured, so more or less they are representing same phenomena, and above of all to remove redundancy *Mean* is the fastest way.Next step is Change Point Detection using MEDC. Assumption is each sensor is having equal capacity for detection. So whichever sensor will become cluster head, first change point detection will be carried by it. The change will be detected on basis of Fuzzy theory. Fuzzy theory is basically decision taken based on fuzzy rules. If cluster head finds that change detected is more than 50% then only it will notify to its base station. A benefit of this approach is that by this energy of cluster heads will also get saved.

4. Evaluation

We had used MATLAB for evaluation of different parameter. First experimental results are for clustering in terms of Network life time. Network life is judged by number of alive nodes. Next experiment is performed for change point detection in terms of fire detection using FIS tool of MATLAB.

4.1. Experiment for Clustering

Performance of MEDC protocol has been measured over MATLAB with following Parameters. xm=100, ym=100, eo=0.05, n=100, ETX=50*0.000000000001, ERX=50*0.000000000001, Efs=10*0.000000000001, EDA=5*0.000000000001, Eadv=50*0.00000000001, RC=15, PS=32, and adv=10, Where xm and ym are used for field; eo is initial energy of a sensor; n is the number of sensors over random field; ETX is transmission energy used; ERX is receiving energy used; Efs is free space communication energy used; EDA is data aggregation energy; Eadv is energy used for advertisement; RC is a range of communications; PS is communication packet size and adv is the size of advertisement packet. Evaluation of MEDC, shows a number of live sensors with passing times or can say per round figure 1. After this, we had shown comparative results of MEDC and HEED see figure 2. Why we took HEED for comparison is because HEED is very famous Distributed Protocol [7]. We had executed HEED on same parameter and also taken some more parameters that are required for HEED like pmin=0.0001 (lower bound to probability), cprob=0.5 (Initial probability assigned to each sensor), chprob (Cluster head Probability, which will be assigned 0 at an initial level).

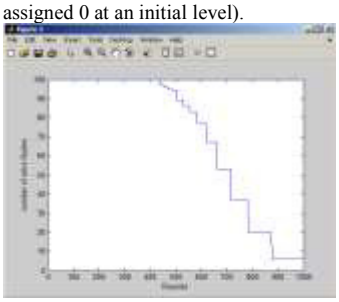

Figure 1: Performance Evaluation of MEDC

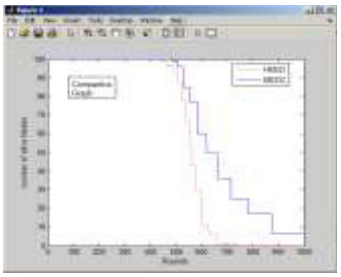

Figure 2: Comparative Performance Evaluation of MEDC with HEED

4.2. Experiment for change point detection

Before Change point detection information fusion will be performed. Information Fusion means the cluster head will collect and represent from cluster members. First experiment is to find which sensors are cluster heads and how many cluster members are under them. Here in following figure 3 snapshot of executed code on MATLAB is shown. Code information is taken according to MEDC protocol. This information presents that sensor no: 1 is not a cluster head so no cluster member under it. Sensor number 4 is cluster head of one member, sensor number 23 is cluster head of five sensor members. Cluster Head will calculate mean value of values received from member sensors. After this information fusion by calculating Mean value the next step is Change point Detection. Change point detection we had performed on FIS (Fuzzy Inference System). FIS is MATLAB tool to implement fuzzy logic. FIS is a method that interprets the values in the input vector and, based on some set of fuzzy rules, assigns values to the output vector. The FIS is having five steps, first is to Fuzzify Inputs, second is use of Fuzzy Operators third is Apply Implication Method Aggregate All Outputs followed by last step i.e. De-fuzzify the output. Here in this paper for fire detection example we are assuming that sensors are like MTS310 [18]. Each sensor node sense the parameters like temperature, humidity, light intensity, smoke density and the Carbon Monoxide (CO), after that this collected information gets transmit to the Cluster Head [1]. FIS is aimed for Fire Detection which will consider three

input variables i.e. heat index, relative humidity, carbon monoxide. Result of fire detection via FIS will be given by one output variable i.e. fire probability. In simulation values of First input variable heat index is taken according to Table 1 [4] which is data taken from Occupational Safety and health administration [4]. Second input variable is Relative humidity. Relative humidity is defined as percent, measures the current humidity relative to the maximum for that temperature. In simulation value of relative humidity is taken from chart given by National Oceanic and Atmospheric Administration refer figure 4 [15].

```
>> cluster_head_information
  Columns 1 through 19

    0    0    0    1    1    1    3    1    0    1    1    5    3    1    1    0    0    0    0

  Columns 20 through 38

    1    0    0    5    2    0    3    2    1    0    0    1    0    1    2    4    0    0    0

  Columns 39 through 57

    0    5    0    0    0    2    1    1    0    0    4    0    0    0    1    1    0    4    3

  Columns 58 through 76

    3    4    0    0    0    1    1    0    0    0    0    0    0    0    0    3    1    0    1

  Columns 77 through 95

    0    0    0    0    0    0    0    0    0    4    1    0    0    6    6    0    0    0    0

  Columns 96 through 100

    0    6    0    0    0
```

Figure 3. MEDC implemented Cluster Heads Information

Table 1. Heat Index Risk Level

Heat Index	Risk level
Less than 91°F	Lower
91° to 103°F	Moderate
103° to 115°F	High
Greater than 115°F	Very High to Extreme

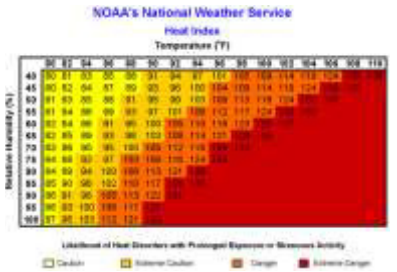

Figure 4. Relative Humidity and Heat Index

Next step is to show fire probability according to these parameters like Heat Index, Relative humidity, carbon monoxide etc. The experimental results are shown here, Figure 5 is representing three input variables are Heat

Index, Relative humidity, Carbon Mono-Oxide and one output variable i.e. Fire Probability. Figure 6 is representing three Input Variables with their membership functions. Figure 7 is representing one output variable i.e. Fire probability with its membership function. Figure 8 is rule viewer which will show the actual results that according to input variable with some given value what the probability of fire is. Like in given case if Heat index is 100 F relative humidity is 70% and carbon monoxide is 50 ppm then the fire probability is .482 means 48.2%. The table 2 will show output results value with different values of input variables.

Figure 5. Three Input Variables and One Output Variable

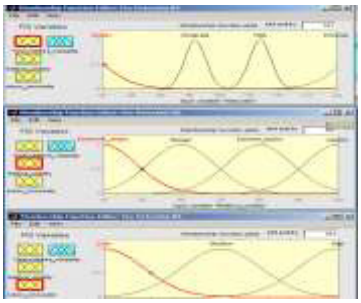

Figure 6. Three Input Variables with membership functions

Figure 7. One Output Variable with Membership function

Figure 8. Rule viewer of Fire Detection

Table 2-value of output probability according to different values of input variables

Input Variables			Output Variable
Heat Index $_{o}$F	Relative Humidity (%)	Carbon Mono-oxide(ppm)	Fire Probabilty
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

5. Conclusion

This paper had presented collective solution of change point detection and clustering. We had presented an extension to our previous work. MEDC clustering protocol had shown improvement in life time in contrast of HEED, the next step is along with clustering is that, now cluster head chosen will also perform first level change point detection. The change point detection will be done by Fuzzy logic. For experimental results of proposed work MATLAB and FIS has been chosen.

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