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CCTS with Two Clustering Techniques for Time Synchronization in Wireless Sensor Network

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Abstract: ***A new time synchronization algorithm for wireless sensor networks, named clustered consensus time synchronization (CCTS) with 2 clustering method LEACH and FCM. However, to obtain faster convergence in the clock synchronization of node and better energy efficiency, the clustering technique is incorporated into the algorithm. The CCTS includes two parts: 1) intra cluster time synchronization and 2) inter cluster time synchronization. In the intra cluster time synchronization, the cluster head is responsible for exchanging messages within the cluster. In the inter cluster time synchronization, cluster heads exchange messages via gate-way nodes. The clustering technique used is LEACH (Low Energy Adaptive Clustering Hierarchy) and for increasing the accuracy of the clustering method, incorporated Fuzzy C Means (FCM) clustering to this algorithm. By using this methods can increase the convergence rate and also can reduce communication traffic.***

Keyword: Clustered Consensus Time Synchronization, Clustering techniques, Fuzzy C Means, Low Energy Adaptive Clustering Hierarchy, Wireless sensor networks.

1. Introduction

A wireless sensor network (WSN) are spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling control of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on.

In wireless sensor network large numbers of nodes are deployed, these nodes sense the data from the environment and communicate the same to the sink or base station. To identifying the correct event time, these nodes need to be synchronized with global clock. Therefore, time synchronization is significant feature in WSNs.

In the Clustered Consensus Time Synchronization (CCTS) algorithm, the ' Fuzzy C Means (FCM)' that are incorporated in the clustering method LEACH. By using this method to the LEACH can increase the clustering accuracy than in the LEACH method. In hard clustering, data is divided into distinct clusters, where each data element belongs to exactly one cluster. In fuzzy clustering (also referred to as soft clustering), data elements can belong to more than one cluster, and associated with each element is a set of membership levels.

2. Problem Formulation and Solution

In the existing system a new time synchronization algorithm for wireless sensor network named clustered consensus time synchronization (CCTS) is proposed. This algorithm is incorporated with clustering method called, LEACH. The LEACH randomly selects nodes as cluster heads and performs periodic reselection, so that the high energy dissipation experienced by the cluster-heads in communicating with the base station is spread across all nodes of the network. Each iteration of cluster-head is called around. The operation of LEACH is split in to two phases that are set-up and steady phases. In the set-up phase, each sensor node chooses a random number between 0 and 1.If this is lower than the threshold for node n, T (n), the sensor node becomes a cluster-head.

The threshold T(n) is calculated as $T(n) = \begin{cases} \frac{P}{1-P[r \times \mathrm{mod}\,(1/P)]}, & \text{if } n \in G \\ 0, & \text{other wise} \end{cases}$

Where P is the desired percentage of nodes which are cluster-heads, r is the current round, and G is the set of nodes that has not been cluster-heads in the past rounds .The steady phase is of longer duration in order to minimize the overhead of cluster formation. During the steady phase, data transmission takes place based on TDMA schedule, and the cluster-heads perform data aggregation/fusion through local computation. The base station receives only aggregated data from the cluster-heads, leading to energy conservation .After a certain period of time in the steady phase, cluster-heads are selected again through the set-up phase. This clustering method had some disadvantage that is, cluster heads have some energy difference and also the cluster-heads will change accordingly after some time. So this cluster method is not much accurate. So that, to increase the accuracy of the clustering better method is needed. For achieving better clustering accuracy the Fuzzy C Means clustering method is incorporated in the existing LEACH algorithm.

a. FCM Algorithm

FCM is a data clustering technique in which a dataset is grouped into 'n' clusters with every nodes belonging to every clusters to a certain degree. A certain nodes that lies close to the center of a cluster will have a high degree of belonging or membership to that cluster and another node that lie far away from the center of a cluster will have a low degree of belonging or membership to that cluster.

This algorithm works by assigning membership to each node corresponding to each cluster center on the basis of distance between the cluster center and the node. More the node is near to the cluster center more is its membership towards the particular cluster center clearly; summation of membership of each node should be equal to one. After each iteration membership and cluster center are updated according to the formula

Membership of i^{th} node and j^{th} cluster center $\mu_{ij} = \frac{1}{\sum_{k=1}^{c}\left(d_{ij}\middle|d_{ik}\right)^{(2|m-1)}}$

j^{th} cluster center $V_j = \left(\sum_{i=1}^{n}(\mu_{ij})^m\right)/\left(\sum_{i=1}^{n}(\mu_{ij})^m\right) \forall_{j=1,2,....c}$

Where, n – number of nodes

V_j – represents the j^{th} cluster center

m –is the fuzziness index $m \in [1, \infty]$

C- represents the number of cluster center

μ_{ij}- represents the membership of i^{th} node to j^{th} cluster center

d_{ij}- represents the Euclidean distance between i^{th} node and j^{th} cluster center

Main objective of fuzzy c means algorithm is to minimize $J(U, V)$

$$J(U,V) = \sum_{i=1}^{n}\sum_{j=1}^{c}(\mu_{ij})^m \|X_i - V_j\|^2$$

Where $\|X_i - V_j\|$ is the Euclidean distance between i^{th} node and j^{th} cluster center

FCM Algorithm steps

Let X = {x_1, x_2, x_3 ..., x_n} be the set of nodes and
V = {v_1, v_2, v_3 ..., v_c} be the set of centers.

1. Randomly select 'c' cluster centers.
2. Calculate the fuzzy membership 'μ_{ij}' using the equation shown above
3. Compute the fuzzy centers 'v_j' using the equation.
4. Repeat step 2) and 3) until the minimum 'J' value is achieved or $||U^{(k+1)} - U^{(k)}|| < \beta$.

where,

'k' is the iteration step.
'β' is the termination criterion between [0, 1].
'$U = (\mu_{ij})_{n*c}$' is the fuzzy membership matrix.
'J' is the objective function.

The clustering technique in-corporated in CCTS is LEACH (Low Energy Adaptive Clustering Hierarchy)and the FCM. BOTH the clustering technique simultaneously select the cluster head and reselecting it, after that the process as same as explained below and obtain the synchronization. In this algorithm, the network is divided into overlapping clusters and the time synchronization process is divided into intra-cluster time synchronization and inter-cluster time synchronization. The intra-cluster time synchronization. Cluster-heads calculate the average values of the skew compensation parameters of intra-cluster virtual clocks of nodes within their clusters and the average values of intra-cluster virtual clocks of nodes, and then they update the clock compensation parameters of intra-cluster virtual clocks and simultaneously broadcast them to the neighboring nodes. Cluster member nodes receive the messages and update the local intra-cluster virtual clock compensation parameters to achieve the synchronization of intra-cluster virtual clocks. The inter-cluster time synchronization. The cluster-heads exchange their intra-cluster virtual clocks and their clock compensation parameters through gateway nodes. The received messages are given corresponding weights according to the size of each cluster. Then cluster-heads update skew and offset compensation parameters of network virtual clocks in order to achieve the synchronization of network virtual clocks.

3. Performance Evaluation

The perform analyses and simulations on convergence rate, communication traffic in MATLAB. The size of the network is 200 nodes distributed randomly. The network is divided into 4 clusters, the number of clusters distributed randomly.

A. Convergence Rate

Analyze the convergence rate of CCTS and CCTS with FCM clustering. The convergence rate can be calculated by the equation

$$k = \frac{1}{\log(1|\lambda)}$$

Where $\boldsymbol{\lambda}$ satisfies Cheeger's inequality $1 - 2\Phi \leq \boldsymbol{\lambda} \leq 1 - \Phi^2/2$. Where Φ is the conduction coefficient of the Markov chain.

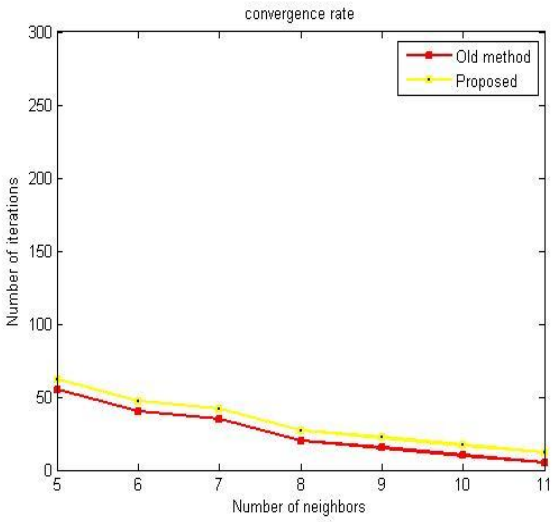

Figure 1: Convergence rate

The figure 1 shows that the convergence rate of networks can be much faster in CCTS with FCM than CCTS when the neighbor numbers of nodes increase.

B. Communication Traffic

In CCTS, the network with M clusters and n nodes needs $1+N_m$ messages within the cluster and n messages for the whole network in the intra-cluster time synchronization. In

the inter-cluster time synchronization, the number of messages exchanged between the clusters is $1 + 3|\overline{D_m}|$ and in the whole network is $\sum_{m=1}^{M}(1 + 3|\overline{D_m}|)$. So, in CCTS, the number of messages exchanged in a single-step iteration is $n + \sum_{m=1}^{M}(1 + 3|\overline{D_m}|)$. The comparison of communication traffic between CCTS and CCTS with FCM in a single-step iteration shown in figure 2. It shows the number of messages exchanged in the networks can be much higher in CCTS with FCM than CCTS when the size of network gets larger.

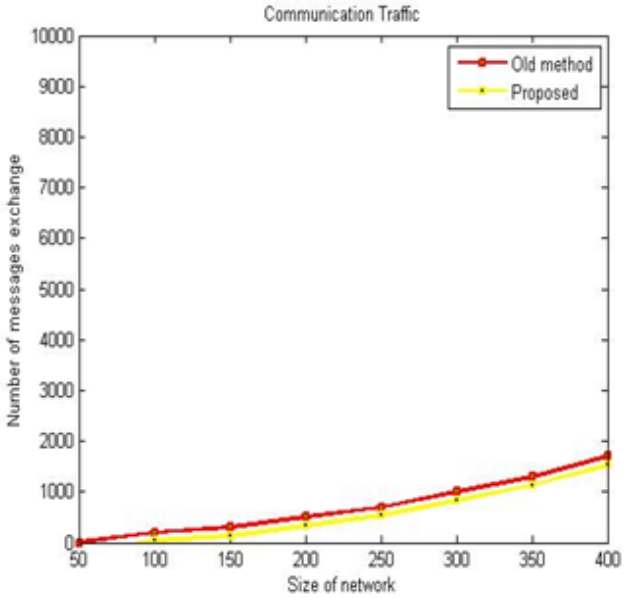

Figure 2: Comparison of communication traffic between CCTS and CCTS with FCM

4. Conclusion

In the existing system LEACH clustering method is used in the algorithm, here accuracy of clustering is less. Fuzzy c means clustering technique is incorporated in the existing method, thus increase the accuracy of the clustering. The clustered consensus time synchronization algorithm with clustering LEACH had good convergence rate but increase traffic in the communication. This new algorithm increases the clustering accuracy and also the convergence rate by incorporating the FCM to the existing system and also reduces the communication traffic than CCTS. Here by incorporating the FCM to the CCTS algorithm thus can increase the clustering accuracy and also the convergence rate and reduce the communication traffic.

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