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Study of an intelligent fuzzy based cluster head selection scheme for WSNs

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ABSTRACT

Wireless Sensor Network is a resource constraint network, in which all sensor nodes have limited resources. In order to save resources and energy data must be aggregated to reduce the amount of traffic in the network. Data aggregation has to done with the help of clustering scheme. Clusters reduce the localized traffic by means of grouping sensor nodes and compress the data together and then transmit only compact data to base station. Therefore optimal cluster head selection is important to maximize the lifetime of the network by utilizing the limited energy in an efficient manner. Various algorithms are proposed for the selection of cluster head for maximizing the network life time. This paper is focused on the survey of such algorithms.

Index Terms: Cluster, Hierarchical Cluster, Cluster Head Selection, Energy factor.

I. INTRODUCTION

Wireless Sensor Network (WSN) consists of autonomous sensors to monitor physical or ecological conditions, such as temperature, sound, pressure, etc.. The development of wireless sensor networks was motivated by military applications such as battlefield supervision; today such networks are used in many manufacturing and consumer applications, such as process monitoring and control, health monitoring, etc. Every sensor node has a power source typically in the form of a battery. Base stations may have one or more components of the WSN with infinite computational energy and act as a gateway between sensor nodes and the end user as they typically forward data from the WSN on to a server. [1].A new class of networks has evolved which is known as WSN, generated according to different needs of human. These networks are composed of large number of tiny sensor nodes are battery driven. These network nodes employed in the system without any infrastructure mainly with a view to keep an eye on the environmental and physical conditions and collectively pass all the collected data through the network the main locations called the sink nodes1 (cluster architecture show in fig.1)[2].

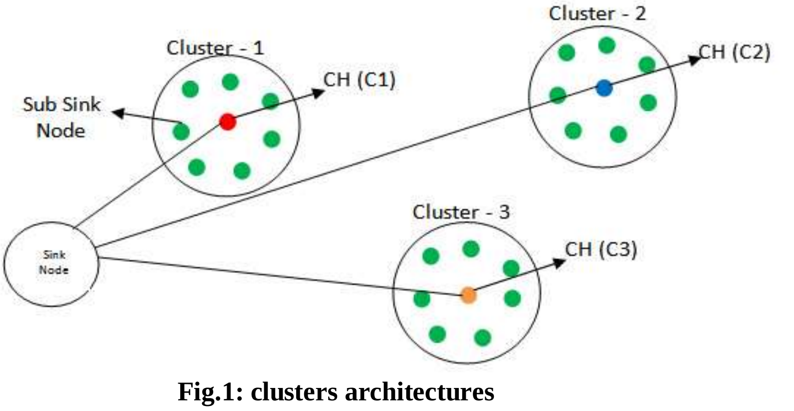

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Fig.1: clusters architectures

Battery life of these sensor nodes is limited and is impossible to recharge, therefore protocols for such networks should be design to maximize the network life time. Energy consumed is directly proportional to the distance of the communicating node to the sink node therefore more the distance, more is the energy consumed. [2] Each cluster has a chosen cluster head which is responsible for aggregating the data collected by its cluster members and disseminating the same to the sink node. Energy, battery life and distance of the node from the sink node are the key factors which are taken into consideration while electing the cluster head.

II Related work and motivation

A lot of work has been done in the field of wireless sensor networks [3]. Authors have proposed different methods for categorizing the documents.

a) Low-Energy Adaptive Clustering Hierarchy (LEACH) : In LEACH (Low-Energy Adaptive Clustering Hierarchy) protocol the data is sent to the cluster heads who in turns forward the same to the sink node after aggregating. The rounds in the LEACH operation are divided into two namely - a set-up phase and a steady-state phase. Organization of the clusters is done in the set-up phase and the data is sent to their cluster heads in the steady-state phase. Cluster Heads repeat after every P rounds, where P is the percentage of the cluster heads. Therefore each round has 1/P probability of becoming a cluster head in each round. A node that is not a cluster head selects a new cluster head that is closest to it at the end of each round and joins that cluster head. Head than creates a schedule for each node to transmit the data [4].

b) Power Efficient Gathering in Sensor Information Systems (PEGASIS) : PEGASIS is a chain-based protocol and an improvement over LEACH protocol. In PEGASIS, each node communicates with its immediate neighbour and finally transmits to the base station turn by turn 4, 7. Greedy algorithm or the phenomena of sending the chains by the sink nodes to the sensor nodes can be applied in organizing the sensors into chain. Only one node is allowed to aggregate the data and send it to sink. However this protocol needs a wider knowledge of the complete topology of the network whereby increasing the complexity of the protocol. Since there is only a fixed data path followed by every node, so in case of node failures discovering a new path is often difficult .This protocol helps in conserving energy but it does not focus much on the quality of service issue.

III- CLUSTERING IN WSN

Fig.2 shows collection of cluster head. Hierarchical clustering is the efficient way to utilize the energy in an efficient manner. Grouping of sensors that performing similar tasks are known as clusters. In hierarchical cluster, it contains Cluster Head, Regular Nodes and Base Station. After the cluster head is selected, it collects the data from all of its member nodes and aggregates it in order to eliminate the redundancy. Thus it limits the amount of data transmission to Base Station, hence remaining energy level is increased and network lifetime is maximized. There are several key attributes which must be carefully considered, while designing the clusters in WSN:

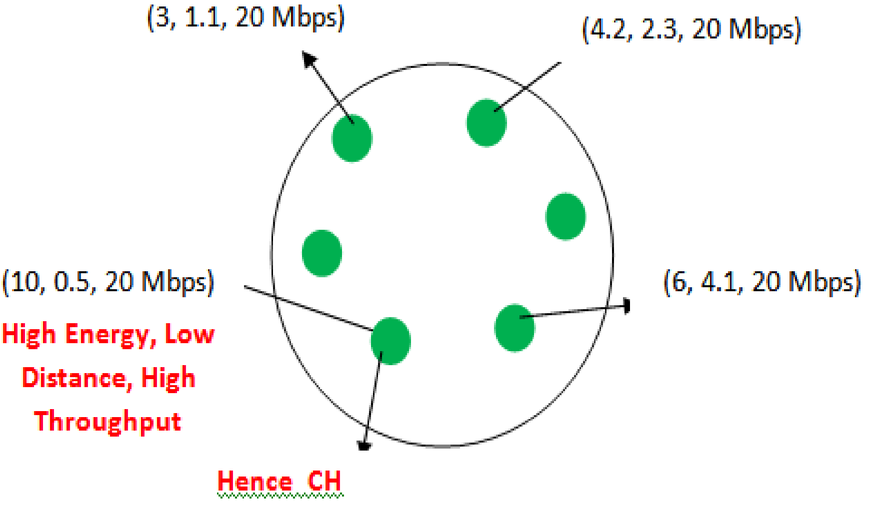

Fig.2: collection of cluster head

A. Clustering Parameters

1) Number of Clusters:
It may be varied according to the CH selection algorithms. In some cases this count will be the predestined one.

2) Intra-cluster Communication
Communication between the regular node and CH may be one-hop communication or multi-hop communication.

3) Nodes and CH Mobility
Cluster formation is dynamically changed in the case of sensor nodes are in mobility.

4) Node Type and Roles
Nodes may be in homogeneous or heterogeneous nature. In homogeneous, all sensor nodes have same capabilities such as same energy level, configurations. In heterogeneous, nodes are varied in configurations.

5) Cluster Head Selection

CHs are elected from the deployed nodes based on the criteria such as residual energy, connectivity, communication cost and mobility.CH selection may be in deterministic or probalistic manner.

6) Multiple Levels

In very large networks, multi level clustering approach is used to achieve better energy distribution.

7) Overlapping

Most of the protocols do not support for overlapping of different clusters.

8)A Survey on Algorithms for Cluster Head Selection in WSN

B. Issues to be Considered in Clustering

To create an organizational structure among sensor nodes in WSN, it has the ability to deploy them in an ad hoc manner, as it is not feasible to organize these nodes into groups‘pre -deployment. For this reason, there has been an large amount of research in ways of creating these organizational structures(or clusters).The clustering phenomenon, plays an important role in not just organization of the network, but can dramatically affect network performance. There are several key limitations in WSNs, that clustering schemes must consider [6].

1) Limited Energy

Unlike energetic designs, wireless sensor nodes are ―off-grid‖, meaning that they have limited energy storage and the efficient use of this energy will be vital in determining the range of suitable applications for these networks. The limited energy in sensor nodes must be considered as proper clustering can reduce the overall energy usage in a network.

2) Network Lifetime:

The energy limitation on nodes results in a limited network lifetime for nodes in a network. Proper clustering should attempt to reduce the energy usage, and hereby increase network lifetime.

3) Limited Abilities:

The small physical size and small amount of stored energy in a sensor node limit many abilities of nodes in terms of processing and communication abilities. A good clustering algorithm should make use of shared resources within an organizational structure, while taking into account the limitation on individual node abilities.

4) Application Dependency:

Often a given application will heavily rely on cluster organization. When designing a clustering algorithm, application robustness must be considered as a good clustering algorithm should be able to adapt to a variety of application requirements.

IV- CLUSTERING ALGORITHMS BASED ON WITHOUT ENERGY CONSIDERATION

A. LEACH Protocol [Low Energy Adaptive Clustering Hierarchy]

LEACH protocol organizes the nodes by themselves. Regular nodes in cluster send data to Cluster Head (CH). Cluster Head aggregates the data and sends to base Station. In LEACH [7] Cluster Head Selection is based on the desired percentage of CHs for the network and number of times the node has been a CH so far. Each node should select a random number between the interval 0 &1. If the generated random number is less than threshold then the node becomes a CH for current round. Threshold is obtained by using the following formula: T(n) = { P/1-P*(r mod 1/P) , if n ε G Where, P is the desired percentage of clusters; r denotes the current round; G denotes set of nodes that have not been CHs in the last 1/P rounds. Cluster Head Selection, Cluster Formation and Data Communication are taken place at a time instant is known as rounds. Each round has two phases: Set-up Phase & Steady State Phase. During Set-up Phase Cluster Head announces its election by sending advertisement message to all other nodes in order to form the cluster. During Steady State Phase each CH creates TDMA schedule for their members to transmit their data and it also tells when it to transmit. Nodes can send data during their allocated period. Radio of regular nodes is turned off until their scheduled time reached. Thus the energy is saved. Finally CH aggregates all data and sends to Base Station. Problems in Leach are:

1. CH selection is random and it does not consider about energy consumption of nodes. Therefore there may be a chance for CH will die earlier than other nodes. When CH dies, the cluster will become useless.
2. It cannot cover large area and CHs are not uniformly distributed.
3. It cannot be able to address the schedule ability and predictability measures.

V- CLUSTERING ALGORITHMS BASED ON ENERGY CONSIDERATION

A. Energy Residue Aware (ERA) Algorithm: In this algorithm, CH election is same as that of LEACH [7]. But it differs from cluster formation that is association between cluster head and other nodes. After the CH is elected according to LEACH, CH estimates their residual energy and broadcast this information to all other nodes. Residual energy of CH is calculated by subtracting the remaining energy of CH in current round from energy requirement for transmitting data to base station. All other regular nodes calculate their residual energy by subtracting their remaining energy in current round from energy requirement for transferring data to every CH. After this they associate with one CH according to the sum of maximum energy residue path. Thus it maximizes the network lifetime by balancing the energy consumption of the network. In LEACH, regular nodes choose their cluster head according to shortest distance; due to this there will be a chance for dying CH in earlier. Compared to LEACH, ERA prolongs network life time by energy consumption of nodes. ERA ensures optimal CH selection, prolongs network life time but it does not focus on predictability of network.

B. LEACH – C Algorithm [LEACH – Centralized]: In this, Cluster Head Selection depends on the current location of the node and residual energy. During setup phase, each node sends its current location and residual energy to base station. Base station estimates the average energy from the collected energy information. It finds that which nodes energy level is higher than average energy level; and those nodes will be selected as Cluster Head. After selection, base station broadcasts the message along with selected Cluster Head‘s ID to all nodes. Node whose ID is matched with the ID containing in the message becomes CH. In LEACH –C, CHs are dispersed throughout the network because it is based on location & residual energy. Here the problem is, base station is responsible for calculating average energy level; in case any one of the node fails to communicate with base station due to far away from base station then the successful probability of CH selection is less. LEACH – C considers the energy level of network but not focuses on predictability of network.

Algo to choose cluster ch's :

1. . Algorithm: Cluster Leader Selection
2. Input: Individual Sensor Node parameters
3. Output: Resultant Cluster Head Selection by nodes

Steps:

1. Initialize total number of sensor nodes.
2. Initialize number of cluster heads.
3. For every round,
4. FIS return selected CHs // k_ch store the ids of CHs
5. If (id of node=k_ch) then
6. Nid is a cluster head
7. Broadcast message to all nodes in the vicinity
8. Wait for reply messages
9. Perform cluster formation
10. else
11. wait to receive the messages from cluster heads
12. if (Received Msg = = 1) then
13. Choose it as a cluster leader
14. Else If (Received Msg>=2) then
15. Estimate the shortest dist, choose shortest dist. node as CH.
16. else
17. Nid is itself CH.
18. end If
19. round is completed .
20. Go to next round.

VI-FACTORS AFFECTING CLUSTER HEAD

CH selection technique in clustered sensor networks greatly affects the efficiency of the sensor networks. While going through various papers on efficient cluster head selection schemes, various parameters have been found out that greatly affect the performance of cluster head, these are listed below:

1. Residual energy – energy level in each node. The cluster head elected must have sufficient amount of energy so that it can survive for longer time as the cluster head consume power in receiving messages from its members, aggregate them and then finally send to the sink. So, residual power of node is the critical factor that must be considered while selection.

2. Number of Neighbors – number of nodes in neighborhood. The power consumed by the cluster head is also proportional to the number of nodes in its vicinity. More the number of members, more power will be dissipated in receiving their messages and in aggregation as more aggregate must have to be aggregate after removing redundancy.
3. Centrality – how central the node is to the cluster. If the cluster head is in the center of its cluster, it would be at the minimum distance from its members, so the non cluster head nodes will have to dissipate less energy for sending message to the cluster head, results in overall less energy dissipation in that cluster.
4. Proximity to sink – distance from base station. If cluster head is present nearer to the sink, less energy would be consumed in transmitting message to the sink. So, it is also the prime factor contributing towards the efficient cluster head selection.
5. CH to CH distance – distance between two cluster heads. Two cluster heads must be separated by a minimum distance as if they are very close, they will cover same nodes, so nodes will send data to both nodes resulting in data redundancy.

In our proposed approach, all the above factors are considered for cluster head selection in dual stage fuzzy environment. As the performance of LEACH is based on the random parameter means randomisation play an important role in cluster head selection hence in the efficiency of the networks. In our proposed scheme, five parameters affecting the cluster head and one random parameter are taken in dual stages to finally elect the cluster heads.

VII- APPLICATIONS OF WIRELESS SENSOR NETWORKS

1. **Environmental Applications :** Wireless Sensor Networks cover a wide range of environmental applications like tracking the movements of birds, small animals, and insects; monitoring environmental conditions that affect crops and livestock; irrigation; macro instruments for large scale Earth monitoring and planetary exploration ; chemical and biological detection; precision agriculture; biological, earth and environmental monitoring in marine, soil and atmospheric contexts; forest fire detection; meteorological or geophysical research ; flood detection; bio- complexity mapping of the environment; and pollution study[7].
2. **Home Appliances:** As technology advances, smart sensor nodes and actuators can be embedded in appliances such as vacuum cleaners, micro wave ovens, refrigerators, and VCRs. These sensor nodes inside the domestic devices can interact with each other and with the external via the Internet or Satellite. They allow end users to manage home devices locally and remotely more easily [7].
3. **Health Applications:** Some of the health applications of sensor networks are providing interfaces for the disabled; integrated patient monitoring; diagnostics; drug administration in hospitals; monitoring the movements and internal processes of insects or small animals; tele monitoring of human physiological data; and tracking and monitoring doctors and patients inside a hospital.
4. **Military Applications:** Since sensor networks are based on the dense deployment of disposable and low cost sensor nodes, destruction of some nodes by hostile actions does not affect a military operation as much as the destruction of a traditional sensor, which makes sensor networks concept a better. Some of the military applications of sensor networks are approach for battlefields.[7]
    1. **Monitoring friendly forces, equipment and ammunition:** Leaders and commanders can constantly monitor the status of friendly troops, the condition and the availability of the equipment and the ammunition in a battlefield by the use of sensor networks. Every troop, vehicle, equipment and critical ammunition can be attached with small sensors that report the status. These reports are gathered in sink nodes and sent to the troop leaders. The data can also be forwarded to the upper levels of the command hierarchy while being aggregated with the data from other units at each level.
    2. **Battlefield Surveillance:** Critical terrains, approach routes, paths and straits can be rapidly covered with sensor networks and closely watched for the activities of the opposing forces. As the operations evolve and new operational plans are prepared, new sensor networks can be deployed anytime for battlefield surveillance.
    3. **Reconnaissance of opposing forces and terrain:** Sensor networks can be deployed in critical terrain and some valuable, detailed, and timely intelligence about the opposing forces and terrain can be gathered within minutes before the opposing forces can intercept them.
    4. **Targeting:** Sensor networks can be incorporated into guidance systems of the intelligent ammunition.
    5. **Nuclear, biological and chemical attack detection and reconnaissance:** Sensor networks deployed in the friendly region and used as a chemical or biological warning system can provide the friendly forces with critical reaction time, which drops casualties drastically. We can also use sensor networks for detailed reconnaissance after a nuclear, biological and chemical attack is detected.
    6. **Battle damage assessment:** Just before or after attacks, sensor networks can be deployed in the target area to gather the battle damage assessment data.
5. **Office Building:** Airflow and temperature of different parts of the building can be automatically controlled.
6. **Warehouses:** Improve their inventory control system by installing sensors on the products to track their movement.

VIII CONCLUSIONS & FUTURE SCOPE

Wireless Sensor Networks have a great importance in today's scenario due to their practical applications in research areas as well as in daily life. There is an inherent characteristic of limited energy resource in WSNs; therefore, main focus is to make them energy efficient with enhanced lifetime. Clustering is an important method for lesser energy dissipation by decreasing the number of messages to be sent to the sink. It involves selection of cluster head based on some parameters, and then to send the aggregated messages to the sink after receiving messages from the nodes in its vicinity. The criteria of cluster head selection greatly affect the efficiency of the networks. In our approach, a two level fuzzy based technique is used in cluster head selection. In first level, the SNs are nominated for CH selection by using three parameters, i.e. residual energy, node concentration and centrality of the SNs. In second level i.e. election phase, three parameters i.e. proximity to sink, inter node distance and one random parameter are used to finally elect the cluster heads. The simulation of the proposed approach results in decreased energy consumption with lifetime maximisation when compared with LEACH.

One of the possible future works is to investigate how we can best control the number of associated cluster members in every cluster, to achieve a relative load balance in terms of number of nodes among all clusters formed. This would give better uniformity in their respective energy usage, eventually leading to further prolonged effective network lifetime.

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