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Energy Efficient and Optimal Randomized Clustering Protocol for Self Organization in WSN

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Abstract: The sensor networks are self-organizing and multiple hope wireless networks which do not depend on any kind of physical infrastructure or topology. Therefore such networks required self-organizing sensor nodes deployment especially for disaster management applications. In this project, new hybrid approach introduced for efficient disaster management using energy efficient clustering method and efficient self-organization approach. Self-organization using the clustering approach resulted into efficient network disaster management as well as energy efficiency approach. Since hierarchical clustering minimizes energy consumption by routing data from one node to another. In this paper, we proposed a new algorithm for self-organization of sensors deployed in a geographical area. We propose an energy efficient and optimal randomized clustering protocol. This approach improves overall network performances such as network lifetime, throughput, energy efficiency, communication overheads and Packet Dropped Ratio.

Keywords: wireless sensor network, clustering algorithms, self organization, Low Energy Adaptive Clustering Hierarchy, Energy Efficient Optimal Clustering.

I. INTRODUCTION

Communication technologies has changed tremendously over the past few decades from wired network (e.g. Ethernet, optical network) to wireless network (e.g. Wi-Fi, Cellular network), from centralized network to decentralized network. Along with the improvement and appearance of new communication techniques, the combination of multiple fields also provides considerable contribution in this change. In this scheme, Wireless Sensor Network (WSN) become knows communications and information technologies, coupled with technological advances in sensor technologies. This aggregation opens a door for a new low-cost sensor generation which is capable of a high-level spatial distribution.

Wireless Sensor Network is described as a network of tiny devices with low power consumption, years of operation, but limited computation, communication and memory. These characteristics open opportunities for new applications. However, there are some constraints in designing and operating WSN. Most of researches now focus on energy efficient designs, algorithms and protocols. It is a leap in monitoring and controlling activities not only in military area but also in industrial and civil fields.

In general, sensor networking is a multi-area domain including radio, networking, signal processing, database management, resource optimization, power management, platform technology (hardware and software), etc. The applications, networking principles, algorithms, and protocols for Wireless Sensor Network are in process of development.

A. Wireless sensor network

Wireless Sensor Network (WSN) is a network of spatial distributed autonomous sensors to monitor physical or environmental parameters and cooperatively transfer data to main server. Monitored parameters depend on the functions of sensor node in network such as physical sensors (e.g. temperature, moisture, and radio-wave frequency sensors), chemical sensors (e.g. dissolved oxygen, electrical conductivity, pH sensor), biological sensors (e.g. microorganisms sensor), national security oriented sensors and many other newly invented sensors. Nowadays, sensor is not only a single element but also equipped with multiple on-board sensing elements called sensor node.

A WSN usually has two main parts: (1) sensing system to generate and collect distributed sensor values; (2) data processing and storage system to process and locally store sensor values before forwarding to user.

Sensor network composed by hundred of self-organizing sensor nodes which communicate among each other by radio signal and form an ad-hoc like network. These sensors are small units having limited storage capacity, processing speed and radio bandwidth. Sensor nodes can be manually or randomly deployed and can cover a large area with high density depending on application requirements.

Data processing and storage system can be a normal server which stores sensor values and translates it into readable value for user.

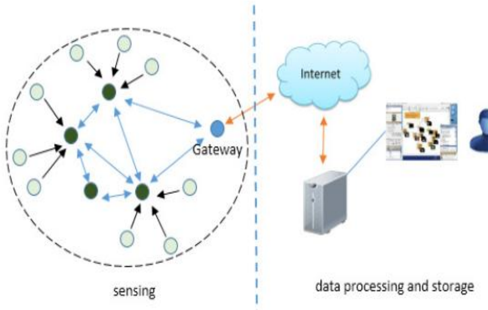

Fig. 1 Wireless sensor network components

WSN is an application oriented technology. Choosing and maintaining a proper network topology play important roles in improving network performance. It can be point-to-point (peer-to-peer), star, mesh, hybrid or tree topology depending on the aim of application and supports from communication technology used in network. A matching topology will enhance network performance in energy efficiency, bandwidth utilization, network deployment or event deployment cost. Generally, WSN topologies mainly use clustered topology.

In Clustered topology, only a subset of nodes (head-nodes) can route data among each other's and the rest will provide data only to routing node which they are connected to. Network is divided usually based on the geographical position of nodes. Nodes close together might be grouped in a cluster. Topology between clusters can be mesh (cluster-mesh), tree (cluster-tree) or their combination.

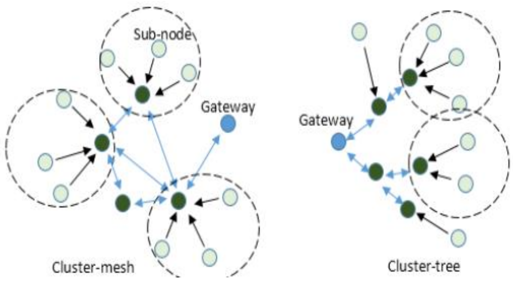

Fig. 2 Cluster Topology

Clustering in network will make network become hierarchical and also improve the bandwidth utilization because only some dedicated nodes maintain connection on communication channels. In stationary WSN, cluster-tree topology has the best energy efficiency while cluster-mesh topology provides the maximum robustness which allows multi-path routing and multiple sinks.

II. LITERATURE REVIEW

In this section we are discussing the different clustering methods presented for self organization in wireless sensor network.

In [1], author M. Aslam, N. Javaid, A. Rahim, U. Nazir, A. Bibi, Z. A. Khan present some energy efficient routing protocol, developed from conventional LEACH routing protocol. Their main focus is on how these extended routing protocol works in order to increase the life time and how quality routing protocol improved for the wireless sensor network. Furthermore, they also highlights some of the issues faced by LEACH and also explain how these issues are tackled by extended version of LEACH.

In [2], authors W. B. Heinzelman, A. Chandrakasan, and H. Balakrishanan develop and analyze low-energy adaptive clustering hierarchy-Centralized (LEACH-C), a protocol architecture for micro sensor networks that combines the ideas of energy-efficient cluster-based routing and media access together combination with data aggregation to obtain good performance in terms of application-perceived quality, system lifetime, and latency. LEACH-C includes a new, distributed cluster formation technique that allows self-organization of large numbers of nodes and also contains algorithms for adapting clusters and rotating cluster head positions to distribute the energy load among all the nodes. To save communication resources, this algorithm also have techniques to enable distributed signal processing.

In [3], K. T. Kim and H. Y. Youn propose PEACH protocol in WSN, which is a power-efficient and adaptive clustering hierarchy protocol. By using characteristics of wireless communication, PEACH forms clusters without additional overhead and supports multi-level clustering. In addition, PEACH is used for both location-unaware and location-aware wireless sensor networks. The simulation results show that PEACH minimizes energy consumption of each node and increases the network lifetime, compared with previous clustering protocols. The performance of PEACH is less affected by the distribution of sensor nodes.

In [4], K. T. Kim and H. Y. Youn propose a protocol called Energy Driven Adaptive Clustering Hierarchy (EDACH). In the presence of faults at the CHs, EDACH can increase the lifetime and reliability of sensor network. To increase lifetime, a proxy node can assume the role of the current CH during one round of communication. EDACH uses CHs which are having highest energy to detect and handle faults in any faulty CH. For performance evaluation, EDACH hires the simulation-based fault injection method which assumes that errors occur according to a predetermined distribution. It reduces the overhead of re-clustering and system reconfiguration and also provides improvement in the stability of the system .

In [5], Y. Hu, W. Li, Z. Kang proposes an energy efficient clustering algorithm for maximizing the lifetime of WSNs. In proposed scheme, a tree topology is adopted to connect the nodes inside each cluster which decides the cluster head based on the energy level of the nodes. A new model for deciding an optimal number of clusters is also proposed. Computer simulation shows that the proposed scheme increases the network lifetime and message delivery ratio compared to the previous methods.

In [6], author O. Younis, S. Fahmy present HEED (Hybrid Energy-Efficient Distributed clustering) protocol that periodically selects cluster heads according to residual energy and a secondary parameter, such as node closeness to its neighbours. HEED ends in O (1) iterations, causes low message overhead and obtain uniform cluster head distribution across the network.

In [7], authors S. Bandyopadhyay, E. Coyle propose EEHC (Energy Efficient Hierarchical Clustering) which is a distributed, randomized clustering algorithm for WSNs.

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In EEHC, CHs collect the information about the individual clusters and send the total report to the base-station. Their technique is based on two stages: Initial and extended. In initial stage, each sensor node decides itself as a CH with a probability p to the neighbouring nodes within its communication range. These CHs are named as volunteer CHs. In the second stage, the process is extended to allow multi-level clustering and generally builds h levels of cluster hierarchy.
In [8], authors D. Baker, A. Ephremides develops Linked Cluster Algorithm (LCA) which is a distributed clustering algorithm that uses TDMA frames for inter-node communication with each frame having a slot for each node in the network for communication and avoids communication collisions between nodes. Many papers focuses on single-hop clustering and guarantees that no node is more than one hop away from leader for proposing cluster formation and CH election algorithms,

In [9], authors Ephremides, J. Wieselthier, D. Baker develop Linked Cluster Algorithm 2(LCA2) that selects the node with the lowest id among all nodes that is neither a CH nor the previously selected CHs.
In [10], authors C. R. Lin, M. Gerla, developed a similar distributed algorithm to LCA2, which identifies the CH by choosing the node with the highest degree.
In [11] authors, Loscri, G. Morabito and S. Marano present TL-LEACH (Two Level LEACH). In their respective clusters, secondary nodes collect data from nodes. The two-level structure of TL-LEACH reduces the number of nodes that need to transmit to the base station so that it also effectively reducing the total energy usage hence energy efficient.

III.PROPOSED SCHEME

To present improved, energy efficient and self organized clustering protocols for wireless sensor network is main motive of this paper. This paper is divided into three sections. In first section we explain Low Energy Adaptive Clustering Hierarchy. After that next section contains Energy efficient and optimal clustering protocol for wireless sensor network. In last section we explain improved energy efficient optimal clustering using bio-inspired T-Ant protocol which is used for data collection. In last we will compare each on the basis of network parameters such as Average throughput, Energy consumption, Communication overhead, Network lifetime and packet delivery ratio.

A. LEACH (Low Energy Adaptive Clustering Hierarchy)
LEACH is hierarchical routing Protocols used for wireless sensor networks. It increases the life time of sensor network. LEACH performs clustering and self-organizing functions for every round. In LEACH routing protocol, sensor nodes creates clusters. In every cluster, one of the sensor node acts as cluster-head and remaining sensor nodes as member nodes of that cluster. Cluster-head can only directly communicate to sink and member nodes use cluster-head as intermediate router in communication between member nodes and sink node. Cluster-head collects the data from all the member nodes, aggregate it and send information to Sink node. Cluster-head dissipates more energy because of these additional responsibilities and it will die quickly as happened in case of static clustering if it remains cluster-head permanently. LEACH solves this problem by rotation of cluster-head to save the battery of individual node. Thus, LEACH maximizes network life time and reduces the energy consumption by shortening the header files of date before transmitting to cluster-head. LEACH routing protocol works on round operation. It is worked in two phases. First is setup phase and second is steady state phase.

In setup phase cluster formation is carried out. After that cluster-head selection is done. Whole network is divided into multiple clusters. Some nodes select us as a cluster-head independently from other nodes. These nodes decide themselves as a cluster-head on basis of percentage P and its previous record as cluster-head. Those Nodes which were not cluster-head in previous 1/p rounds produce a number between 0 to 1 and nodes become cluster-head if it is less then threshold T (n).

$$T(n) = \begin{cases} \frac{P}{1-P*(r \bmod \frac{1}{P})} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

Where G is set of nodes, P= suggested percentage of cluster-head, r =is current round. The node becomes cluster-head in current round, it will be cluster-head after next 1/p rounds. The basic architecture of LEACH protocol is shown in fig below.

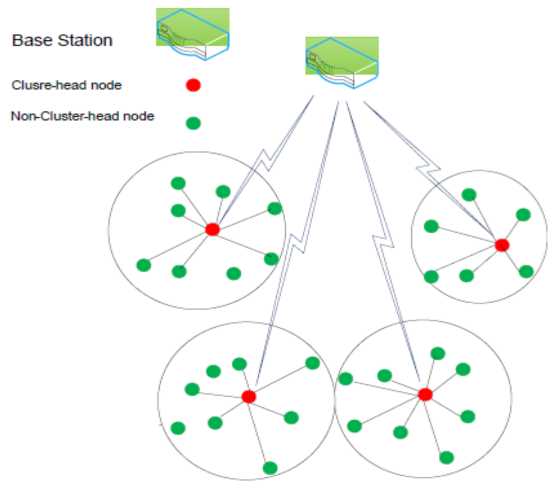

Fig. 3 LEACH

B. Energy efficient optimal clustering Protocol
We first discuss the system model and energy model used in the proposed routing scheme.

A. System and Energy Model:
We consider a WSN of a number of sensor nodes distributed randomly in the target area. The sensing nodes periodically form the clusters and have enough transmission power to reach the BS.

The following assumptions on the sensor nodes and underlying network employed:

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- All nodes are having the same capabilities and they are homogeneous. Each node is assigned a unique identifier.
- All sensor nodes are having same initial energy.
- When two communicating sensor nodes are not within each other's radio range, data are forwarded through other nodes.
- The BS has no energy constraint and is located far away from the target area.
- A routing and MAC infrastructure are in place, and the communication environment is contention and error-free.
- To reduce the number of messages in the network, data fusion or aggregation is used.

B. Protocol approach:
In this subsection we introduce the proposed scheme which employs tree topology in each cluster to evenly distribute the energy load among the sensors in the network. The proposed scheme consists of two phases, clustering phase and data transmission phase. We discuss each of them In the following sub-sections in detail.

1) Optimal number of cluster:
The cluster-based protocols adopting a simple hierarchical path selection approach do not need any information on the location of the nodes or upper layer control. Since each node is selected as CH with the same probability, the load can be balanced. However, the following issues need to be resolved. Firstly, the optimum number of clusters, kopt, needs to be decided. If the number of clusters is smaller than kopt, some nodes may exhaust its energy for transmitting data to the CH locating far. With excessive number of clusters, on the other hand, the nodes will quickly deplete their energy for direct communication to the BS. LEACH sets kopt as 5% of the nodes without any formal model.

Secondly, each node has equal probability to be a CH. If a node of low energy is selected as a CH, however, it will quickly deplete its energy due to the heavy load of CH. This shortens the network lifetime. Therefore, we need to introduce a new threshold value, which is decided based on the probability of optimal number of CHs and the residual energy of the nodes, to properly select the CHs.

2) Selection of cluster head:
LEACH adopts the random mechanism of CH selection, in which CH is randomly selected and all the sensor nodes within a cluster take turns to be the CH. This leads to balanced energy consumption of all nodes, and hence a longer lifetime of the network. However, this approach can locate the CHs unevenly. It causes the energy consumption of the nodes unbalanced and reduces the lifetime of the network. In order to solve this problem, the proposed scheme introduces three parameters to stochastically select the CH. The first parameter is the energy ratio between the current energy vs. initial energy. The second one is the round number. The third one is the count that the node has been selected as the CH.

After the CHs are selected using the proposed probability function, each node electing itself as a CH for the current round broadcasts an advertisement message (ADV_Msg) to other nodes. When a node receives an ADV_Msg messages from the CHs, it sends the join-request message (Join_REQ) to the CH which it chooses as its CH based on the received signal power. After the CH receives the message (Join_REQ), the CHs identify their member nodes based on the received Join_REQ message. Once the clusters are created, tree configuration in each cluster begins.

3) Tree configuration in cluster:
After the clusters are formed, a tree is built with the member nodes where the CH is the root. In the tree structure one sensor node can have one parent and many children nodes. All member nodes in a cluster are arranged in m levels starting from a CH. The CH is the root of tree, and it is at level 0.

4) Data collection and Transmission:
Once the level based tree construction in each cluster is complete, the data collection and transmission phase begins. In this phase each node sends the collected data to the parent node during the pre-allocated time slot appointed by the CH. We choose to implement a time division multiple access (TDMA)-based MAC layer for the slot assignment.

IV. PRACTICAL ANALYSIS

A. Simulation Platform
For simulation of this work we need following setups requirement for the same

i. Cygwin : for conversion of windows environment into Linux
ii. NS-allinone-2.32
iii.

B. Network Scenarios
Two network scenarios and traffic files needs to generate in order to evaluate the performance of the routing protocols under the different network conditions.

Following table shows network scenarios and other parameters used for practical analysis

Number of Nodes	30/60/90/120/150
Traffic Patterns	CBR(Constant Bit Rate)
Network Size	1000 x 1000 (X x Y)
Maximum Speed	11 mbps
Simulation Time	20 sec
Routing Protocol	LEACH, Optimal clustering
MAC Protocol	802.11
Initial Energy (J)	50 J (for each node)

Table 1 Network Scenario and Parameters

C. Performance Metrics

- PDR Vs Number of Sensor nodes
- Network lifetime Vs Number of Sensor nodes
- Avg. Energy consumption Vs Number of Sensor nodes
- Avg. Throughput Vs Number of Sensor nodes
- Communication overhead Vs Number of Sensor node

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D. Result Analysis

In this section, we are presenting graphs for performance metrics defined in above section and compare each performance metrics in each clustering protocol

a. Packet Dropped Ratio (PDR):

It is calculated as the difference of generated packets by the source node with received packets at destination node. The simulation in turn gives the packet dropped ratio across entire sources and destinations identified in the network.

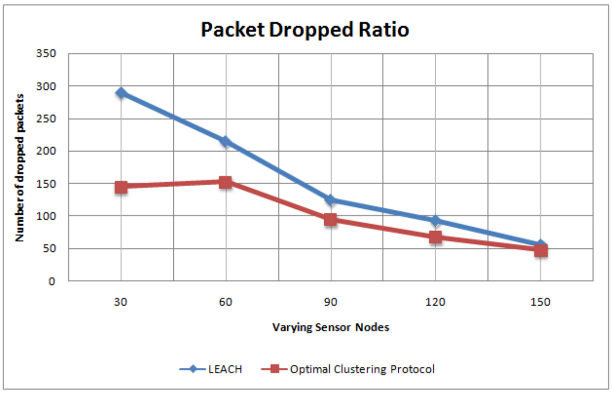

Fig. 5 Packet Delivery Ratio analysis

b. Network Lifetime:

With higher importance on the efficient use of the critical network resources such as battery power, the Optimal clustering protocol prolongs the network lifetime in terms of energy retained in the individual sensor nodes and across clusters than LEACH clustering protocol. Comparative analysis result shows that Optimal clustering protocol gives better network lifetime than LEACH protocol.

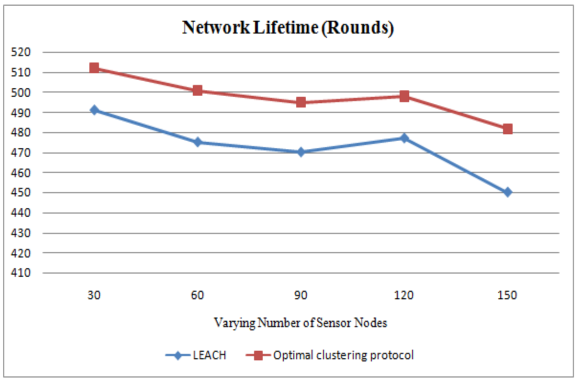

Fig. 6 Network Lifetime Analysis

c. Average energy consumption:

The energy consumption is defined as the percent of energy consumed by a node with respect to its initial energy. At the end of the simulation run, the initial energy and the final energy left in the node are measured. The percent energy consumed by a node is calculated as the energy with respect to the initial energy. The percent energy consumed by all the nodes is calculated as the average of their individual energy consumption of the nodes.

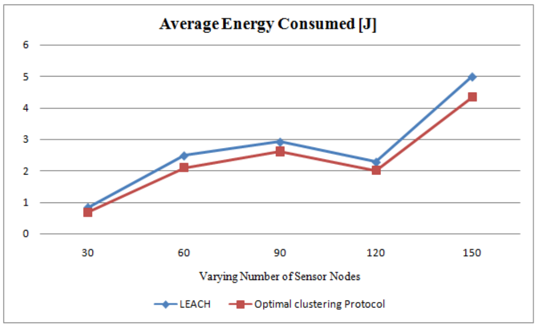

Fig. 7 Average Energy Consumption Analysis

d. Average Throughput:

Average Throughput is defined as average the overall rate of successful message delivery across all communication channels or communication links present in the network.

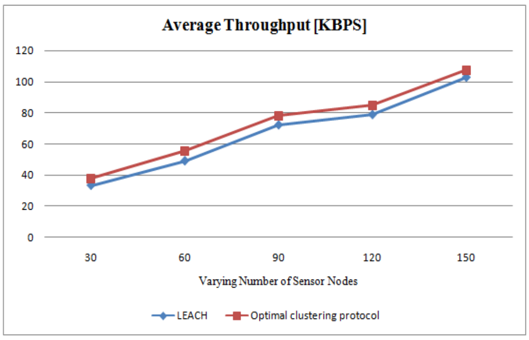

Fig. 8 Average Throughput Analysis

e. Communication Overhead:

The total number of control packets that contain control information is given by the total number of actual data packets and hence a least communication overhead is calculated during the simulation.

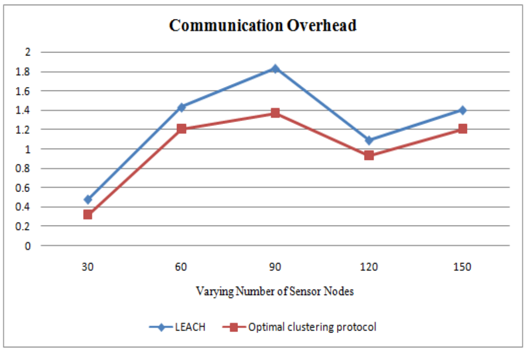

Fig. 9 Communication Overhead Analysis

V. CONCLUSION

In this paper, we have described the detail overview of project scenario. First we have taken energy efficient clustering protocol i.e. LEACH for self organizing wireless sensor network. In general, clustering in WSNs has very high importance in research. Throughout this work we have concentrated on the main characteristics of sensor networks such as throughput, communication overhead, network lifetime and energy consumption. We also introduce the proposed scheme which employs tree topology in each cluster to evenly distribute the energy load among the sensors in the network. Also compare the results of proposed scheme with LEACH protocol.

In next section we are proposing improved energy efficient optimal clustering using T-Ant Protocol which uses bio-inspired data gathering protocol in disaster affected wireless sensor network. This protocol also improves all the network parameters with respect to above two protocols.

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