Cluster Initialization in Dense Distributed Wireless Sensor Networks using Jumping Ants

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***Abstract*—** A wireless sensor network is used as an effective tool for collecting data in various situations. Recent researches in wireless communications and electronics has enabled the development of low-cost wireless sensor network. Wireless sensor networks are group of sensor nodes with a set of processors and limited memory unit embedded in it. Reliable routing of packets from sensor nodes to its base station is the most important task for these networks. Clustering is an important task for attaining some valued outputs like improved energy efficiency, reduced delay, increased throughput and reduced data losses. In order to produce well balanced clusters, the cluster head is rotated periodically with the help of a distributed algorithm. This paper gives a detailed study of various distributed clustering approaches. A detailed research is made on optimized cluster initialization based on jumping ant approach in order to avoid random cluster initialization. Also this mechanism shows directions on how to rotate the cluster head periodically and energy efficiently. The algorithm consists of three stages. In the first stage, the ants move towards the available food. In the second stage, the ants that gets sufficient food stays in that cluster. In the third stage, the foodless ants jumps and form another cluster. This mechanism clearly shows an excellent improvement over those with random initializations.

Keywords*—Wireless sensor network, distributed clustering algorithm, ant colony optimization, jumping ant, energy efficiency, network lifetime.*

I. INTRODUCTION

A Wireless Sensor Network consists of a group of spatially distributed sensor nodes which are interconnected without using wires. Each of the distributed sensor nodes typically consists of one or more sensing elements, a data processing unit, communicating components and a power source, which is usually a battery. The sensed data is collected, processed and routed them back to the desired end user through a designated sink point, referred as base station. Now it has become feasible to construct multifunctional sensor nodes with advanced capabilities. Such sensor nodes are relatively of smaller size, lower cost and lesser power consumption. WSNs are originally motivated for the use in military applications, such as border monitoring. In a typical sensor network, each sensor node has a microprocessor and a small amount of memory for signal processing and task scheduling. Each node is also equipped with one or more sensing devices such as acoustic microphone arrays, video or still cameras, infrared (IR), seismic, or magnetic sensors [1].

Each sensor node communicates wirelessly with a few other local nodes within its radio communication range. Sensor networks extend the existing Internet deep into the physical environment. The resulting new networks is orders of magnitude more expansive and dynamic than the current TCP/IP network and is creating entirely new types of traffic that are quite different from what one finds on the Internet now. Information collected by and transmitted on a sensor network describes conditions of physical environments-for example, temperature, humidity, or vibration and requires advanced query interfaces and search engines to effectively support user-level functions [2]-[5].

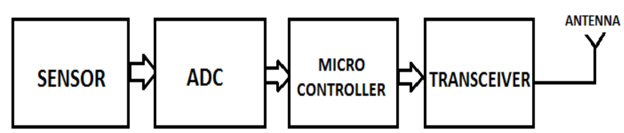

Fig.1: Components in a sensor network

Sensor networks may inter-network with an IP core network via a number of gateways. A gateway routes queries or commands to appropriate nodes in a sensor network. It also routes sensor data, at times aggregated and summarized to users who have requested it or are expected to utilize the information. A data repository or storage service may be present at the gateway, in addition to data logging at each sensor. The repository may serve as an intermediary between users and sensors, providing a persistent data storage. Additionally, one or more data storage devices may be attached to the IP network, to archive sensor data from a number of edge sensor networks and to support a variety of user-initiated browsing and searching functions [6]-[11].

II. REVIEW OF EXISTING DISTRIBUTED CLUSTERING ALGORITHMS

One of the well-known clustering algorithm is Energy-Efficient Hierarchical Clustering (EEHC) [14], a randomized clustering algorithm organizing the sensor nodes into hierarchy of clusters with an objective of minimizing the total energy spent in the system to communicate the information gathered by the sensors to the information processing center. Another clustering algorithm, Linked Cluster Algorithm (LCA) [15] was mainly implemented to avoid the communication collisions among the nodes by using a TDMA time-slot. It uses a single-hop scheme, attains high degree of connectivity when CH is selected randomly. With an objective to form overlapping clusters with maximum cluster diameter of two hops, CLUBS [16] was implemented in WSNs. The clusters are formed by local broadcasting and its convergence depends on the local density of the sensor nodes. This algorithm can be implemented in asynchronous environment without losing efficiency. The main drawback is the overlapping of clusters, clusters having their CHs within one hop range of each other, thereby both clusters will collapse and CH election process will restart. Fast Local Clustering Service (FLOC) [17] achieves re-clustering in constant time and in a local manner in large scale networks, exhibits double-band nature of wireless radio-model for communication. According to Energy Efficient Clustering Scheme (EECS) [18], all CHs can communicate directly with base station. The clusters have variable size, such that those nearer to the CH are larger in size and those farther from CH are smaller in size. It is proved to be energy efficient in intra-cluster communication and excellent improvement network lifetime.

Energy Efficient Unequal Clustering mechanism (EEUC) [19], was proposed for uniform energy consumption within the network. It forms unequal clusters, with an assumption that each cluster can have variable sizes. Based on nodes' residual energy, connectivity and a unique node identifier, the cluster head selection is accomplished in Distributed Efficient Clustering Approach (DECA) [20]. It is highly energy efficient, as it uses fewer messages for CH selection. The main problem with this algorithm is that high possibility of wrong CH selection which leads to discarding of all the packets sent by the sensor node. In order to select CH based on weight: a combination of nodes' residual energy and its distance to neighboring nodes, Distributed Weight-based Energy-efficient Hierarchical Clustering (DWEHC) [21] has been proposed. It generates well balanced clusters, independent on network topology or size. Hybrid Energy-Efficient Distributed Clustering (HEED) is a well distributed clustering algorithm in which CH selection is done by taking into account the residual energy of the nodes as well as intra-cluster communication cost leading to prolonged network lifetime.

III. ADAPTIVE CLUSTERING MECHANISMS

Low Energy Adaptive Clustering Hierarchical Protocol (LEACH) uses the following techniques to achieve the design goals: randomized, self-configuring and adaptive cluster formation, Local control for data transfers and low-energy media access control and application specific data processing. LEACH protocol has many rounds and each round has two phases, a setup phase and steady state phase, in set up phase it provides cluster formation in adaptive manner and in the steady state phase transfer of data takes place. LEACH uses a TDMA or a CDMA MAC to reduce inter-cluster and intra cluster collisions. Cluster formation based on many properties such as the number and type of sensors, communication range and geographical location. The energy consumption of the information gathered by the sensors node to reach the sink will depend on the number of cluster heads and radio range of different algorithms, because the energy consumption can be reduced by organizing the sensor nodes in the clusters. LEACH-F: In this author proposed an algorithm in which the number of clusters will be fixed throughout the network lifetime and the cluster heads rotated within its clusters. Steady state phase of LEACH-F is identical to that of LEACH. LEACH-F may or may not be provided energy saving and this protocol does not provide the flexibility to sensor nodes mobility or sensor nodes being removed or added from the sensor networks [12]-[13].

LEACH-C: LEACH cluster formation algorithm has the disadvantages of guarantee about the number of cluster head nodes and its placement. Since the clusters are adaptive, so there is poor clustering set-up during a round will affect overall performance. However, using a central control algorithm to form the clusters may produce better clusters by distributing the cluster head nodes throughout the network.

LEACH-B : Authors proposed decentralized algorithms of cluster formation in which sensor node only knows about own position and position of final receiver and not the position of all sensor nodes. LEACH-B operates in following phases: Cluster head selection algorithm, Cluster formation and data transmission with multiple accesses. Each sensor node chooses its cluster head by evaluating the energy dissipated in the path between final receiver and itself. It provides better energy efficiency than LEACH.

LEACH-ET: In this cluster will change only when one of the following conditions is satisfied: first, Energy consumed by anyone of the cluster head nodes (CHs) reach energy threshold (ET) in one round. Second, every sensor node should know the energy threshold (ET) value. If in initial phase, anyone of the cluster head nodes dies. If any sensor node acts as a cluster head node (CHs) in a certain round, it should have the energy dissipated value and compares the dissipated value with the energy threshold (ET) value. Energy–LEACH: it provide improvement in selection of cluster heads of LEACH protocol It makes residual energy of the node as the main factor which decides whether these sensor nodes turn into the cluster head or not in the next round. E- LEACH improves the cluster head election procedure that is chosen in LEACH protocol node cannot be chosen to be a cluster head node. This protocol provides longer network life time and energy saving compared to LEACH protocol.

TL-LEACH: its works in three phases, cluster-head casing, Cluster setup and data transmission. In this protocol the author improve the LEACH in which some of the cluster heads elected during setup phase in LEACH were chosen again as the level-2 cluster heads (CHs), which have the communication with the base station.

MH-LEACH: In this author proposed a protocol which improves communication mode from a single hop to multi hop between cluster head and base station. In LEACH protocol each cluster head directly communicates with sink and the distance between the sink and cluster head does not matter, if the distance is large it will consume more power. So modified form like MH LEACH protocol which adopt an optimal path between the base station and cluster head and multi hop communication takes place among cluster heads.

ACHTH –LEACH: The author has induced ACHTH - LEACH to improve LEACH and rectify its defects. The clusters are set up based on the Greedy k-means algorithm. The cluster heads are elected by considering the residual energy of sensor nodes. And the cluster heads may adopt two-top transmission to reduce the energy spent on sending data to the BS. The simulation results show that ACHTH-LEACH effectively prolong the lifespan of the network by the balanced clustering approach and the two-hop communication to the BS. The performance of ACHTH-LEACH can be further improved if some parameters and threshold values are optimized in and the percent of nodes alive is less than threshold values are optimized [21] –[22].

MELEACH-L: In this paper the authors enumerated energy-efficient multi-channel routing protocol for wireless sensor networks. With the aid of controlling the size of each cluster and separating CHs from backbone nodes, MELEACH-L manages the channel assignment among neighbor clusters and the cooperation among CHs during the data collection. Analysis and simulations clearly show the validity of the two criteria for large-scale WSNs and the energy-efficiency of MELEACH-L. cluster formation, Local control for data transfers and low-energy media access control and application specific data processing. LEACH protocol has many rounds and each round has two phases, a setup phase and steady state phase, in set up phase it provides cluster formation in adaptive manner and in the steady state phase transfer of data takes place. LEACH uses a TDMA or a CDMA MAC to reduce inter-cluster and intra cluster collisions. Cluster formation based on many properties such as the number and type of sensors, communication range and geographical location. The energy consumption of the information gathered by the sensors node to reach the sink will depend on the number of cluster heads and radio range of different algorithms, because the energy consumption can be reduced by organizing the sensor nodes in the clusters [38]. LEACH-F: In this author proposed an algorithm in which the number of clusters will be fixed throughout the network lifetime and the cluster heads rotated within its clusters. Steady state phase of LEACH-F is identical to that of LEACH. LEACH-F may or may not be provided energy saving and this protocol does not provide the flexibility to sensor nodes mobility or sensor nodes being removed or added from the sensor networks.

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MS-LEACH: In this paper the authors have analyzed the problem of energy consumption of the single-hop and multi-hop transmissions in a single cluster. Finally a critical value of the cluster area size is determined. MS-Leach is based on the critical value. Simulation results clearly show that MS-Leach outperforms at most by 200% in term of network lifetime. It is proposed as future work its relationship between multi-hop and single-hop transmissions will be analyzed in-depth in various protocols and new mechanisms of routing will be developed.

Trust-Based LEACH: Since the commonly security solution based on cryptography and other traditional methods which cannot incorporate new challenges from internal attackers, and trust is recognized as a novel approach to defend against such attacks. In this paper the authors have proposed a trust-based LEACH protocol to provide secure routing, while keeping the necessary functionalities of the original protocol. The decision-making is based on the decision trust, evaluated independently and adaptively for different decisions by basic situational trust.

LEACH-DCHS-CM: The authors have presented a LEACH-DCHS-CM algorithm against the characteristic of the frequent formation of the clusters in LEACH-DCHS algorithm. Highlighted the option of using energy balance clustering algorithm when the number of failed nodes up to a certain extent. As a future wok main concentration on the “certain value” settings of nodes also deserve further research.

TB-LEACH: A new protocol of Cluster-Head Selection Algorithm for LEACH based on time (TB-LEACH). Principle of TB-LEACH is stated and the main flowchart and pseudo codes realizing TB-LEACH. Analysis between new protocol and LEACH protocol is done which significantly shows that there is an improvement which is done by formation of a constant number of clusters; TB-LEACH constructs the cluster by using an algorithm based random-timer, which doesn't require any global making is based on the decision trust, evaluated independently and adaptively for different decisions by basic situational trust.

IV. THE PROPOSED MODEL

This investigation presents a Jumping Ant based Cluster Formation (JACF) algorithm that combines the advantages of Ant based algorithm and Zone based algorithm, also employing jumping mode to reduce time needed for cluster initialization. The first part relates to how each node uses proactive clustering mechanism to maintain the topology of q hops. The other part concerns how each node applies jumping ants for a node which has failed to become a cluster member, turning in to a cluster head. Each node has its own zone, and each ant joins a cluster within q hops. Hence, each ant jumping q+1 hops denote the failure to become a cluster member.

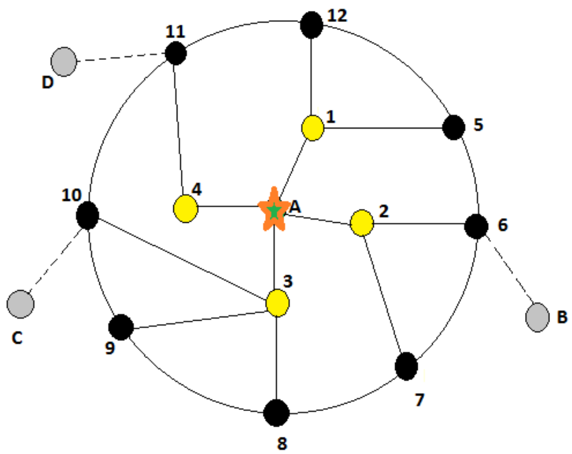

Fig.2: The proposed model

The node which has jumped to q+1 hops has the maximum probability of constructing a new cluster. This work explains and simulates the proposed algorithm, using q = 2. The setting q = 2 was chosen because it is sufficient to demonstrate the predominance of the proposed algorithm. Each node in the proposed algorithm can discover detailed information of neighboring nodes within q hops. These neighboring nodes can be organized into a zone called the cluster. The node that jumps for q>1 hops is called as a jumping ant or a next cluster head. Those nodes within a zone are classified into boundary and interior nodes. The cluster initialization and cluster formation is considered to involve the following stages that are discussed precisely.

A. Cluster head discovery

Ants are classified as forward, backward and guide ants. Forward and backward ants are responsible for collecting path information and updating pheromone. A guide ant constructs an optimal cluster when all the backward ants have arrived at source a node, or when the network topology has changed. The initial cluster head (ICH) node creates several forward ants to search for cluster members. The ants gather path information as they travel along the path. A node creates a backward ant when a forward ant arrives there. The backward ants are sent back following the reverse path and sends information to the cluster head. The guide ant is generated when all backward ants have arrived at the source. The guide ants help in forming a cluster with a maximum of q hops from the cluster head.

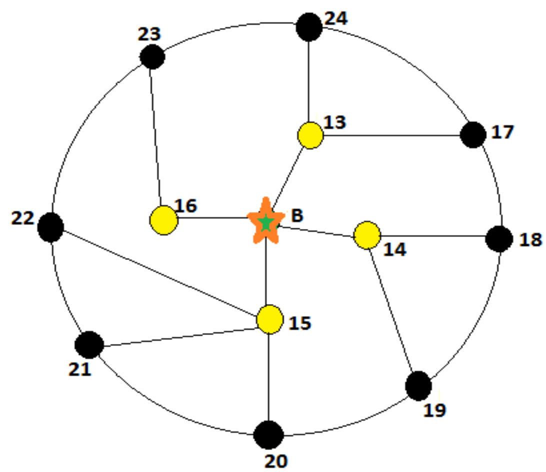

Fig.3: Operation of the proposed model

B. Forward directional ant

Every node in the network can be considered as a CH or cluster member nodes. A node that wants to become a CH sends forward ants to search for its cluster members and obtain path information. When a forward ant is generated by source node, it adopts the pheromone table to obtain the next visiting node and record the path information. In the proposed algorithm, ants prefer to move to a node that has not been visited. Such behavior is introduced to prevent ants from being enticed into the already clustered node. A forward ant moving to an intermediates node utilizes the probability of pheromone table, adds the next node to intermediates node stack and obtains local heuristic information to update path information of the forward ant packet. If the forward ant moves to the interior node, then the interior node need not do anything, but only relays the forward ant to the next node. The forward ant is killed when it arrives at the cluster node and a backward ant is then created. The cluster node also employs path information to obtain a grade to assign to the backward ant.

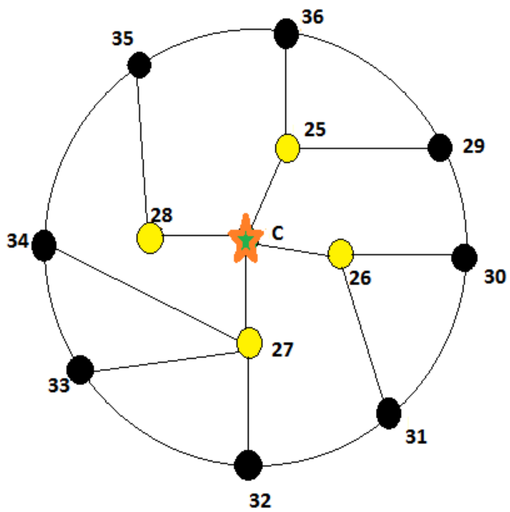

Fig.4: Path selection in the proposed model

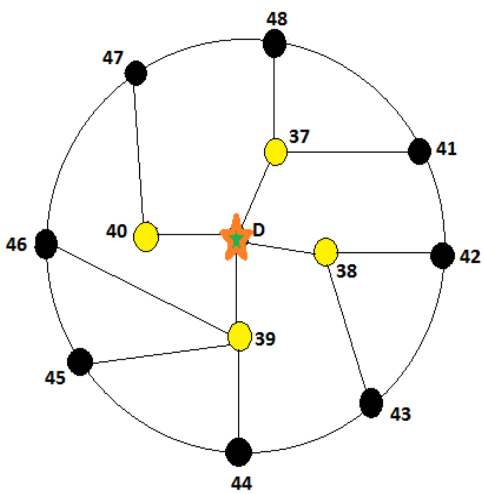

Fig.5: Final Path selection in the proposed model

C. Backward directional ant

When the backward ant is received, if this node is intermediate node of the backward ant's stack, then the node collects the grade from the backward ant's stack and then joins the node that have sent the backward ant as its cluster member. If the node is in q>2 hops, then the node does not get a chance to join this particular cluster. The backward ant is killed when it arrives at the CH.

D. Network topology changed

A guide ant is generated when the network topology changes. The guide ant can carry information and helps a node with q>2 hops to become a new cluster head. This section discusses two cases, where the changed node is an interior CH node, when it is a boundary next CH node.

E. Data Aggregation

The application model considered for this work consists of a single destination (base station) and multiple sources. Since the nodes are wirelessly connected which communicates to neighbors in vicinity, therefore multi-hop communication is used to reach the destination. It is assumed that density of nodes gives a connected node graph. For a application setting, data aggregation is applied in the network. "Data aggregation merges message data in-network while traversing through network" it is also termed as data fusion. The aggregation gain [20] can be measured as (original – aggregated) original in the given application message size. The aggregation suffers from delay termed as aggregation delay. There is a tradeoff in delay and gain in aggregation. The simulation study reveals that energy-efficiency is related to number of source nodes in correlated sensing.

F. Age of last encounter timers with transitivity

A number of different utility functions could be envisioned for this purpose. These could also take into account other relevant information (e.g. GPS position, speed, history of encounters, etc.) in addition to the timer values. However, it is beyond the scope of this paper to evaluate all these options, and we defer this for future work. Some efforts towards the design of multi-parameter utility functions can be found in [12]. Here, for simplicity, we will assume that these timers is our utility function (i.e. messages get forwarded to nodes with smaller and smaller timer values for the destination).We summarize here the functionality of the Spray and Focus protocol. Each node maintains a vector with IDs of all messages that it has stored, and for which it acts as a relay; whenever two nodes encounter each other, they exchange their vectors and check which messages they have in common; each message also carries a TTL (time-to live).

V. CONCLUSION

Each of the distributed sensor nodes typically consists of one or more sensing elements, a data processing unit, communicating components and a power source, which is usually a battery. The sensed data is collected, processed and routed them back to the desired end user through a designated sink point, referred as base station. Now it has become feasible to construct multifunctional sensor nodes with advanced capabilities. Such sensor nodes are relatively of smaller size, lower cost and lesser power consumption. WSNs are originally motivated for the use in military applications, such as border monitoring. In a typical sensor network, each sensor node has a microprocessor and a small amount of memory for signal processing and task scheduling. Each node is also equipped with one or more sensing devices such as acoustic microphone arrays, video or still cameras, infrared (IR), seismic, or magnetic sensors. This paper gives a detailed study of various distributed clustering approaches. A detailed research is made on optimized cluster initialization based on jumping ant approach in order to avoid random cluster initialization. Also this mechanism shows directions on how to rotate the cluster head periodically and energy efficiently. The algorithm consists of three stages. In the first stage, the ants move towards the available food. In the second stage, the ants that gets sufficient food stays in that cluster. In the third stage, the foodless ants jumps and form another cluster. This mechanism clearly shows an excellent improvement over those with random initializations.

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