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Performance Evolution of LEACH, COTS and MST Algorithms in Cluster Formation with Cluster Head Selection in Wireless Sensor Networks

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Abstract - The distributed mechanism of LEACH algorithm is used for cluster formation and cluster head selection, it may result in poor cluster structure in which some clusters contain a much larger number of nodes than others do. Furthermore, randomly choosing CHs lead to the fact that there is a high chance for one node to be a CH during several rounds of operation, this node consumes more energy and may die out within a short period of time.COTSis an improvement of LEACH is used by removing the cluster-reforming process and adding a rescheduling slot to the end of every round, energy is significantly saved.A novel routing protocol adapting Minimum Spanning Tree (MST), is formed using Prims algorithm to maximize network life time and reduce network delay. The results were analyzed based on the overall improvement and performance of the network.

Keyword – *Leach, COTS, MST*

1. Introduction

Wireless Sensor Network(WSN)s are used in disaster management, detection of wildlife movement, climate monitoring, monitoring the building security, measuring the structural reliability of constructions, vehicle traffic density and military surveillance. Security, operating systems and deployment strategies should be addressed [107] to realize the full potential of WSN. At the base level, collection of data from sensor nodes and transmission to sink node increases the WSN traffic flow. Further, WSNs flat network structures suffer from scalability in large/dynamic wireless networks[2]. Hence, efforts are made to manage the traffic smoothly.

For the advantages of scalability and efficient communication, cluster-based protocols attract a great attention in WSN research. Dividing a network

into interconnected substructures is known as clustering and the interconnected substructures are called as clusters. Clustering establishes a network hierarchy and divides network nodes into virtual groups based on rules to improve network scalability. A node is assigned different roles like cluster-head, cluster-gateway and cluster-member in a cluster. A cluster-head is a local coordinator, coordinating intra-cluster communication, while cluster-gateways are non-cluster-head nodes establishing inter-node communication with clusters and transmission ranges [3]. Among divided clusters, Cluster Head (CH) is a controller in a substructure (Base Station in a zone/cluster), communicating with other CHs and coordinating cluster activities involving data aggregation and transfer of aggregated data to sink through other CH in multi hop networks. Cluster based routing addresses nodes hetero-genetically and limits routing information propagated inside a network. Hierarchical routing is also possible where paths are recorded between clusters instead of nodes. This increases route life and decreases routing control overhead. The cluster members are responsible for sending/receiving information through cluster-heads and cluster-gateways. Routing data from CH to BS has an important role in improving the network QoS. The concept of grouping the sensor nodes into clusters and rotating (CH) roles among cluster members enables to balance the data traffic load and energy consumption in networks.

With One Time Set up (COTS)[10-11] and Minimum Spanning Tree (MST) protocols [12-17] are used for cluster formation and cluster head selection and to identify an ideal path from Cluster Head(CH) to Base Station(BS).

2. Low-Energy Adaptive Clustering Hierarchy (LEACH)

LEACH[4] was the first energy-efficient hierarchical clustering algorithm for WSNs to reduce power consumption. Clustering is rotated among nodes in LEACH, based on duration. Direct communication is used by CHs to forward data to BS. It uses clusters to prolong WSN life. LEACH is based on an aggregation (fusion) combining/aggregating original data into a smaller sizes carrying only meaningful information to individual sensors. LEACH divides a network into several sensor clusters constructed through use of localized coordination and control to reduce data transmitted to the sink and to make routing/data dissemination scalable and robust. LEACH uses the randomize rotation of high-energy CH position instead of choosing a static manner, to give all sensors a chance to as CHs avoiding individual sensors battery depletion leading to their deaths[5].

LEACH operation is divided into rounds of two phases each:

- a setup phase organizing a network into clusters, CH advertisement, and transmission schedule creation and
- a steady-state phase for data aggregation, compression and transmission to sink.

LEACH is a dynamic clustering mechanism and energy-conserving routing protocol for WSNs [6]. Forming clusters for accessible sensor nodes depends on their signal strength. The CH is selected as a router to send other nodes data in cluster to the base station. Data processing is performed at cluster-heads and time divided into rounds/intervals with equal length. When the round starts, cluster-heads are generated randomly among nodes whose remaining energy is elevated than the normal remaining energy of other nodes. LEACH uses single-hop routing where node transmits directly to a CH and sink. So, it is not applicable to networks used in large regions. Further, the idea of dynamic clustering brings extra overhead, e.g. head changes, advertisements etc., which diminish any gain in energy consumption. While LEACH helps sensors in their cluster dissipate energy slowly, CHs consume more energy when they are far from the sink. Also, LEACH clustering terminates in finite iterations, without guaranteeing good CH distribution assuming uniform energy consumption by CHs.The operation of LEACH Protocol is depicted as shown in fig 1.

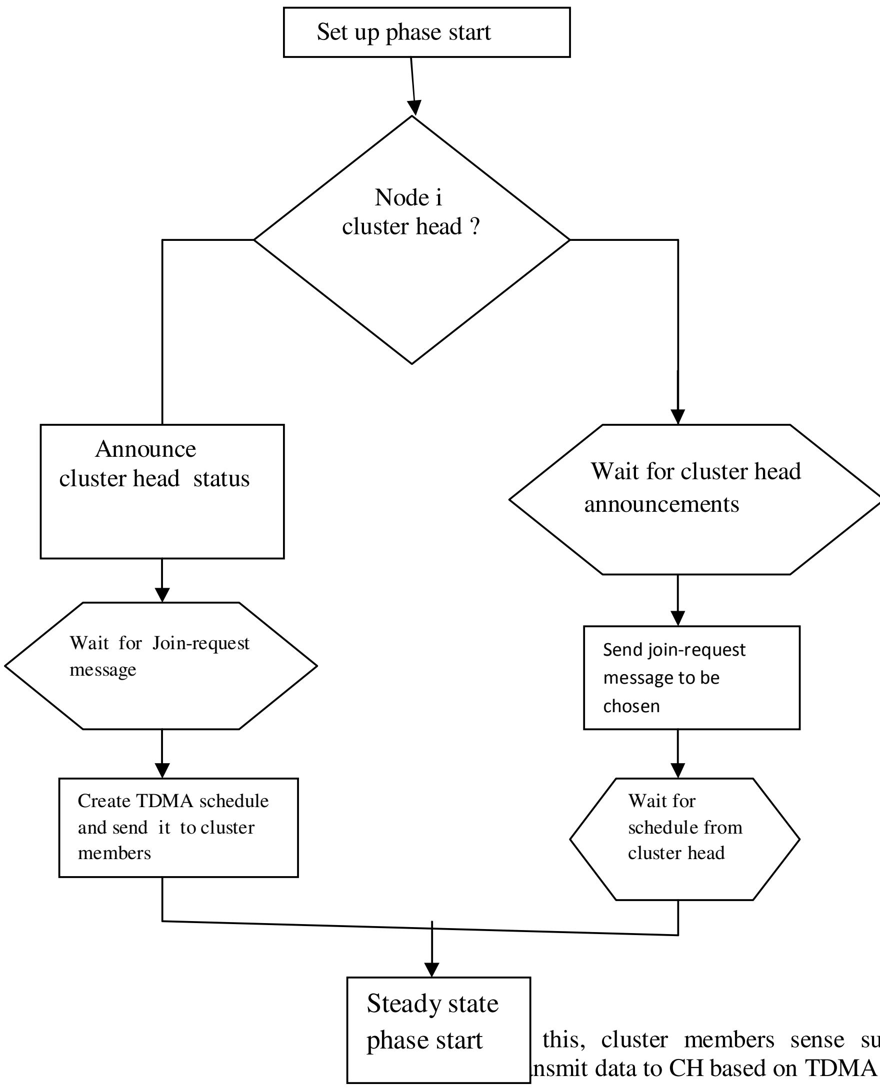
2.1 Setup Phase:

A sensor node n generates a random number between 0-1 comparing it with a pre-defined threshold T (n) value. If random number is less than T (n), then sensor node turns to a CH in that round or it becomes a cluster member. The computation is seen by the equation 1.

$$T(n) = \frac{p}{1 - p(r \bmod \frac{1}{p})} \forall n \in G$$

.... (1)

Where, p is number of network CHs computed as percentage, r is number of selection rounds and G represents nodes not selected in round 1/p.



this, cluster members sense surroundings and
nsmit data to CH based on TDMA schedule

Fig.1. Flowchart of LEACH Protocol

send messages to other cluster nodes informing them of their status. Based on messages receiving signal strength, non-CH nodes choose which CH to join. CH create schedules and send them to cluster nodes. Nodes send data to respective CH nodes, for the remaining portion of the round, which CHs aggregate and send to a BS. CHs number and rounding periods are related to energy consumption.

2.2 Steady-State Phase

received at setup phase. Sensor nodes go to sleep mode saving energy for other slots.

A steady-state phase has few frames, and a frame is split in two time slots: a time slot for SNs and another for CH. SNs transmit data to CH in the time slot for CH. The CH compresses (aggregates) data and transmits it to a BS. As a cluster operates in a frame unit, it refuses to work in the remaining time when it does not have enough time for a frame.

3. Clustering with One-Time Setup (COTS)

An energy-efficient clustering scheme called COTS removes cluster-reforming and adds a rescheduling slot to the end of a round. The setup phase has hundreds of slots though it depends on the nodes and random access pattern. Energy is greatly saved by skipping the cluster-reforming process. In COTS, CHs role is rotated among cluster members by transmitting the cluster head order at a rescheduling slot. The idea of COTS [7] is summarized as follows.

- A cluster is formed just once at first round's setup phase.
- When a cluster is formed, CH creates a cluster head list having other member nodes in order of the closest to the furthest. The list rotates the CH role among member nodes. The list is broadcast to other members during the first round's setup phase.
- In a steady-state phase, CH collects data from members. When it does not get data from a member, the latter is regarded as dead by CH.
- The CH at ever round's rescheduling slot creates a new CH order based on the last collected data packets set and broadcasts the new CH order to members. When a member does not receive it, it simply invalidates current CH order.

The setup phase is initiated once in a network's life as proposed by[8]. During setup phase, COTS creates many slots. Clusters formation is similar to LEACH in the first round. A CH list is formed of all members in a newly formed cluster. Based on the node proximity regarding the current CH, a CH list is ordered.

The list rotates CH in a cluster during every round. After a round a new CH is selected based on the CH list, and CH id is transmitted during rescheduling slot as in figure 3.This avoids setups at every round, energy consumption is reduced and network life increased. This also avoids clusters reformation. Living status of members in each cluster is shared during rescheduling slot. During a round, the CH list is updated to remove dead nodes and information on surviving nodes is sent to the listed members so that a cluster node knows live nodes status. the operation of COTS algorithm and its rescheduling slot as shown in fig.2 and fig 3 respectively.

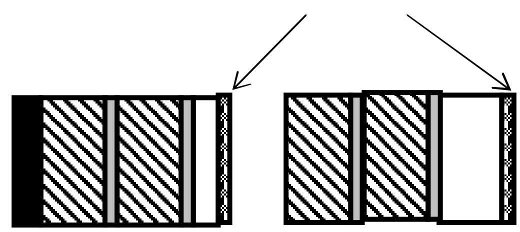


Fig.2. Rounds of COTS

4. Minimum Spanning Tree (MST)

MST is a sub-graph spanning over all graph vertices without any cycle. It consists of minimum sum of weights over included edges. A minimum spanning tree is formed from an edges subset with two properties in an undirected graph:

- it spans graph, i.e., it includes all vertices in the graph, and
- it is a minimum, i.e., total weight of edges is as low as possible [9].

In MST, route formation is based on edge weight. Weight is computed using Euclidean distance between two points forming an edge. Inconsistent edges are longer when computed using Euclidean distance and are removed from the graph. The process is repeated till a shortest path is chosen from CH to BS using a most efficient CH in between [10].

Two important MST applications in wireless networks are broadcasting/data aggregation. A MST broadcasts a tree to reduce energy consumption.

$$\sum_{(u,v)\in T} d^{\alpha}(u,v) \quad \ldots\ldots\ldots\ldots \quad (2)$$

Broadcasting based on MST consumes energy in a constant factor of an optimum. Data aggregation combines data from different sources en route to eliminate redundancy and reduce transmissions thereby saving energy [11-13]. Common aggregate functions are minimum, maximum, average, etc.The function of MST is depicted in the figure 5[14].

A popular paradigm to compute aggregates is constructing a tree rooted at a sink where nodes forward (locally) aggregated data from a sub tree to parent. In such cases, MST is an optimal data aggregation tree. As energy is an important constraint in sensor network, much work focused on constructing low energy sub graphs. But, it is counterproductive to use much resource (time/ energy) to compute a low-cost sub graph, e.g., a MST; energy used by an algorithm is also an important measure. Motivated by this, and in addition to distributed algorithms traditional time/message complexity, a complexity term called work complexity is defined as

$$w = \sum_{i=1}^{M} r_{i=1}^{\alpha} \quad \text{............ (3)}$$

where r_i is transmission distance for message i and M is number of messages exchanged by nodes to run the algorithm/protocol. So, total radiation energy is proportional to work done by the algorithm (Khan 2009).

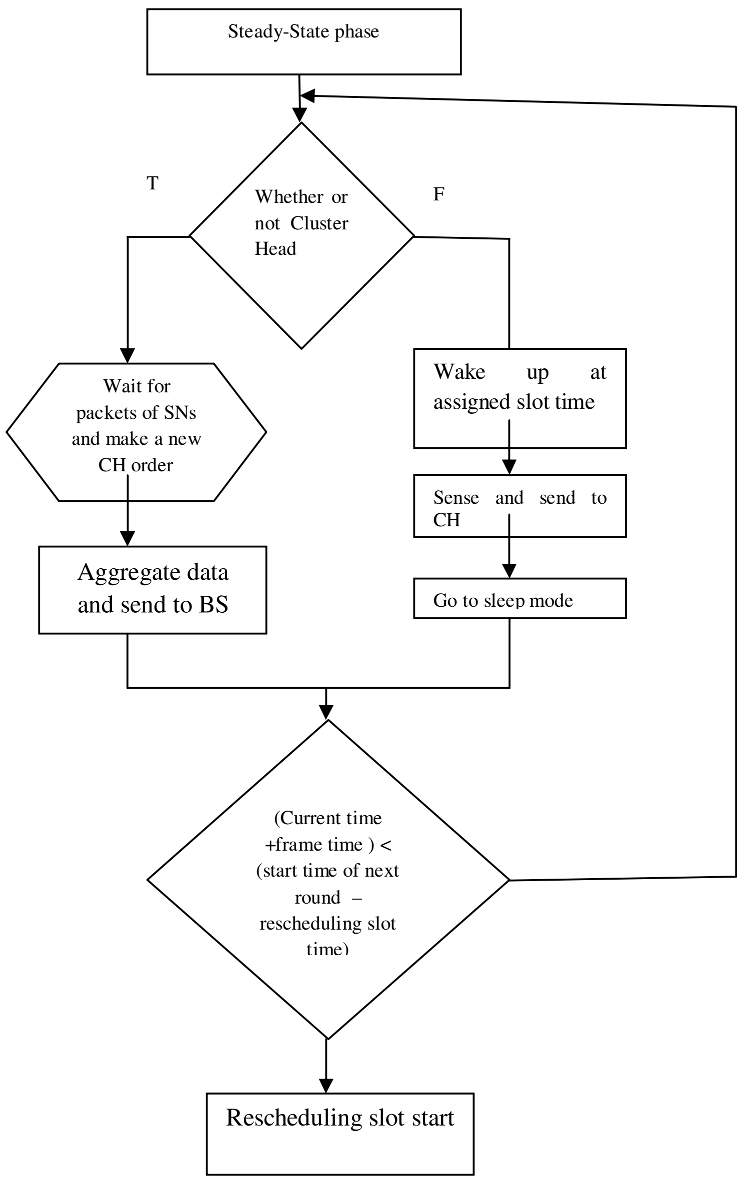


Fig 3. Flow chart of COTS Protocol

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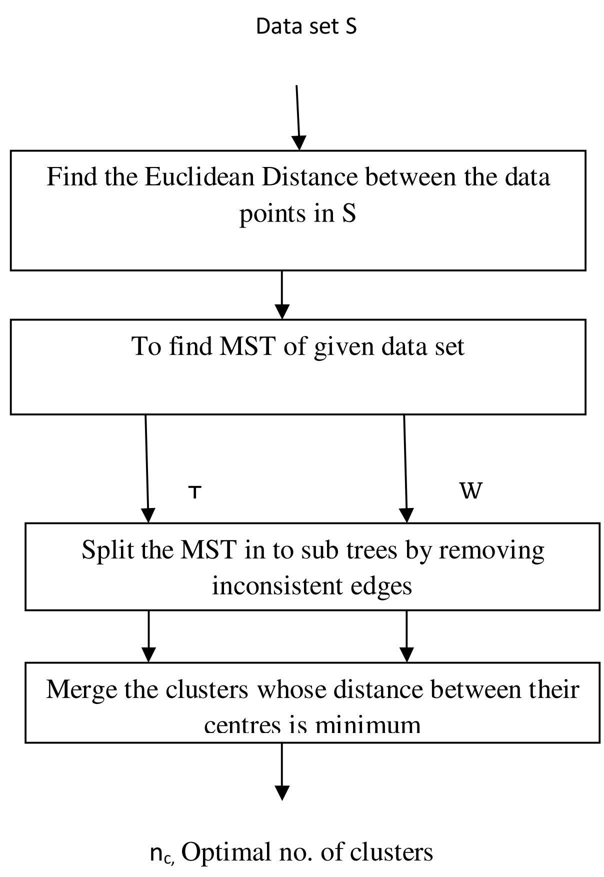


Fig 4. Block Diagram showing the MST Algorithm

3. Results And Discussion

The following parameters are considered for simulation:Radio Propagation range of node -100m; Network area-2750 sqm; Initial energy of node - 2.5 J; Number of nodes -75 to 275;Figures 5-9 show the result values and graphs respectively for performance metrics such as number of clusters formed, average end to end delay, average packet delivery ratio, lifetime computation and remaining energy of nodes (J).

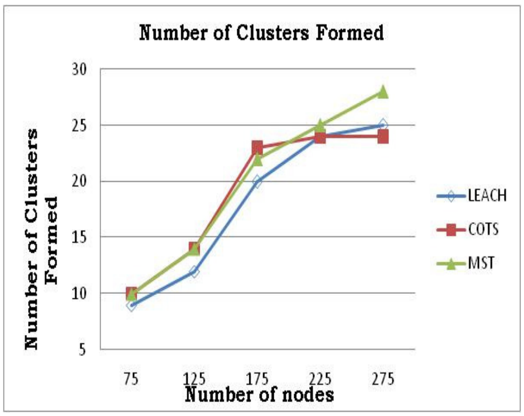


Fig.5 number of clusters formed

From figure 5 ,it is observed that the MST performs better in cluster formation than LEACH and COTS.

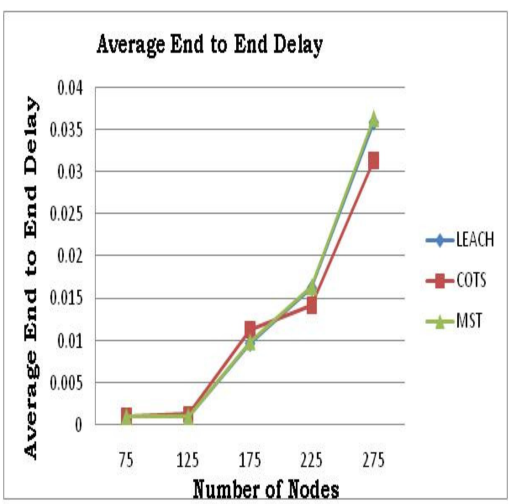


Fig 6. Average End to End Delay (sec)

It is observed that the COTS performs better in average end to end delay by lowering delay than LEACH and MST as shown in figure 6.

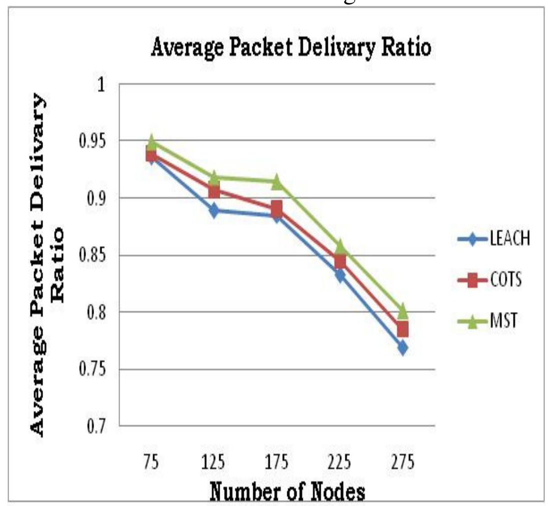


Fig 7. Average Packet Delivery Ratio

it is observed that the MST performs better in average packet delivery ratio than LEACH and COTS as shown in figure 7.

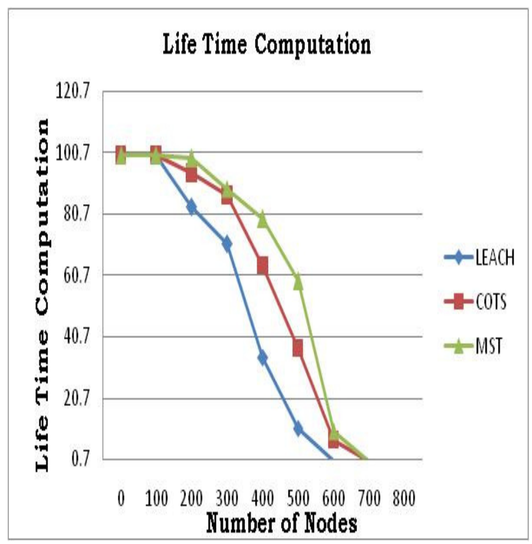
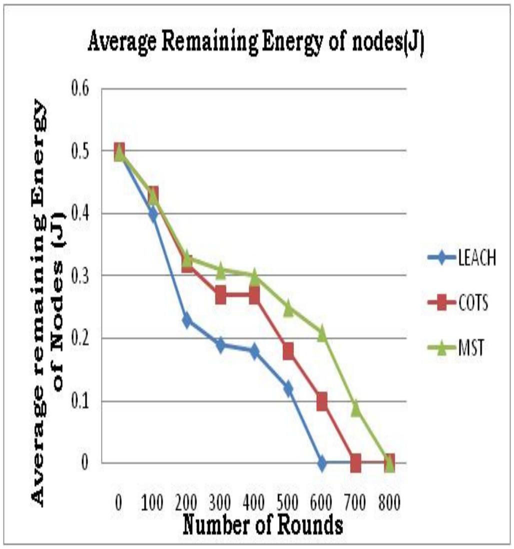


Fig 8. Lifetime Computation

It is observed that the MST performs better lifetime computation than LEACH and COTS as shown in figure 8.



. Fig 9. Remaining Energy of Nodes (J)

It is observed that the MST performs better remaining energy consumption of nodes than LEACH and COTS as shown in figure 9

4. Conclusion

An evaluation in made to improve the performance of LEACH, COTS and MST. In LEACH, an idea of dynamic clustering brings an extra overhead which decreases the gain in energy consumption but local compression is done for reducing the global communication. MST are useful in constructing networks, by describing the way to connect a set of sites using the smallest total amount of wire. The proposed COTS significantly reduces energy consumption incurred by the setup phase of every round by realizing novel clustering without repeated setup, resulting in improved performance and prolonged network lifetime. Results show that MST performs better in cluster formation, average packet delivery ratio, lifetime computation and nodes remaining energy consumption but decreases in average end to end delay calculation than LEACH and COTS.

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