# AN ADAPTIVE CLUSTER BASED ROUTING PROTOCOLS (COTS & MST) FOR WIRELESS SENSOR NETWORKS

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ABSTRACT :

This paper uses the Clustering with One Time Set up (COTS), Minimum Spanning Tree (MST), and Low Energy Adaptive Clustering Hierarchy (LEACH) protocols for cluster creation, CH selection, and determining the best route from CH to Base Station (BS). Based on the simulation findings, it was shown that MST outperforms LEACH and COTS in average end-to-end latency calculation, but performs better in cluster formation, average packet delivery ratio, lifespan computation, and nodes' residual energy consumption.

*Keyword:LEACH,COTS,MST,CH,BS*

## 1. INTRODUCTION

Wide-area networks (WSNs) are able to detect and report on a wide range of characteristics, including temperature, pressure, and humidity, in almost any kind of environment [4]. It is possible to have physical access to sensor nodes since a network is established in close proximity to the physical source of an event; however, owing to cost restrictions, there is no tamper-resistance included [18]. The resources that are available to WSN sensors are highly limited. These resources include memory, energy, bandwidth, processing, and all forms of communication.[1] Wireless sensor networks are susceptible to both external and internal security threats. In the network, it is not feasible to repeat the process of replacing or charging the battery. In the event that one or a few network nodes fail, the main network operation will not be impacted since neighboring nodes will take over and continue to operate normally.

Cluster-based protocols are in high demand in the field of wireless sensor network research because of their scalability and their ability to effectively communicate. Clustering refers to the process of dividing a network into substructures that are linked with one another, and the substructures that are interconnected are referred to as clusters. The process of clustering creates a hierarchy inside a network and splits the nodes of the network into virtual groups according to rules in order to increase the scalability of the network. There are a variety of roles that may be given to a node inside a cluster, including cluster-head, cluster-gateway, and cluster-member. On the other hand, cluster gateways are non-cluster-head nodes that create inter-node connection with clusters and transmission ranges [3]. A CH is a local coordinator that is responsible for managing communication inside the cluster.

## 2. LOW-ENERGY ADAPTIVE CLUSTERING HIERARCHY (LEACH)

For wireless sensor networks (WSNs), LEACH is a dynamic clustering technique and an energy-conserving routing system [9]. LEACH was the first hierarchical clustering method that was energy-efficient and utilized in wireless sensor networks (WSNs) to get rid of power usage. The LEACH algorithm is based on an aggregation (fusion) that combines or aggregates the original data into smaller pieces, with the primary purpose of transporting substantial information to discrete sensors. In order to lower the amount of data that is communicated to the base station (BS) and to make routing and data dissemination more scalable and reliable, LEACH divides a network into a large number of sensor clusters that are formed via the use of localized coordination and control. It employs the random rotation of the high-energy cluster head position rather than selecting a static approach in order to provide all sensors with the opportunity to function as CHs, hence preventing the depletion of individual sensors' batteries, which would otherwise result in their deaths [5]. What determines the formation of clusters for available sensor nodes is the signal intensity of those nodes. The CH is chosen to act as a router in order to transmit data from other nodes in the cluster to the BS. The processing of data is carried out at CHs, and time is split into rounds or periods of equal duration. At the beginning of the round, CHs are generated at random from among the nodes that have a higher amount of residual energy than the average amount of energy that other nodes have left.

Through the use of single-hop routing, LEACH ensures that each node transmits directly to both a CH and BS. Therefore, it is not applicable to networks that are used across large areas. While LEACH assists sensors in their cluster in gently dispersing energy, cluster heads are able to store more energy when they are located at a location that is farther away from BS. In a similar manner, the LEACH clustering algorithm concludes with limited iterations and assumes that cluster heads use the same amount of energy. Each cycle of the LEACH operation is comprised of two phases: the first phase is the setup phase, which involves assembling a network into clusters, CH advertising, and the construction of a transmission schedule. The second phase is the steady-state phase, which involves data collection, compression, and their transmission to sink.

### 2.1 SETUP PHASE

A sensor node n takes a value between zero and one and compares it to a threshold T(n) that has been pre-set. The sensor node either becomes a member of the cluster or changes to a CH in that round if the random number is less than T(n). Table 2.1 displays the LEACH Protocol pseudo code. Figure 2.1 shows the flow diagram of the LEACH methodology.

Table 2.1 Pseudo code of LEACH Protocol

1. Set-up phase :

- Based on T(n), threshold , CHs are selected
- All Cluster Heads (CHs) broadcast ADV(advertisement) message to all non-CH nodes
- All non-CH nodes select their CHs, based on RSSI of ADV message
- After selecting cluster, it (non-CH node) sends join-REQ (Request) back to CH. Now CHs create TDMA Schedule & send to the all non –CH nodes

2. Steady-state phase:

- Sensor nodes begin sensing & transmitting data to CHs as per their TDMA Schedule
- After receiving data, CHs aggregates data to the BS in one-hop manner, thus reducing the number of transmissions & hence saving energy
- After certain time, N/W goes back to set-up phase again &enters another round
- Each cluster communication, using different CDMA codes to reduce the interference from other cluster nodes.

The computation is given from equation (2.1)

$$T(n) = \frac{p}{1 - p(r \bmod \frac{1}{p})} \forall n \in G \qquad (2.1)$$

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.

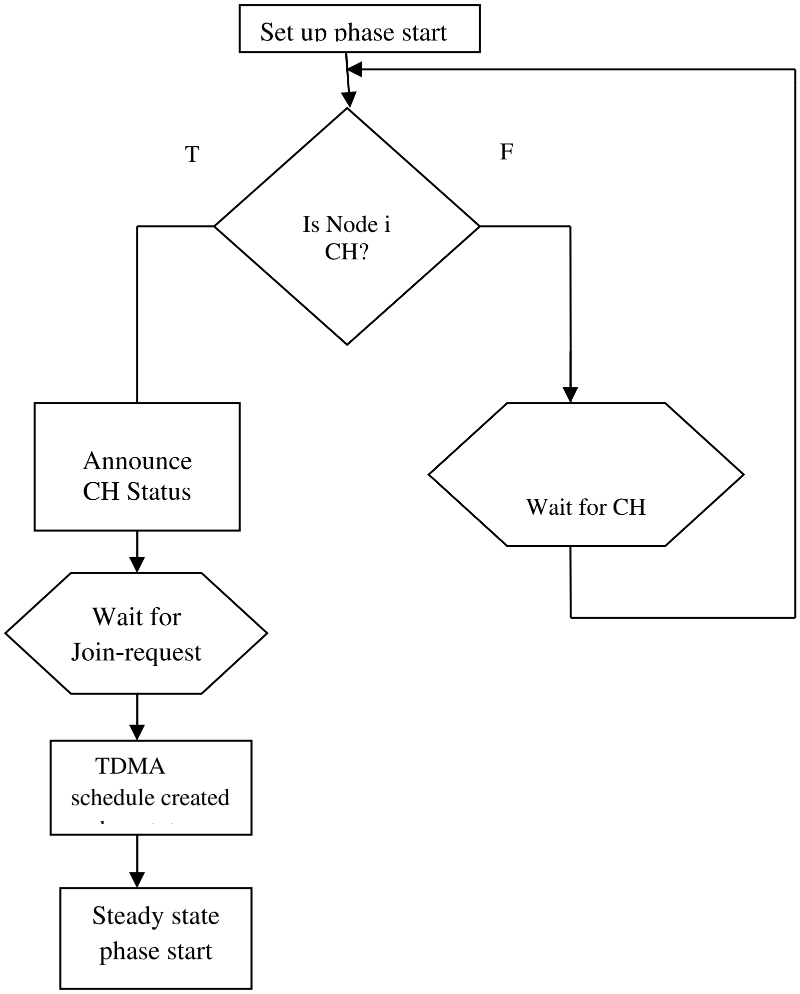


Fig 2.1 Flowchart of LEACH Protocol

Heads of clusters are chosen at random. Nodes update other nodes in the cluster on their status by messages sent by them in their role as cluster heads. Nodes that aren't part of the CH decide which CH to join based on the strength of the signals they receive. Cluster nodes receive schedules generated by CH. For the rest of the round, nodes communicate with their corresponding CH nodes, which then aggregate the data and transmit it to a BS. Ratios of cluster heads to rounding periods and energy consumption are connected.

## 2.2 STEADY-STATE PHASE

Following the establishment of a TDMA schedule during setup, data sensed by cluster members is transferred to the cluster head during the steady state phase. When not in use, sensor nodes fall into sleep mode to conserve power for later use. There are two time slots in a single frame during a steady-state phase: one for the CH and one for the Sensor Nodes. The sensor nodes communicate with the cluster head during the designated time period. Data is aggregated by the cluster head and sent to a sink. When there isn't enough time for a frame, a cluster will not work during the remaining time because it operates in a frame unit.

## 3.CLUSTERING WITH ONE-TIME SETUP (COTS)

Removing cluster-reforming and adding a rescheduling slot to the conclusion of each round, COTS[10,11] is an energy-efficient clustering scheme. Although the exact number of slots in the setup phase is dependent on the nodes and random access pattern, it can be hundreds. Eliminating the need to establish clusters significantly reduces energy use. As depicted in figure 3.1, the cluster head id is broadcast during the rescheduling slot, and a new CH is chosen after each round using the CH list.

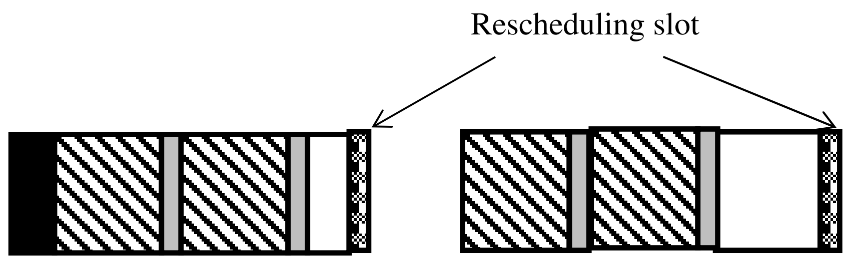


Figure 3.1 Rounds of COTS protocol

With this, you won't have to worry about setups every round, which means less power usage and longer network life. Cluster reformation is also prevented by this. During the rescheduling slot, we share the living status of all members in each cluster. In order for a cluster node to know the status of live nodes, the CH list is updated during a round to remove dead nodes and information on surviving nodes is given to the listed members. The cluster leader gathers information from members during the steady-state phase. A member is considered dead by the cluster head when it stops receiving data from that member. At the rescheduling slot of each round, the cluster head updates the CH order with the most recent set of gathered data packets and broadcasts it to all members. The present CH order is null and void if a member does not get it.

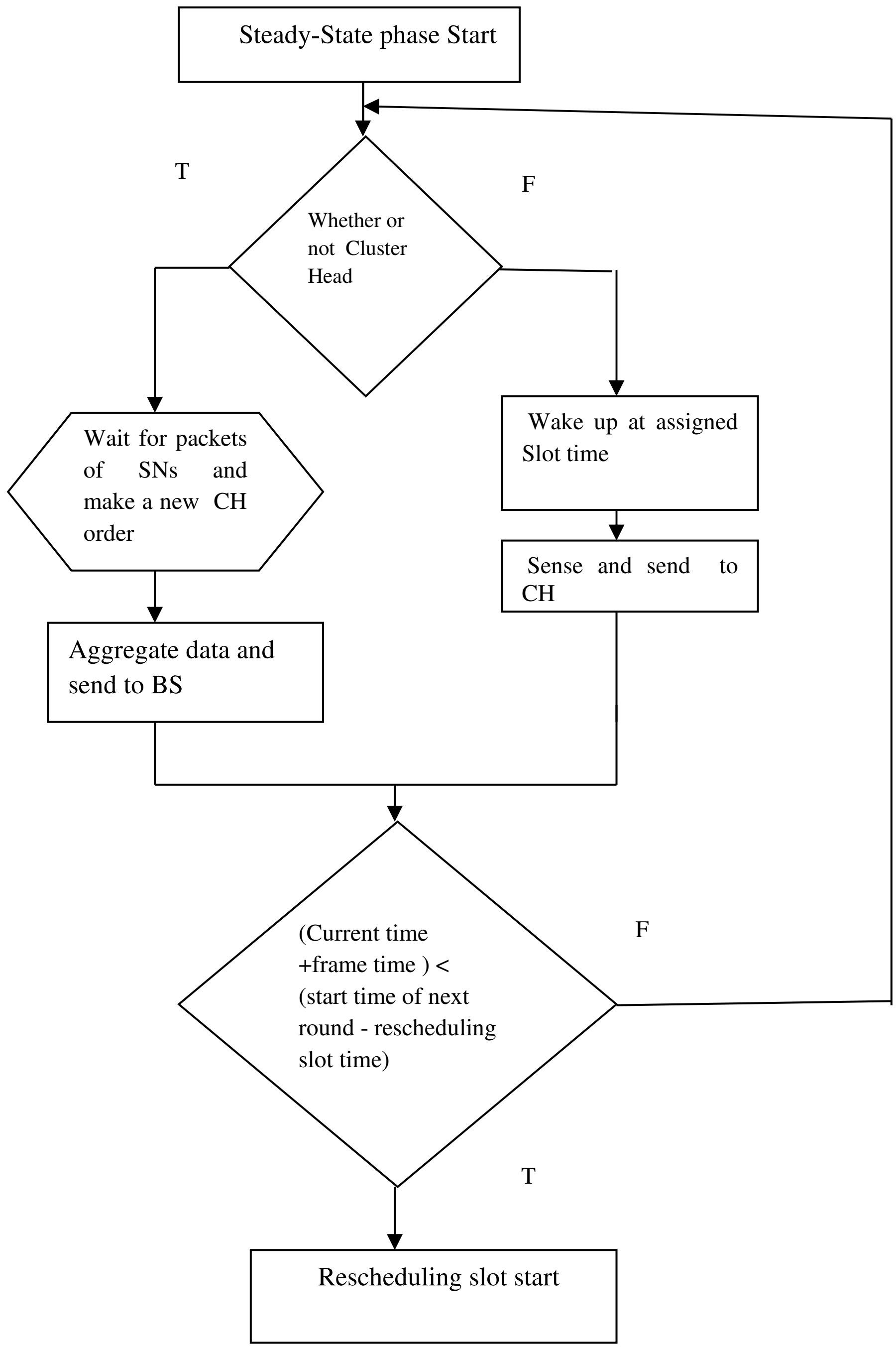


Fig 3.2 Flow chart of COTS Protocol

## 4. MINIMUM SPANNING TREE (MST)

In a graph, MST is a non-cyclic sub graph that spans all vertices. The minimum total of weights over the edges that are included makes up this. A minimum set theory (MST) is constructed from a subset of edges in an undirected graph that satisfy two conditions: first, it encompasses all of the graph's vertices; and second, it has the lowest feasible total weight of edges [12].

Edge weight, determined by taking the Euclidean distance between any two points that make up an edge, is the foundation upon which MST's route formation rests. Edges that aren't uniform are cut off because they're lengthier. Until a shortest path is selected from CH to BS, the process is repeated. Huang, G., Li, X., and He, J. suggested employing the most efficient CH in the middle.

$$\sum_{(u,v)\in T} d^{\alpha}(u,v) \tag{4.1}$$

Where d is transmission distance, u-transmit messages-receive messages-Transmission range, Alpha-propagation constant.

Data aggregation combines data from diverse sources to remove redundancy and reduce transmissions thereby saving energy [13]. Common aggregate functions are minimum, maximum, average, etc. A current model to compute aggregates is constructing a tree rooted at a sink where nodes forward (locally) aggregated data from a sub tree to parent. Here, 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 worthless to use many resources (time/ energy) to calculate a low-cost sub graph, e.g., a MST ; energy utilised by an algorithm is a significant measure. Inspired by this, and in addition to distributed algorithms traditional time/message complexity is defined as

$$w=\sum_{i=1}^{M} r_{i=1}^{\alpha} \tag{4.2 }$$

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 developed by Khan,M.,

### 4.1 FLOW CHART FOR MST ALGORITHM

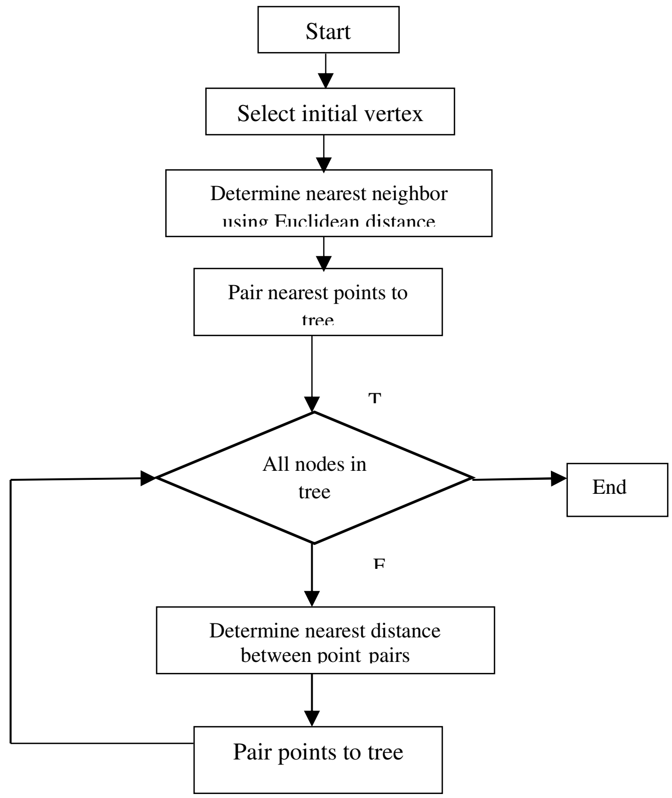


Fig 4.1 Flow chart of MST algorithm

## 5. RESULTS AND DISCUSSION

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) are depicted in tables 5.1 to 5.5 and figures 5.5 to 5.5 The Percentage (%) Difference Formula gives performance comparison of different values of LEACH, COTS,MST .

$$\% \text{ Difference Formula} = \frac{(Highiervalue - Lowervalue)*2}{Highiervalue + Lowervalue} \times 100 \qquad (5.1)$$

Table 5.1 Number of Clusters Formed

| Number of nodes | LEACH | COTS | MST |
|---|---|---|---|
| 75 | 9 | 10 | 10 |
| 125 | 12 | 14 | 14 |
| 175 | 20 | 23 | 22 |
| 225 | 24 | 24 | 25 |
| 275 | 25 | 24 | 28 |

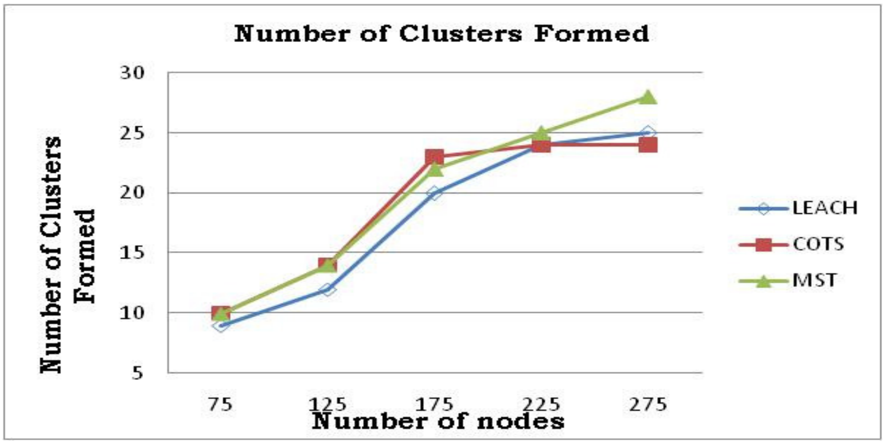


Fig 5.1 Number of Clusters Formed for MST

From figure 5.1 and table 5.1 it is observed that the MST performs better in cluster formation than LEACH and COTS when number of nodes increase. When number of nodes is 75 and 125, the number of clusters formed for MST and COTS is same but increases for MST by 10.53% and 15.39% than LEACH. When number of nodes is 175, number of clusters formed for MST increases by 9.52% than LEACH and slightly decreases by 4.44% than COTS. When number of nodes is 225, the number of clusters formed for MST increases by 4.08% than LEACH and COTS. When number of nodes is 275, number of clusters formed for MST increases by 11.32% than LEACH and by 15.39% than COTS.

From figure 5.2 and table 5.2 it is observed that the MST has slightly higher average end to end delay than LEACH and COTS. When number of nodes is 75, average end to end delay for MST increases by 0.49% than LEACH and by 2.31% than COTS. When number of nodes is 125, average end to end delay for MST increases by 0.09% than LEACH and decreases by 20.07% than COTS. When number of nodes is 175, average end to end delay for MST increases by 2.18% than LEACH and decreases by 12.91% than COTS. When number of nodes is 225, average end to end delay for MST increases by 0.97% than LEACH and by 14.7% than COTS. When number of nodes is 275, average end to end delay for MST increases by 1.52% than LEACH and by 14.81% than COTS.

Table 5.2 Average End to End Delay (micro seconds)

| Number of nodes | LEACH | COTS | MST |
|---|---|---|---|
| 75 | 1.002 | 0.984 | 1.007 |
| 125 | 1.003 | 1.228 | 1.004 |
| 175 | 9.672 | 11.25 | 9.885 |
| 225 | 16.263 | 14.174 | 16.423 |
| 275 | 35.872 | 31.399 | 36.422 |

From figure 5.3 and table 5.3 it is observed that the MST performs better in average packet delivery ratio than LEACH and COTS. When number of nodes is 75, average packet delivery ratio for MST increases by 1.41% than LEACH and by 1.03% than COTS. When number of nodes is 125, average packet delivery ratio for MST increases by 3.30% than LEACH and by 1.25% than COTS. When number of nodes is 175, average packet delivery ratio for MST increases by 3.27% than LEACH and by 2.68% than COTS. When number of nodes is 225, average packet delivery ratio for MST increases by 3.05% than LEACH and by 1.56% than COTS. When number of nodes is 275, average packet delivery ratio for MST increases by 4.15% than LEACH and by 2.07% than COTS.

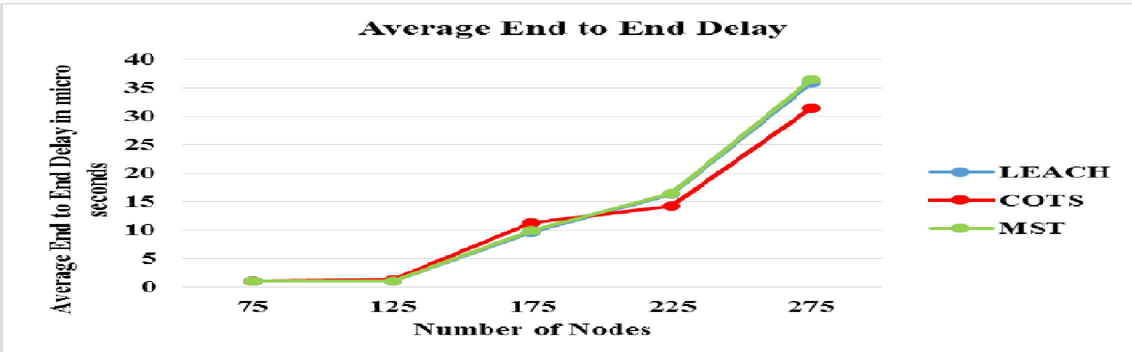


Fig 5.2 Average End to End Delay (micro seconds) for MST

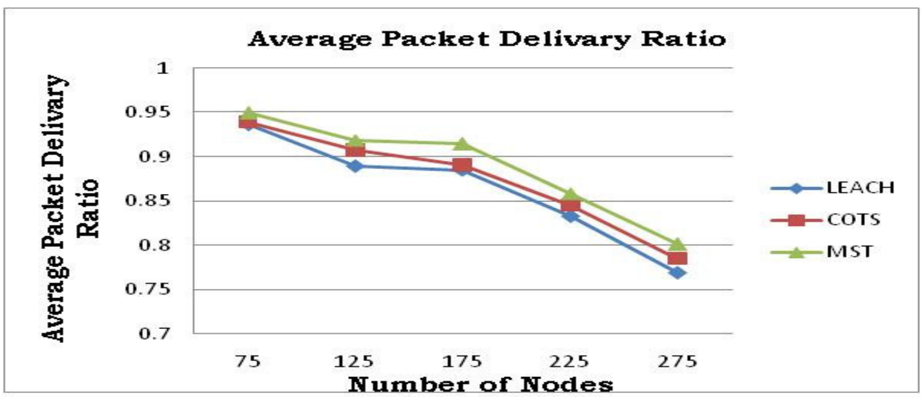


Fig 5.3 Average Packet Delivery ratio for MST

Table 5.3 Average Packet Delivery Ratio

| Number of nodes | LEACH | COTS | MST |
|---|---|---|---|
| 75 | 0.9361 | 0.9397 | 0.9494 |
| 125 | 0.8894 | 0.9078 | 0.9192 |
| 175 | 0.8853 | 0.8905 | 0.9147 |
| 225 | 0.833 | 0.8455 | 0.8588 |
| 275 | 0.7689 | 0.7851 | 0.8015 |

The lifetime computation is based on the percentage of nodes alive for number of rounds. From figure 5.4 and table 5.4 it is observed that the MST performs better in lifetime computation than LEACH and COTS. When number of rounds is 200, lifetime computation for MST increases by 17.58% than LEACH and by 5.18% than COTS. When number of rounds is 300, lifetime computation for MST increases by 22.5% than LEACH and by 2.27% than COTS. When number of rounds is 400, lifetime computation for MST increases by 79.65% than LEACH and by 20.98% than COTS. When number of rounds is 500, lifetime computation for MST increases by 137.14% than LEACH and by 45.83% than COTS. When number of rounds is 600, lifetime computation for MST increases by 200% than LEACH and by 35.29% than COTS.

From figure 5.5 and table 5.5 it is observed that the MST performs better in remaining energy consumption of nodes than LEACH and COTS. When number of rounds is 100, remaining energy consumption of nodes for MST increases by 7.23% than LEACH and same for COTS. When number of rounds is 200, remaining energy consumption of nodes for MST increases by 35.71% than LEACH and by 3.08% than COTS.

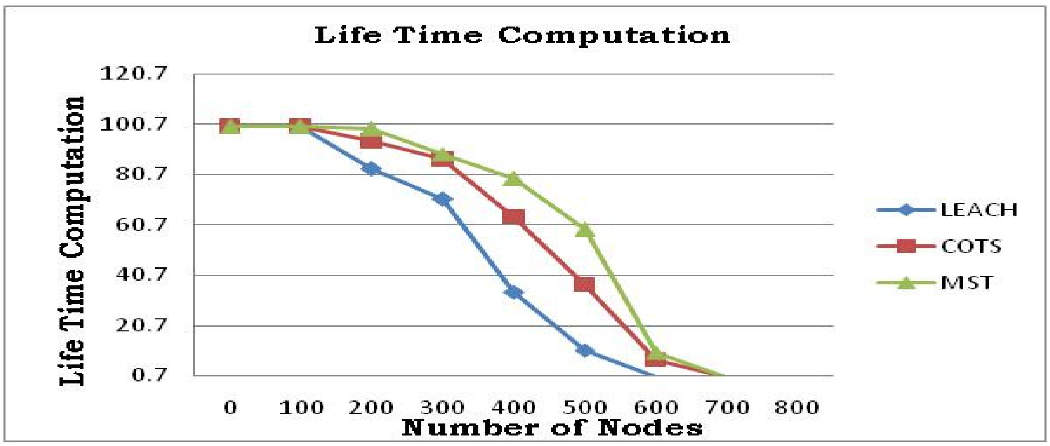


Fig 5.4 Lifetime Computation

Table 5.4 Lifetime Computation

| Number of Rounds | Percentage of nodes alive- LEACH | Percentage of nodes alive- COTS | Percentage of nodes alive- MST |
|---|---|---|---|
| 0 | 100 | 100 | 100 |
| 100 | 100 | 100 | 100 |
| 200 | 83 | 94 | 99 |
| 300 | 71 | 87 | 89 |
| 400 | 34 | 64 | 79 |
| 500 | 11 | 37 | 59 |
| 600 | 0 | 7 | 10 |
| 700 | 0 | 0 | 0 |
| 800 | 0 | 0 | 0 |

When number of rounds is 300, remaining energy consumption of nodes for MST increases by 48% than LEACH and by 13.79% than COTS. When number of rounds is 400, remaining energy consumption of nodes for MST increases by 50% than LEACH and by 10.53% than COTS. When number of rounds is 500, remaining energy consumption of nodes for MST increases by 70.27% than LEACH and by 32.56% than COTS. When number of rounds is 600, lifetime computation for MST increases by 200% than LEACH and by 70.97% than COTS.

Table 5.4 Average remaining energy of nodes(J)

| Number of Rounds | Average remaining energy of nodes(J)-LEACH | Average remaining energy of nodes(J)-COTS | Average remaining energy of nodes(J)-MST |
|---|---|---|---|
| 0 | 0.5 | 0.5 | 0.5 |
| 100 | 0.4 | 0.43 | 0.43 |
| 200 | 0.23 | 0.32 | 0.33 |
| 300 | 0.19 | 0.27 | 0.31 |
| 400 | 0.18 | 0.27 | 0.3 |
| 500 | 0.12 | 0.18 | 0.25 |
| 600 | 0 | 0.1 | 0.21 |
| 700 | 0 | 0 | 0.09 |
| 800 | 0 | 0 | 0 |

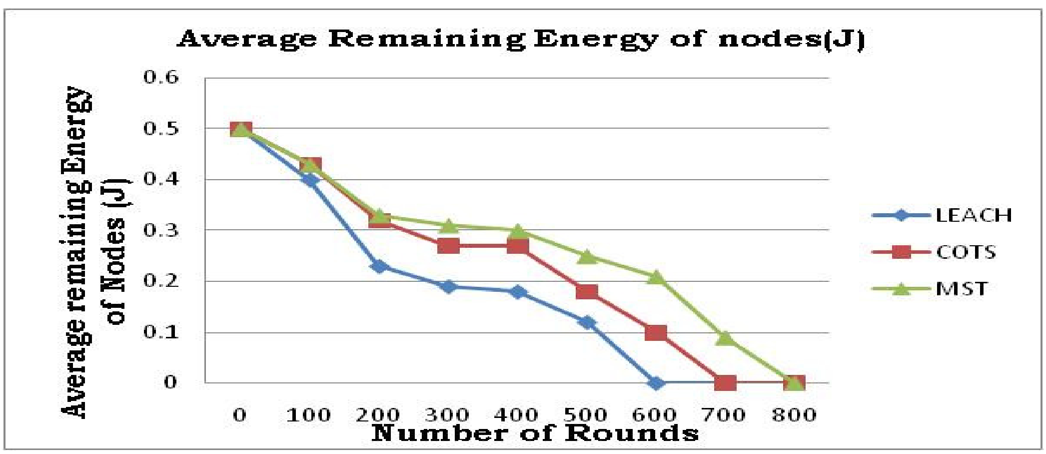


Fig 5.5 Remaining Energy of Nodes(J)

## 4. CONCLUSION

An evaluation is 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 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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