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Routing And Communication Using Clustering For Wireless Sensor Networks

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Abstract----
The best method for better design of protocol that can minimize communication cost and energy usage in WSN has undergone various researches into which are employing different kinds of communication modes that promise a better utilization of network resources. This paper discusses about how extensively these different communication modes for WSN that are hierarchically clustered and further we have used the techniques of multilevel clustering for communication purpose and hence enhanced the lifetime.
Keywords:-**Routing, Communication Modes , MLCC, DLCC**

INTRODUCTION

Wireless sensor nodes in a network can be designed to communicate using different types of communication modes. Some literatures proposed protocols that use a single-hop communication mode to send their data to the BS and some other are employed hierarchical modes of communication (multi-hop) for sensors outside each other's range to reach BS. The design objectives of different communication modes could be to extend the entire network life-time of the sensors or to reduce communication cost. In this we investigated a systematic cost-based approach for both single-hop and multi-hop communication modes and further proposed a hybrid communication which focused on data aggregation model. The shift in communication paradigm from ad hoc networks to wireless sensor networks that has motivated several research into design of an energy aware protocol for WSNs. Most protocol designs have not successfully balanced the trade-off between using the multi-hop mode for energy conservation to the single-hop mode for reduced communication cost. When sensor nodes are organized in a hierarchy or multi-level cluster structure using multi-hop communication mode, it is obvious that the nodes closer to the BS dies out first as a result of being over-burdened from relaying packets of other far away nodes. Although this method may seem to reduce the unnecessary energy drainage of the network when properly leveraged, the downside of the multi-hop approach is the BS-centric dying pattern of the sensor nodes around the BS if not properly utilized and the cost can be considerably very expensive. However, when nodes communicate directly to the BS using a single-hop, the nodes farther away use much more energy to reach the BS. Thus, nodes far away die out first due to the long range of transmission. On the other hand, it could be cheaper in terms of cost to deploy a single-hop communication network. A good exploitation of the above mentioned communication modes can yield desirable results. The authors in [43] proposed a multi-hop communication mode between cluster-heads and sink. Their result revealed an improvement to existing LEACH that used single-hop mode. In the next sections, this thesis examines these communication modes and then propose a dual and multi-hop communication modes that leverages on both layered and clustering architecture for the design.

2. RELATED WORK:-

2.1 Single-hop communication mode

When nodes communicate directly with the BS without relaying their packets, it is referred to as single-hopping. The design of single-hop technique could vary in different network topology. A protocol design may require the nodes to form clusters among themselves such that each non-cluster member sends its data to their respective cluster heads and the cluster-heads performs data aggregation before forwarding the refined data to the BS. An example of this protocol is LEACH. On the other hand a protocol design can completely adopt a layered architecture where each node is required to send its data directly to the BS. One of the protocols that used this approach is the Direct Transmission protocol .In this approach, each node transmits directly to the base station. If the BS is far away from the nodes, direct transmission will require large transmission energy. Figure 1 depicts the single-hop communication mode for a clustered WSN.

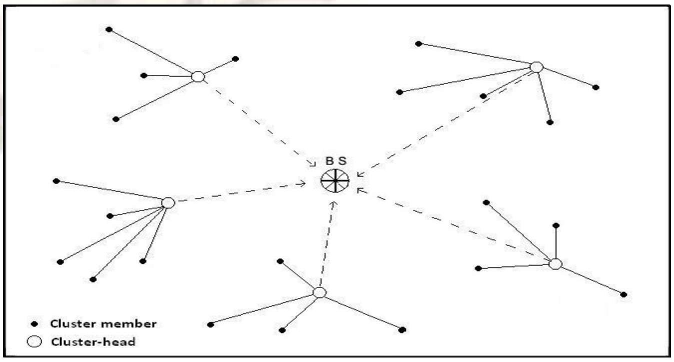

Figure 1: Single-hop Network Design

2.2 Total Energy Dissipation for a Single-hop Mode in a Clustered WSN

The total energy dissipation for a network system is expressed as the sum of energy consumed by the sensor nodes to sense an event and transmit the sensed data to a central location or the BS.

And the threshold level is given by:-

The threshold T(n) is given by:

$$T(n)= \begin{cases} \dfrac{P_{opt}}{1-P_{opt}\left[r \bmod \left(\frac{1}{P_{opt}}\right)\right]} & \text{if } r \in K \\ 0 & \text{otherwise} \end{cases}$$

(2.1)

If the sensor node is a cluster-head, the energy expended will be the sum of energy consumed to sense the environment, to receive data from cluster members, to perform data aggregation and to transmit the refined data to the BS. Thus, assuming that the BS is located at the center of the sensing region as shown in Figure 4.1. The total energy expended by a cluster-head is given by:

$$E_{CH} = kE_{elec}\left(\frac{n}{c}-1\right) + kE_{DA}\left(\frac{n}{c}\right) + E_{Tx}(k, d_{toSink}),$$

(2.2)

where E_{CH} is the energy expended in receiving B0 number of k bits from cluster members, and EDA is the energy expended to aggregate the data and then transmit with ETx(k; d_{toSink}) energy. In this regard, the free space path loss is used since the BS is at the center of the sensing region. If the sensor node is a cluster member, the energy expended is given by:

$$E_{non-CH} = kE_{elec} + k\epsilon_{fs} d^2_{toCH},$$

(2.3)

Thus, the total energy expended in a single-hop communication network will be the sum of energy expended by non-cluster members and the cluster-heads expressed as:

$$E_{cluster} \approx E_{CH} + n/c\, E_{non\,CH}$$

(2.4)

However, to ensure an optimal setting for this type of communication mode, the following issues need to be considered: an optimal number of cluster-heads per round per epoch and the battery dimensioning that will ensure at least a guaranteed network lifetime.

2.3.1 Dual-hop and Multi-hop communication mode

Authors have proposed using multi-hop routing scheme to relay data to the BS. One of the earliest work to use this model is the Minimum-Transmission-Energy (MTE). The aim of this scheme is to use the route with minimum energy consumption. But minimization of energy in multi hop routing is only one of the criterion. Some other criteria for a multi-hop network might include maximal available power, minimal hop and maximal-minimal available power. Also the idea behind all of these modified protocol designs in this is to exploit the minimum energy route based on distance estimation. This method is same as to the idea used in LEACH, SEP-E and SEP in the sense that energy is estimated as a function of distance, except that this method exploits further the energy resources around the BS by relaying packets to nodes closer to the BS. Similar to the single-hop mode, multi-hop can be classified as inter-cluster-based and/or intra-cluster-based for clustered architecture or layer-to-layer hopping for layered architecture. However, none of the authors have actually assessed the impact of using a dual-hop in a three-level hierarchically clustered network in an energy homogeneous setting. Here, a dual-hop is defined as a communication mode between two cluster-heads with the aim of relaying their aggregated data to the BS. In the section that follows, the total energy consumptions for both dual and multi-hop modes are discussed. The idea is to see how these schemes scale well, as opposed to using a single-hop scheme such as LEACH in a homogeneous small-scaled network of sensors.

2.3.2 Total Energy Dissipation in a Dual and Multi-hop Network in a Clustered WSN

This section presents and examines the total energy that is expended in a dual-hop and multi-hop networks for a clustered architecture. Let us consider Figure 4.8, as a dual-hopping network, if we partition the network area logically into three different levels, say level 1, 2 and 3 with C2 as level 2 (local cluster-heads) and C3 as level 3 (relay cluster-heads). When the clusters are formed in the network, C2 cluster-heads aggregate the data from level 1 nodes as their cluster members and transmit the data to C3 cluster-heads. Interestingly, level 2 cluster-heads sees level 1 nodes as their cluster members, likewise level 3 cluster-heads sees level 2 nodes as their cluster members.

Following the assumptions are used in SEP and LEACH.

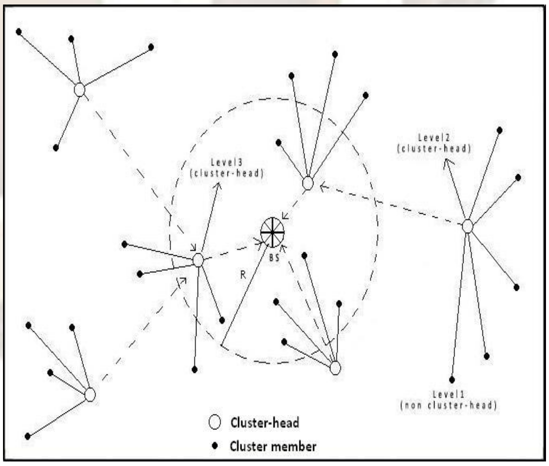

Figure 2: Dual-hop Network Design

2.3.3 Assessing different communication modes in the design of LEACH Protocol

This section presents an improvement to LEACH protocol in two different forms, first by considering a multi-hop system of communication using a concentric circle of radius R among cluster-heads, and secondly, by using a dual-communication between two types of cluster-heads with the same initial energy E0. In LEACH, each cluster-head communicates directly with the BS. This approach proves to consume more energy as cluster-heads farther away from the BS will use more energy to transmit their data to the BS since the energy expended is a function of the distance. The proposition is the same as LEACH in terms of the probability model of choosing cluster-heads but differs in terms of communication modes. However, we proposed a multi-hop system among all nodes at a fixed power level. Data exchanged between sensors not within each other's radio range is forwarded by other sensors in the network regardless of whether a node is a cluster-head or a cluster member. This thesis, on the other hand, uses same approach, and it also considers a dual-hop and a multi-hop system between elected cluster-heads to transmit data to the BS. In both cases, the following assumptions (for the network model and cluster formation process) were made:

1. All sensors can transmit with enough power to reach the BS if needed, and the nodes can vary their transmission power.
2. Each node possess enough computational power to perform various signal processing duties and support different MAC protocols.
3. The model used assumes that the nodes always have data to send to the end user throughout the network operation.
4. The sensors are randomly distributed according to a homogeneous spatial distribution in a 2-dimensional space, and the topology does not significantly affect the performance.
5. For Multi-hop LEACH with Concentric Circle (MLCC) the cluster-heads aggregates the data from their cluster members before forwarding to the next closest cluster-head to the BS. In case of Dual-hop LEACH with Concentric Circle (DLCC) the next closest cluster-head is chosen within the concentric circle of radius R.

The following sections discuss these protocols and their algorithms in details.

2.3.4 Dual-hop LEACH with Concentric Circle

The idea behind this scheme is much similar to the single-hop LEACH in terms of network model and cluster formation process as discussed earlier, except this method communicate with BS using two hops and further exploits a radius of connectivity R around the BS, and chooses an optimal path that uses less energy for transmission among the cluster-heads. The goal of this method is to assess the impact of more than one-way communication mode among the cluster-heads and observe how much it does affect the overall performance of the original LEACH protocol. In this instance cluster- heads farther away from the BS will relay their aggregated data to cluster-heads closer to the BS. The local cluster-heads communicate aggregated data from their cluster members to only relaying cluster-heads located within the radius R of the BS. Recall, that this form of communication is what is referred to as dual-hopping in this thesis. Figure 4.9; shows the flow chart algorithm for DLCC. The problem that may arise is that cluster-heads closer to the BS will be overburdened with relaying of packets. To cope with such problem a concentric circle of R is formed around the BS with a newly defined epoch Tdelay. The Tdelay is chosen as a function of the normal epoch

T_{normal} = 1/P opt, given as:

$T_{delay} = \tau\, T_{normal}$

where τ is a constant of optimality. The cluster-heads within R logically constitute a layered architecture with the BS, since they are one hop away. These cluster-heads report directly to the sink, while the other nodes outside the BS form a clustered network and dual-hop to reach the BS. The T_{delay} helps any cluster head within R to transmit less frequently than cluster-heads outside R. However, there is still tendency that in some instances nodes within radius R will die out a little faster than nodes outside R. If this situation arises, then there is likelihood that some packets will be dropped. To solve this kind of problem, cluster-heads farther away have the option of transmitting directly to the BS.

3 DLCC Algorithm

Following the discussions of a two-level single-hop network, by extending the algorithm to three-level yields DLCC. In DLCC the level 1 nodes transmit their data to level 2 local cluster-heads, which performs data aggregation and then locate and transmit the data to the closest cluster-head that is within the concentric circle of radius R, if any, otherwise it transmits directly to the BS. The relay cluster-heads within R wait for a Tdelay epoch, performs data aggregation before forwarding the refined data to the BS. This process generates two levels of clustering with a probability p2 and p3 for election as cluster-heads. The level 3 node becomes relay cluster-head to level 2 and level 1 nodes.

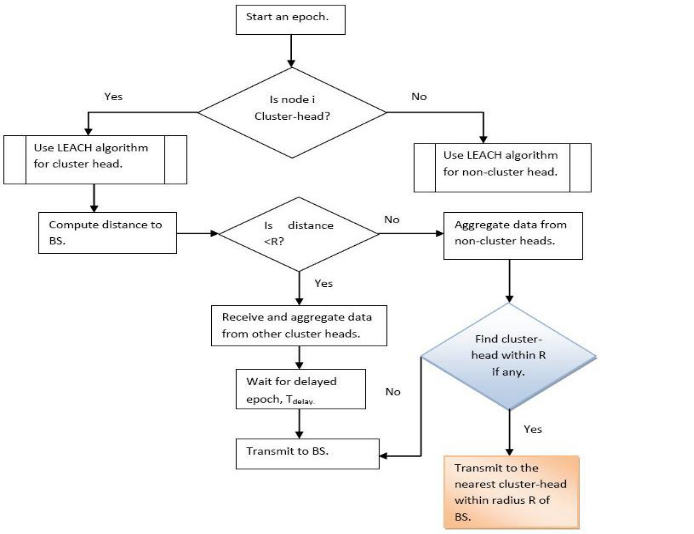

Figure 3: DLCC algorithm Flow chart

3.1 Multi-hop LEACH with Concentric Circle

Multi-hop LEACH with Concentric Circle(MLCC) is similar to DLCC except it extends the algorithm to an Nth level system. It also exploits a radius of connectivity R around the BS to cope with the BS-centric dying pattern that normally accompanies a multi hop network and then chooses an optimal path that uses less energy for transmission among the cluster-heads. In this instance, cluster-heads farther away from the BS will relay their aggregated data to cluster-heads closer to the BS. The relaying cluster-heads may be within or outside the radius R, depending on which is closer. This is one of the other differences between the MLCC and DLCC. The effects of choosing relaying cluster-heads outside the BS is noted in the simulation results, as this increases the number of hop counts, and reduces the performance when compared with DLCC. The remaining process of cluster-head selection and communication model remains the same as with DLCC. The relay cluster-heads within R uses a Tdelay as specified in DLCC.

Figure 4: MLCC algorithm Flow chart

3.2 MLCC Algorithm

In earlier section, a single-hop communication mode with 2 levels of hierarchy was discussed. This section extends the algorithm to Nth levels as described by the energy model. Here it is assumed there are Nth $>$ 1 cluster-heads, level 2 nodes are the first level of cluster-heads until it iterates to Nth $>$1 cluster-heads. The level 2 local cluster-heads receive the data from level 1 nodes, gathers the data and transmits to level 3 local cluster-heads. The same procedures follows until the data reaches the Nth level relay cluster-heads, here the data is further aggregated before relaying to the BS. MLCC and DLCC to the BS through the hierarchy of cluster-heads depends on two factors:(1) the probability popt of becoming cluster-head in each level of hierarchy; and (2) the maximum number of hops between cluster-heads to reach the BS (in the case of MLCC there is no restriction to the maximum number of hops). The idea is that a multi-hop communication mode can still be deployed in smaller networks by exploiting the resources around the BS, and would be as efficient as that of single-hop mode, contrary to the notions of authors in [24], [18]. The flow chart algorithm per round per epoch for MLCC is given in Figure 4.10. The energy model, network model and parameter settings of this scheme are the same as discussed earlier.

4 Simulation Results

Let us assume 100 nodes randomly placed in a network of 100m$\times$ 100m with the same type of nodes called normal nodes equipped with 0.5J of energy, although this value is arbitrary for the purpose of the study, it does not affect the behavior of the protocols. The simulation is carried out with the location of the BS, at (x = 50; y = 50) inside the sensing field, the goal is to study the behavior of LEACH, MLCC and DLCC to this scenario and see how much the cost of transmission affects the performance of these protocols. Let the popt remain the same. This means by setting popt = 0.1, on average there would be 10 nodes as cluster-heads per round. If we consider an homogeneous setting with equal initial energy in the nodes, the epoch for this system would be equal to 1/popt = 10 rounds. In the next subsection, a discussion of the results of experiments for each of these protocols are highlighted below: LEACH goes to unstable region faster than MLCC and DLCC, although the difference between MLCC and DLCC is not so high. DLCC extends the stable region better than in LEACH and MLCC by dual hopping among cluster-heads to reach the BS. The instable period in DLCC is significantly lowered compared with LEACH, and a little lower when compared with MLCC. This is because DLCC exploits the energy resources around the BS better than in LEACH and MLCC by reducing the transmission cost. Thus it can be stated that the stable and instable region in MLCC is better compared with LEACH (see Figure 5). This is due to two factors: the MLCC leverages on multi-hopping to significantly extend the stable region and the concentric circle of R to reduce the instability in the system.

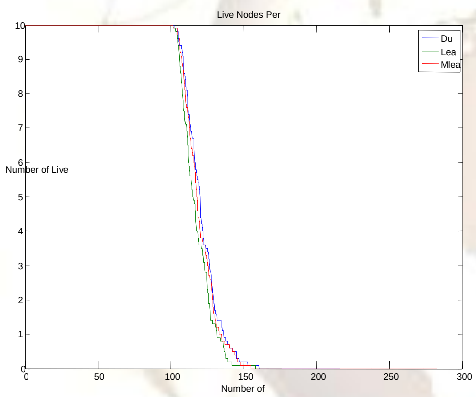

Figure 5: The performance of DLCC, MLCC and LEACH (m = 0; α = 0), Etotal = 50J in the presence of low energy homogeneity from one of the experiments.

Conclusion and Future Work:-

The following areas outlined briefly in this section are open research issues that needs to be explored further for future works in the area of wireless sensor networks:

The lowest distance and routing path can be provided to send the data from Base station to cluster head and feedback node can be provided so as to increase the lifetime.Another viable research direction is; how to control the number of associated cluster members in every cluster. The idea is to create a relative load balanced cluster. The mobility of the sink could be randomized or could be triggered by a dying sensor nodes depending on the optimization strategy in place. The evolution of wireless charging technology promises a long-term breakthrough for WSN if properly leveraged and could create new potential areas of research in wireless sensor networks.

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