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DCCNT: Dynamic Clustering based Circular Network Transmission for Heterogeneous Wireless Sensor Network

M. Jagadeeswara Reddy [1], Dr. P. Chenna Reddy [2]
[1] Research Scholar, Rayalaseema University, Kurnool
[2] Director, Academic Audit, Jawaharlal Nehru Technological University, Anantapur

Abstract: WSNs are application specific, we deployed heterogeneous (Un similar) sensor nodes in the circular area to monitor the network events. In the proposed research we deployed 3-level hierarchy of nodes (namely Advanced, Medium, Normal) in the network named as Heterogeneous WSN. The overall circular network divided into two concentric circles based on the transmission range of Base Sink (BS), which contains nine sub regions together and each region may contain a different number of sensor nodes. The first sub-region considered as an intra cluster communication, BS directly collects the sensor nodes information and, the remaining eight sub regions considered inter cluster communication which data are aggregated by Cluster Head (high energy node) in each road and simultaneously updates to the Mobile Sink (MS). DCCNT provides two mathematical models; packet flow and drop rate estimation is based on a linear programming model, one other model estimates the overall energy consumption of the nodes in each round. Simulation done with MATLAB and results show that DCCNT achieved better stability of nodes, throughput than SEP and DEEC.

1. Introduction

Wireless Sensor Networks build with tiny and light weight nodes are called sensor nodes. InWSN's, sensor nodes are equipped with a limited amount of energy. Hence, design and operational aspects of the sensor network should be energy efficient [1-5]. The IOT applications are emerging have 3-layer reference model, beneath layer has sensor/ tiny devices [6][7]. Monitoring and measuring the physical events done with a variety of WSN application, which useful for Industry, Battlefield, Agriculture, Healthcare, Natural hazards to monitor Atmospheric conditions., etc. [8-10]. Data broadcasting from the cluster to BS classified into 4 unique ways, namely event specific, query based, Continuous and hybrid way. Event specific applications track the triggering occurrences in the area of WSN. Query based approach is controlled by BS (BS define and execute query parameters). Continuous data transmission approach allows each node to transmit the data periodically. Hybrid approach is used for some large scale applications, which use multiple methods at a time. Energy utilization will be computed at each round whenever BS aggregates the data of the sensor nodes. Therefore, designing the efficient clustering strategy is a critical metric for WSN[11,12,13].

Clustering not only improves the data transmission capability bit also allows to achieve better scalability (in terms of nodes) without latency (due to high load) which improves the performance [14]. In this paper our main focus is to achieve scalability of the networks with increasing lifespan and packet drop ration at BS of the network. we presented an enhanced version of clustering with one static BS which located at the center of the network along with two mobile sinks, whichcoveredthe multiple inter clustering areas. The proposed clustering strategy reduces the direct transmission and increases the data aggregation capability, which saves energy by decreasing data transmission distance. A Hierarchical Clustering mechanism covers more number of nodes to improve scalability [15] [16] [17] [18].

Rest of the proposed paper classified into 6 sections. Section II describes the overall related work of the problem. Section III explains the motivation for current work. Design methodology and implementation of the proposed protocol is explained in section IV. MATLAB simulations and conclusion of the proposed research is discussed in the section V and VI respectively.

2. Related Work

Wireless sensor network is classified into two types based on the type of nodes deployed in the network environment, namely homogeneous and heterogeneous. Homogeneous WSN contains all the nodes have equal energy level, whereas as different energy level of nodes in heterogeneous WSN. Some of the previous clustering mechanism related to homogeneous and some are belonging to heterogeneous. Homogeneous hierarchical Clustering Protocols again further classified into two, based on the transmission, one is single-hop and another is multi-hop [19]. Homogeneous clustering protocols with single-hop communication,i.e.LEACH, LEACH- (C, F, ET, E, TB), sLEACH, CLUDDA, RRCH, MELEACH-L, V-LEACH, pLEACH, WST-LEACH, LEACH-SC,

EBC).Homogeneous clustering protocols with Multi-hop communication, i.e. LEACH (M, TL, L, MS).Heterogeneous clustering protocols with single-hop (EECHE, NEAP).Heterogeneous clustering protocols with multi-hop (SEP, DEEC, M-LEACH, EECS, EEHC [21], SDEEC [22], DBEC [23] and C4SD [24]).
LEACH [11] is the basicprotocol, which is the standardized the probability based clustering strategy for homogenous network. SEP (a stable election protocol) [12] is the initial protocol for heterogeneity and performing poor in terms of multi-level heterogeneity. E-SEP (Enhanced SEP) [20] enhances SEP from two levels of a heterogeneity into three levels. In DEEC, [13] cluster heads selected based on probability ofaverage energy ratio of the network and residual energy. It considers average network energy as a reference energy and outperform the LEACH, SEP. [25] explained to improve network lifetime, throughput for multi hop angular routing for WSNs outperforms DEEC, SEP, LEACH.

3. 3.Motivation

In WSN node has limited energy capability, Optimal energy utilization achieve through efficient techniques, clustering is one of the among. Many researchers exclusively worked on the design of new clustering strategies based on the application and constraints. Through literature, scalable and energy efficient clustering for a circular network field is still emerging. Some of the limitations of the previous research work as follows:

- In previous work, deployment of nodes is done uniformly (in terms of the number) in all sub regions rather than random deployment, which is not suitable for all the applications.
- Mobiles sink moves in a circular trajectory of the outer circle, one inclock wise direction another in an anti-clockwise. For an Instance, both the mobile sinks at the same place will not track the eventsoccurred in other regions, which will impact the scalability.
- Circular trajectory considers as exactly the middle center of the outer circle, which is limited to the two level concentric circles.
- The nodes which are not in the communication area of MS, switch to sleep mode unable to track dynamic events.
- At a point, a node may receive two MSs broad casting message, which increase the computation cost of each node.

Our work is focuses on design and implementation of efficient clustering for a circular network filled with heterogeneous sensor nodes.

Radio Energy Dissipation Model: The radio energy dissipation model represented in figure.1. As per model if "L" bit data want to transmit with distance "d" can be calculated as

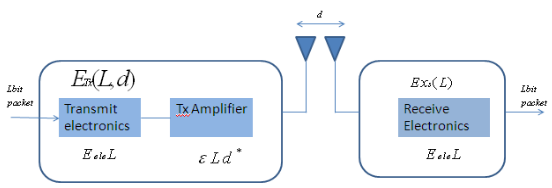

Fig .1. Radio energy dissipation model

$$E_{Tx}(L,d)=\begin{pmatrix} E_{Tx}(l.D)=l.Eelec+l.\varepsilon fs.d & if\ d\ \leq\ do \\ l.Eelec+l.\varepsilon fs.d^{4} & if\ d\ \geq\ do \end{pmatrix} \text{------------}\rightarrow(1)$$

forreceivinginformation, energy will be

$$E_{Rx}(L,d)=L.E_{elec} \text{-----}\rightarrow(2)$$

Assume the outer circle area "A" with "N" number of sensor nodes deployed ,which creates "k "number of clusters. In the hierarchical approach the total energy dissipated in each round by one cluster head as

$$E_{Rou}=\sum_{k=1}^{k}E_{CH_K}+\sum_{i=1}^{N-k}E_{nonCH_i} \text{---}\rightarrow(3)$$

E_{CH_k} is the energy consumed by particular cluster head by performing summation of the operations (data transfer from CH to BS defined in the equation (1) , receive and aggregate) and E_{nonCH_i} is the energy consumed by non CH i .

The overall energy consumed by overall CH in a round is

$$\sum_{i=1}^{N-K} E_{CH_k} = L((K+N).E_{elec} + N.E_{Aggregation} + \in_{amp} .\sum_{i=1}^{l} d^4{}_{toBS_i} + \in_{freespace} .\sum_{i=1}^{K-l} d^2{}_{toBS_i}) \text{ ---→(4)}$$

The overall energy consumed by all non CH nodes is

$$\sum_{i=1}^{N-K} E_{nonCH_k} = L((N-K).E_{elec} + \in_{amp} .\sum_{i=1}^{m} d^4{}_{toCH_i} + \in_{freespace} .\sum_{i=1}^{N-K-m} d^2{}_{toCH_i}) \text{ -----→(5)}$$

from an equation (4) and (5) the overall energy consumed by both cluster heads and non-cluster heads in hierarchical clustering protocols is

$$E_{Rou} = L\Big(2.N.E_{elec} + N.E_{DA} + \in_{amp} (\sum_{i=1}^{l} d^4{}_{toBS_i} + \sum_{j=1}^{m} d^4{}_{toCH_j}) + \in_{freespace} (\sum_{i=1}^{K-l} d^2{}_{toBS_i} + \sum_{j=1}^{N-K-m} d^2{}_{toCH_j}) \text{ ------------→(6)}$$

At each round the overall energy consumed by all sensor nodes explained in an equation (6), is an important metric to prolong the network lifetime. Optimal clustering approach should be right in place to save energy in each round, otherwiseenergy utilization will be more. To address the issues, we proposed DCCNT to prolong network lifespan and scalability.

DCCNT: The Proposed Protocol

We proposed a new clustering protocol; DCCNT (Dynamic Clustering based Circular Network Transmission for Heterogeneous Wireless Sensor Network), for HWSN (Heterogeneous Wireless Sensor Network). The proposed protocol adapts direct communication and dynamic clustering in a circular network field.

In the proposed work, Heterogeneous (Nodes with different hierarchy) sensor nodes are un-uniformly deployed in the circular field. In our work, the overall circular field is divided into the two concentric circle and will extend more based on the design constraints. The inner circle radius (r_{inner})is decided based on the BS(Base station) transmission range,BScollects all the sensor nodes information directly and the outer circle with radius r_{Outer} . The DCCNT schematic diagram presented in the below fig.2.

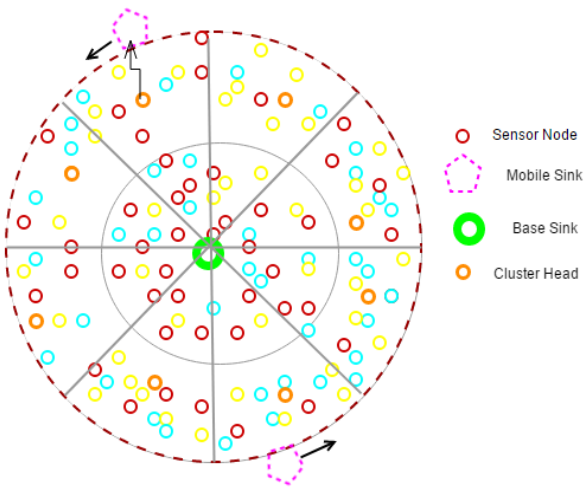

Fig.2. DCCNT schematic diagram.

The overall circular field segmented with a central angle 45 degree (illustrated in fig.3.) created 8 sub regions having anunfixed number of sensor nodes "N", increases the scalability of the network. Each arch length "S" will be calculated as

$$s = r * \theta \text{----------}\rightarrow (7)$$

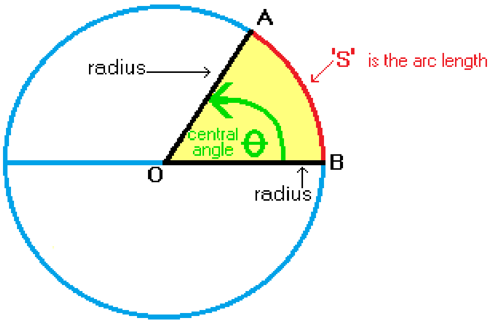

Fig.3.Representattion of Arch in Circular area.

Where "S" denotes arch length, r denotes radius of the circle, θ denotes a central angle.

$$Outercircle\_Sectorarea = \frac{\theta}{360} * \pi * r^2 - \frac{\theta}{360} * \pi * r_{inner}{}^2 \text{-----}\rightarrow (8)$$

After dividing the overall circular field by θ , causes the creation of 8 equal arches. Based on the transmission range of BS, the overall circle is divided into two concentric circle's forms totally 9 sub regions (1 inner circle region, 8 outer circle sub regions) from the center of the circle (Origin).

DCCNT Inherits all the features of the existing approaches and consider a number of topology design assumptions for proposed work as follows.

1. After deployment all the sensors are stationary (i.e. their position never changes once deployed) and have limited energy constraint.
2. The BS (aggregating point) hosted at the center of the network area, with no energy constraint.
3. All the sensors in the topology are not equipped with GPS, so that they unware of their location.
4. Sensor nodes are heterogeneous (i.e. different energy levels)
5. The total amount of sensors are known and randomly deployed.
6. Intra cluster data aggregation carried out byBase Sink(BS) with single hop and inter cluster data aggregation is by multi-hop(MS(Mobile Sink)-→BS).
7. BS and MS capable to connect each other for data transmission.
8. Assume all the sensor nodes have a limited capability to transmit the data within the sub region except CH's.
9. Nodes of energy consumption iscalculated with the first order radio model.
10. Mobile Sinksmove with equal velocity, where one moves opposite to the other maintaining equal distance.

DCCNT proposed with three Sinks (1 static sink, 2 Mobile Sinks) to increase the throughput along with scalability of the network. Two Mobile sinks move around at the outer circle path synchronously with constant velocity and anti-clock wise. The Outer MSs (MS_{One} and MS_{Two}) use the circle equations of a moving path as follows

For MS_{One} ,the equations of a circle are :

$$X_{One} = -R_{One} \cos(\theta) \text{---}\rightarrow (9)$$

$$Y_{One} = R_{One} \sin(\theta) \text{---}\rightarrow (10)$$

For MS_{Two} , the equations of a circle are :

$$X_{Two} = R_{Two} \cos(\theta) \text{---}\rightarrow (11)$$

$$Y_{Two} = -R_{Two}\sin(\theta) \text{---}\rightarrow(12)$$

Where , θ varies between $0 \le \theta \le 360^0$.This proposed architecture with two mobile sinks moving in anti-clockwise perform better than the previous for event-base data collections presented in the simulation results section.

As per DCCNT architecture, the total no of nodes in both inner circle and the outer circle region is

$$N = \rho_{Out}\pi r^2_{Out} - \pi r_{in}^2(\rho_{Out} - \rho_{in}) \text{---}\rightarrow(13)$$

In the outer circle region, the total energy consumption is depending on the distance between CH to non-CH and CH to MS is

$$E_{Rou} = \in_{mp} (\sum_{i=1}^{l} d^4_{toBS_i} + \sum_{j=1}^{m} d^4_{toCH_j}) + \in_{fs} (\sum_{i=1}^{K-l} d^2_{toBS_i} + \sum_{j=1}^{N-K-m} d^2_{toCH_j}) \text{--}\rightarrow(14)$$

In the outer circle region cluster head selection based on the residual energy,node which is having greater energy than the threshold become a CH in first stage is:

$$E_{\text{minCH}} = |S_k| * \left(E_{Rx}(L,d) + E_{\text{Aggregation}}\right) + E_{Tx}(L,d). \text{--------}\rightarrow(15)$$

Where as in the second stage, it calculates the distance from MS is

$$\sum_{i=1}^{8} d_{toBS_i}^{DCCNT} \le \sum_{i=1}^{8} d_{toBS_i} \text{-----}\rightarrow(16)$$

Therefor from the equations (4)(5), we conclude as

$$\sum_{i=1}^{8} d_{E_{CH_k}}^{DCCNT} \le \sum_{i=1}^{8} E_{CH_k} \text{-----}\rightarrow(17)$$

Simulation results

The proposed protocol performance evaluated by using MATLAB simulation. The over topology and design constraints are explained in the above sections. In Fig.4.we evaluated the DCCNT performance with other protocols.DCCNT prolong a larger number nodes alive nodes at higher rounds.DCCNT prolong network lifetime and stability achieved by using MS (Mobile Sinks) at the outer region. The outer region data gathered by MS over time ensure the data collection from every part of the network to Base station.

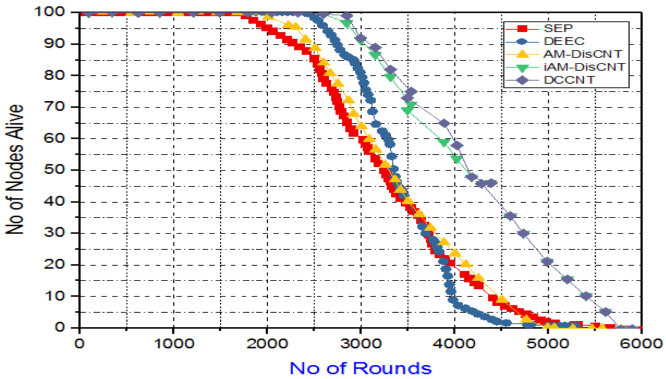

Fig. 4. Network lifetime

Figure 5 illustrate the performance comparison of a number of packets sent toBS. DEEC outperforms with all existed protocols. At a higher rate of rounds, the proposed DCCNT bit performs better than DEEC.Figure 6 shows comparison of the end-to-end delay between DCCNT and previous approaches. DEEC have higher delay to queuing and distance between sender and receiver is long, which reduced in DCCNT outperforms with other protocols.

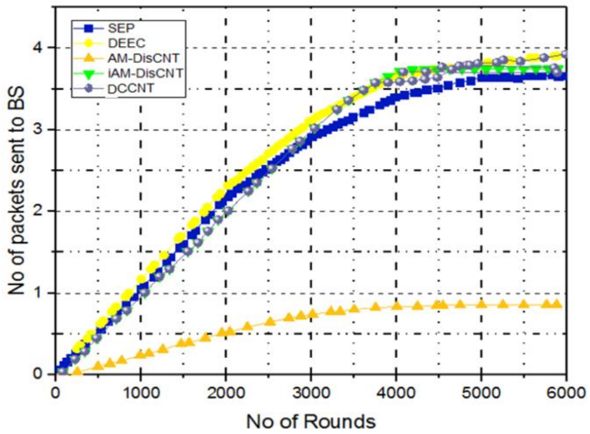

Fig. 5.No. of packets sent to BS

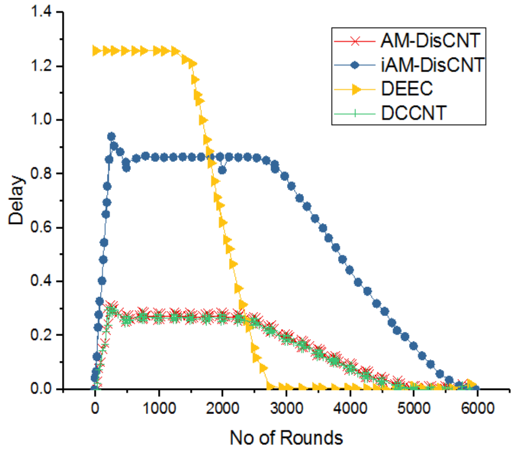

Fig. 6. End to end delay

Conclusion

The proposed protocol, DCCNT (Dynamic Clustering based Circular Network Transmission for Heterogeneous Wireless Sensor Network) for HWSNs; DCCNT adopts a maximum residual energy based on CH selection. The overall network topology is dived into two concentric circles (i.e.inner and outer circle). Inner circle data is gathered from single hop. The outer circlefurtheris divided into 8 sub regions, each sub region works as one cluster (using k-means Algorithm)reduces the distance between nodes to CH and CH to MS maintain high throughput constantly for the higher number of rounds. The proposed protocol DCCNT outperforms than SEP, DEEC and othersexposes good throughput, Stability period, network lifetime.

In the future, the research will enhance to measure the proposed protocol performance for other application specific under a different assumption of the network. Optimization of the proposed protocol process steps in terms of CH selection approach, tests the protocol performance with real time test beds also.

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