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Common Node Exploitation Approach for Path Optimization in Wireless Sensor Networks

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Abstract

Wireless Sensor Networks employ clustering approach to improve operational efficiency where the cluster head is gateway for communication between sink and member nodes in the cluster. While forming clusters, often tend to overlap with neighbouring clusters creates overlap region. Nodes in the overlap region are capable of communicating with neighbour cluster heads. Usually the nodes belonging to one cluster are prohibited from making overtures with other clusters. This paper proposes a Common Node Exploitation (CNE) approach, which a deviates from traditional approach and paves a methodology to exploit the proximity of the nodes belongs to overlapped zone. Based on CNE approach algorithms developed for path optimization, end-to-end delay, packet delivery ratio (PDR) and network energy consumption. Simulations performed have shown that the CNE approach outperforms traditional approaches.

Keywords: Cluster overlap, Common nodes, end-to-end delay, Path optimization, PDR, WSN

1. INTRODUCTION

Wireless Sensors are usually deployed in applications that need remote monitoring of a phenomena in the area where they are deployed. For better conditions and ease of flow of information across the sensors the wireless sensors are networked to process data and transmit sensed information to a base station. The wireless sensor nodes are autonomous in nature, but collaborate with their neighbour nodes to perform various tasks related to sensing, relaying information, data aggregation, network monitoring, etc. in WSN. are to optimize the energy expended for data transmission, and to minimize the time duration in data delivery, i.e. latency. The efficacy of the methods employed are usually evaluated based on the Quality of Service (QoS) assured by the

WSN, in terms of guarantee for reliable and timely delivery of the sensed data to the base station / sink node [1].

Clustering is one of the most popular approach in WSN, aims to reduce the load related to processing of data and transmission in this approach the wireless sensor nodes are grouped into clusters, where each node in the cluster is usually at a single hop distance from a centrally located cluster head (CH). The sensor nodes in a cluster send this sensed data to their CH, which aggregates the cluster data. The aggregated data is relayed to the base station (BS) / Sink in the shortest possible path. There could however, be an overlap/ common zone between neighbouring clusters where a node may be within one hop distane from more than one CH[2]. Issues related to data coherence and conflicts and the data transmission are majorconcern in such scenarios. While most approaches have been proposed in literature to avoid such conflicts, we introduced the Common Node Exploitation (CNE) approach for path optimization studies. In this paper we develop an algorithm based on CNE approach that aims to determine optimal path from a cluster node to the Base Station whenever the latency for a given cluster is more than a predefined threshold, simulations were carried out to study the efficacy of the CNE approach *vis a vis* the traditional approach in terms of packet delivery ratio, end-to-end delay and energy consumption. The simulations results amply demonstrate that extended CNE approach reduces the end-to-end delay, thereby improving Packet Delivery Ratio (PDR) and throughput by the cluster nodes in the network.

The paper is organized as follows: A brief overview of related work is presented in section 2. and we introduce the CNE approach in section 3 and present the CNE algorithm. That the simulation model and the results of the simulations are discussed in Section 4, and Section 5 concludes the work.

2. RELATED WORK

To address issues related to latency, energy consumption, and traffic congestion in WSN most researchers have used the clustering approach [1], [3], [4]. Since CHs take bulk of the communication load, they are responsible to energy drain outs. To address this issue the CHs acts as a gateway node for communication between cluster nodes and the Base Station. LEACH (Low energy adaptive clustering hierarchy) protocol uses randomized rotation of CHs based on member node’s energy [4]. In [5] a routing algorithm based on LEACH is presented to achieve load balance as well as energy efficiency in WSN.

In applications where sensing load is not uniform across the WSN, there may be a load imbalance in the gateways. To counter this, Low *et.al* [2], group the sensor nodes into clusters to enhance the scalability of the network and develop clustering algorithms to balance the load across the gateways.

LEACH is a one-hop protocol where a CH is assumed to relay the data directly to the sink in a single hop. But in practice multiple hops may be required due to transmission range and energy limitations. while forming cluster LEACH and

LEACH-C protocols and few other algorithms prevents such dead nodes not to become as CHs, to achieve load balancing in the WSN [5].

In [6] Xuxun Liu et.al reviewed different routing protocols related to routing, energy efficiency and clusters. A well designed collaborative organization is required between sensors to transmit sensed information to base station in order to save resources. An intelligent adaptive solution for data routing to avoid multiple copies of same message [7] was presented to avoid Flooding or Gossiping using sensors grouping scheme, to build multiple alternative paths. A node can forward information through a set of alternative paths depends on the state of the group leader. Each region has a coverage degree. In general when two sensors are overlapped, it creates three regions. When sensors are moving quickly, this grouping scheme is not useful.

While maintaining reliability and energy efficiency, priority based data forwarding was found to be a better option to reduce latency. In critical applications a scheme that provides differentiated QoS. In [8] a scheme has been proposed to make use of border nodes which are within one hop distance in neighbouring clusters. The border nodes communicate directly with destination nodes, which are within one hop distance. Delay aware routing approach was presented [9] was compared for grid based deployment and random deployment for wireless sensor networks.

In [10] the concept of an Overlapping Area Head (OAH) has been proposed, where an OAH is selected from the overlap region which then acts as a gateway to facilitate inter cluster communication. A node, that covers most number of clusters in the overlap zone, is selected as the OAH. Each CH sends its aggregated data to all neighboring CHs and OAHs, which then try to relay the information to the sink. While the use of OAH enhances reliability as more than one set of aggregated data is relayed to the sink, the approach can potentially lead to traffic congestion, and there by lead to an increase in the energy expended.

Most WSN applications demand QoS guarantees for end to end latency, reliability and energy efficiency. An adaptive scheme that can achieve low latency while maintaining high reliability has been proposed for cluster tree based WSNs in [1], [6]. Assigning data priority while maintaining acceptable reliability and energy efficiency was found to reduced end to end delay.

3. COMMON NODE EXPLOITATION FOR PATH OPTIMIZATION

Clusters overlap is a common phenomenon while the sensors in such overlap zone, though assigned to one cluster, may be within one hop distance from another CH. Such common nodes can potentially respond to any of the clusters if necessary. However, traditionally the nodes are made to claim allegiance only to one cluster, and are prohibited from communicating directly with other CHs. Further, to avoid multi cluster affiliation, the nodes in the network are usually forced to associate themselves with only one CH. Thus, even if a node is located within one hop distance from other CHs, it is made to associate itself with only its own CH [2]. In this paper we introduce a new approach that attempts to deviate from this traditional approach by making the nodes that fall under common zone to communicate directly with other CHs or nodes in other clusters when the end-to-end communication delay is more than a threshold. Thus the Common Node Exploitation (CNE) approach permits the nodes that located within one hop distance from two or more clusters, have the freedom of associating themselves with any of the CHs. Such common nodes send ‘router advertisement' [9] to all reachable sensor nodes from time to time, so that the neighbouring sensor nodes within the transmission range of the common nodes update this information in their routing table.

To study the CNE approach we consider the following two cases and develop an algorithm for each of these cases.

Case 1 assumes a location aware paradigm, where the sensor nodes are deployed in a regular grid based topology. In this scenario nodes are assumed locations to the aware of their latitude and longitude. The second case assumes a random topology, where the nodes are placed in random. In both cases we assume the clustering approach, where the CH is located within one hop transmission range from other nodes in the cluster.

We simulate the first case i.e. location aware network by deploying nodes uniformly, in a two dimensional grid in an WSN deployment area measures of D x D sq units. The WSN deployment space is divided into square shaped cells with side length *S*. As shown in Fig 1. the sensor nodes are placed at each intersection points The number of nodes N_d deployed as per this arrangement is given by:

$$N_d = n^2 + 2n + 1 \qquad (1)$$

Where, *n* is an integer and is equal to *D/S.*

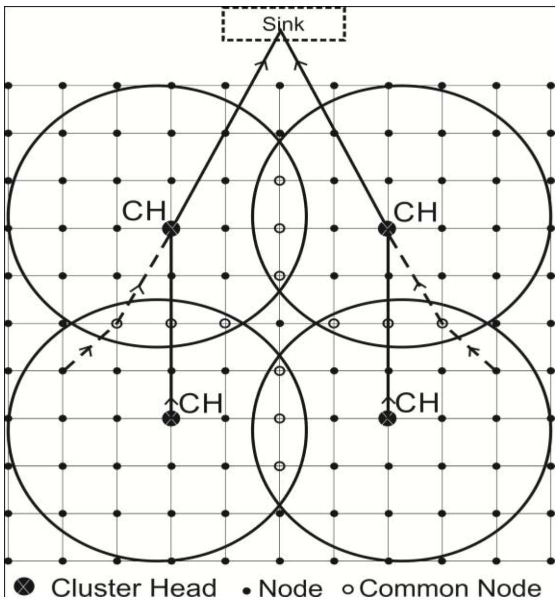


Fig 1. Deployment of nodes at cell intersection points

The distance d from CH to each node is calculated using Haversine [11] formula given below:

$$d = 2 * R * atan^2 (sqrt(a), sqrt(1-a)) \quad (2)$$

where $a = sin^2(\Delta\ latitude/2) + cos(lat1) * cos(lat2) * sin^2(\Delta\ longitude/2)$
and R is earth mean Radius 6,317 km.

The cluster radius/transmission range T_R is chosen to be greater than $D/4$ to ensure that the four clusters try to cover a significant portion of the WSN space.

Each CH forwards aggregated data towards sink via neighbour CH. However to network communication traffic load, if latency at the cluster head is more than the predefined latency then it adopts the proposed approach to find an alternate optimized path to the sink using temporary cluster head to forward data as illustrated in Fig. 2a.

The CH maintains latency information which it shares with its member nodes in the cluster. All common nodes utilise this latency information to make a decision while forwarding sensed data either to CH or through temporary CH. If latency at CH is more, then member nodes forward data to sink using temporary cluster head. The temporary cluster head then find an alternate, shorter, and optimized path to the sink through neighbour CHs that are within transmission range.

Based on the approach we develop an algorithm that determines all possible paths from a node to the sink via all common nodes in its cluster by determining the path lengths the algorithm arrives at the shortest path. This optimized path is then used by nodes to communicate their information to the sink.

Algorithm 1: Extended CNE algorithm for Random Deployment

Input: Deployment Area *DxD* *D* is dimension, location of Sink V_s (X_s , Y_s) ,
Size/ length of Grid (*S*), Network size/Network
density (*Ns*), Number of clusters (*Num*), Transmission range (r).
Output: Determin Optimal Path (P), end-to-end delay(ED), Packet delivery ratio(*PDR*) from
source node to sink V_s
1: For *I* := 1 to *Num*, Do
Randomly generate the point coordinates
$X[i] := X_i ; Y [i] := Y_i ; Pt [i] := Pt;$
End For
2: Assign to each point P_i a node_Id : P_i := node_Id;
3: Randomly select some of the points as CH
∃ i such that CH_i € P_i and $|CH_i| == Num$;
4: Generate cluster members for each CH
V*i* such that *i* := 1 to Num Member Nodes (CH_i , *Pt* , *X, Y, r*);
5: Identify the common nodes lying in the overlap region of neighbor clusters:
Common_Nodes in_Adjacent_cluster (CH_i , CH_j);
6: Calculate Latency at CH.
7: If *Latency* > *default value* Then
Calculate the optimal path (*P)* from each point P_i
in Mem_i to V_s
Via $common\_set_{I,j}$ and CH_j.

	Select P_j as temprorary CH_{ij} and transmit data to CH_j.
	End For
8:	Calculate P, ED and PDR and Energy consumption

To make our simulations more closely resemble the real life situations, we consider random deployment of nodes. Here the nodes are deployed in random in a WSN deployment space of *DxD* sq Units. The WSN space is divided into grids and the nodes closest to the intersection points of the grid are chosen as CH.

We make use of the following equations to determine the distance between any two given nodes.

$$d = \text{sqrt}\left((x_2 - x_1)^2 + (y_2 - y_1)^2\right) \quad (3)$$

Where, (x_1,x_2) and (y_1,y_2) are coordinates of two nodes.

Based on this clusters are formed against each CH. Common Nodes in the overlap regions have the freedom to join any CH closer to the sink. Whenever a node encounters latency greater than its threshold value, it adopts the CNE approach to find alternate optimized path to the sink via the common nodes as illustrated in Fig 2a. A run time simulation snapshot also shown in Fig 2b.

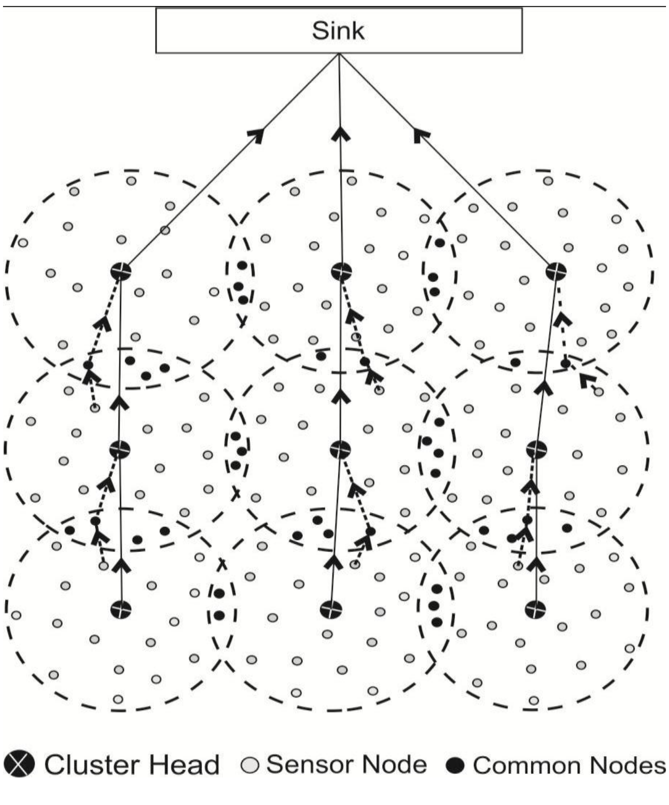


Fig 2a: Nodes in randomly deployed network

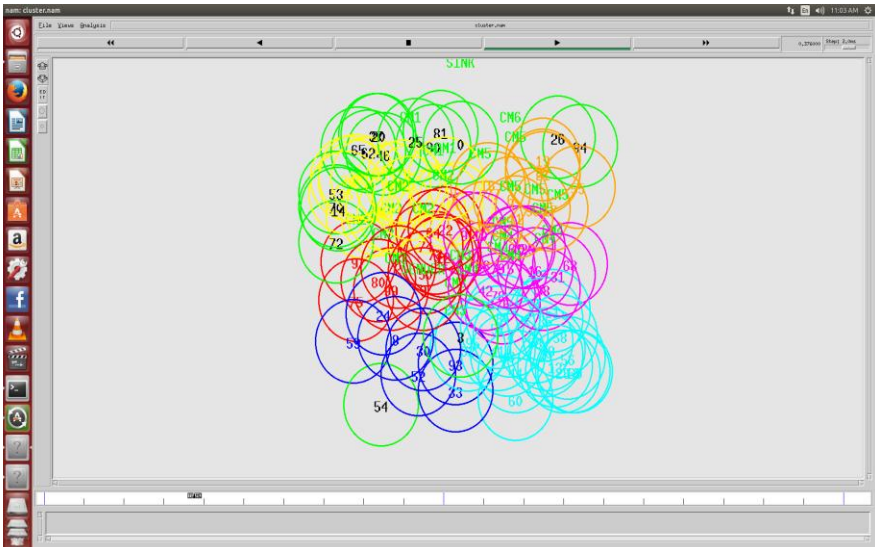
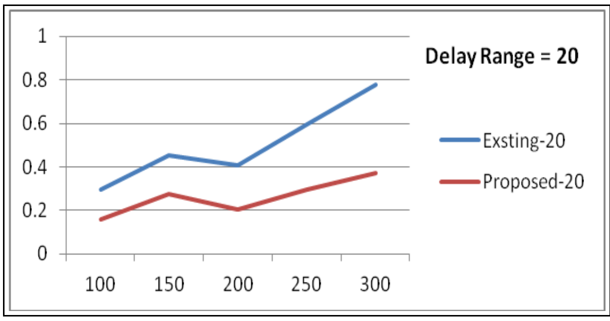


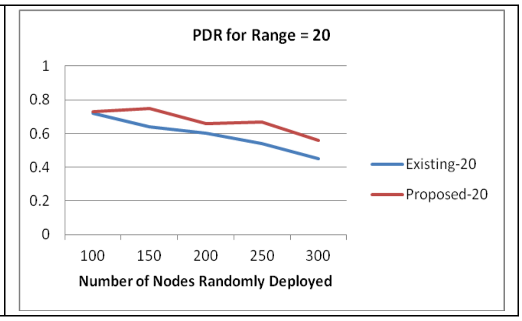
Fig 2b: Simulation in progress

4. SIMULATION AND RESULTS

To study the efficacy of the proposed approach, simulations were carried out to study the efficacy and compared to the traditional method. Nodes are deployed in a WSN space of 100 x100 sq. units for both uniform distribution and random distribution models. The transmission range T_R is chosen as 20, 25 and 30 and the total WSN space is covered by 4 and 9 clusters respectively, for the uniform and random deployment studies. The number of nodes in the WSN space is varied in random distribution method from 150 to 300. The nodes encounter a latency ranging from 1 to 10, and are made to choose the CNE approach if the latency is more than 4.

A comparison of the end-to-end delay and PDR obtained by the traditional method and CNE approach for random node deployment are presented in graphs shown in Fig 3 and Fig 4 respectively. Though there is significant improvement in end-to-end delay and PDR.





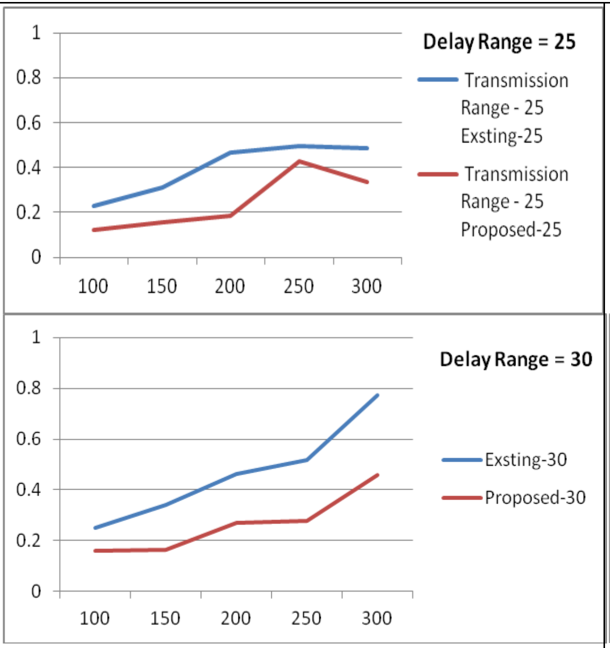


Fig 3: end-to-end delay for variable transmission ranges

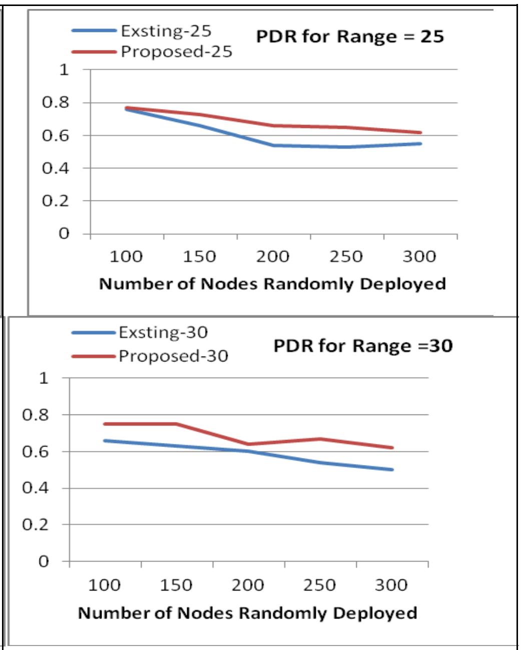


Fig 4: PDR for variable transmission ranges

A comparison of the path lengths obtained by the traditional and CNE approaches for uniform and random node deployment are presented in the bar graphs shown in Fig 5a, and Fig 5b, respectively. The results of the simulation show that the CNE approach significantly reduces the path length.

From the data sheet [12] we understand that the energy consumption in transceiver is 13.5mW in receiving, 24.75mW in transmitting and 15μW in sleep mode. The energy expended E in transmission is a function of its distance [13] and is given $E = kd^c$, where d is the distance between two nodes, k is constant and $2 < c < 4$. For our simulations, we assume $K = 0.1$ and C = 2, and determine the total energy expended by the traditional and CNE approaches along the path to the sink. The results plotted in Fig 6 show that the CNE approach is more energy efficient than the traditional approaches.

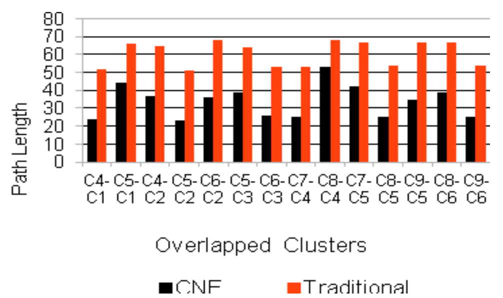


Fig 5a. Path Length in randomly deployed

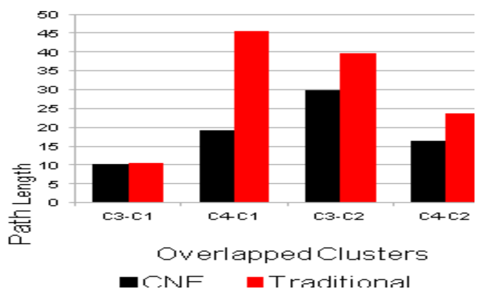


Fig 5b. Path Length in GRID

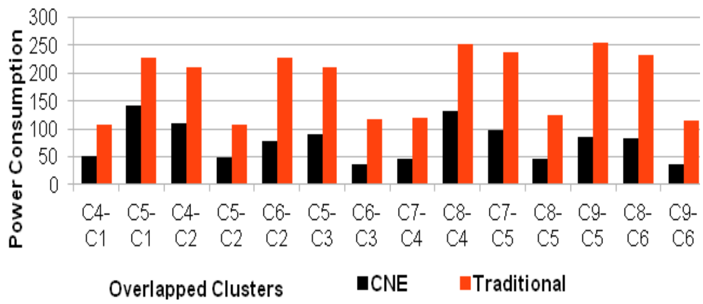


Fig 6. Comparison of Energy consumption in CNE and Traditional method

5. CONCLUSION

We develop the Common Node Exploitation (CNE) approach to exploit the common nodes in cluster overlap zones for optimization of path and energy consumption. Algorithms for reducing path length based on the proposed CNE approach are developed for location aware and random node deployment cases. The simulations carried out for both location aware as well as random deployment of sensors, have shown that the CNE approach based path optimization algorithms outperform the traditional approaches, both in terms of path length, energy consumption, end-to-end delay and packet delivery ratio. As a future work, the CNE approach will be extended to study other QoS issues for like reliability and data aggregation.

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