Proceedings of the International Conference on Intelligent Computing and Communication for Smart World (I2C2SW-2018)
14-15 December 2018

Sink Originated Unique Algorithm for Clustering and Routing to forward Aggregated Data in Wireless Sensor Networks

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***Abstract*— In WSN, efficient communication without compromising the energy of sensor node is the major delinquent issue. In large scale deployment, data redundancy and communication delay will occur due to the crowd of sensor nodes. A Sink Originated Unique Clustering and Routing Algorithm (UCRA) is proposed which works based on each sensor node's Node Handling capacity and processing load of a sensor node is reduced with the forward tree establishment mechanism. The proposed technique was compared with two well-known techniques, Data Routing for In-Network Aggregation (DRINA) and Efficient Data Collection Aware of Spatio-Temporal Correlation (EAST). UCRA conserves 38% more energy and reduces 24% delay when compared with other two techniques.**

Keywords*— *Energy Efficiency, Node Handling Capacity, Data Aggregation, Clustering

I. Introduction

Wireless Sensor Network (WSN) is the most thrust and thriving area for research due to its vital applications and the constraints which affects its performance. One of the major restrictions in WSN for the application areas is the threat of limited energy resources due to irreplaceable batteries.

Apart from power consumption, sensor nodes should ensure scalability to large scale of deployment, be able to cope with node failures, maintains heterogeneity and mobility of nodes and should be able to withstand harsh environmental conditions. Sensor node design plays the major role to fix these characteristics and to improve the transmission performance such as energy efficiency, data rate etc[1][2].

Accoring to Dongfeng Xie et al, effective cluster head (CH) selection was frequently concentrated among nodes in traditional clustering techniques. The entire network is divided into tiny groups as clusters with the objective of reusability of resources such as timeslots, lessening the packet transmissions, only member-CH communications of aggregated data for reducing the energy usage etc.[3]. CH elected based on distance, node density, and probability for equal chance for all nodes to become CH such as LEACH [4]. Clustering methods adopted either centralized or a distributed and implemented for homogeneous or heterogeneous WSNs. From the perspective of Sink, these existing methods failed to address the energy and delay constraints and an alternate is required with centralized algorithm for connection establishment and distributed in nature for packet transmission.

Each sensor node has some capacity to handle a number of sensor nodes while clustering and trans receiving the data. Based on this node handling capacity, total number of nodes covered in a single region can be identified in this work. Clusters are framed by the sink. Sink calculates probability based on the transmitted and received parameters of energy model. To bring the optimal solution, the available node handling capacity is calculated and hybrid routing is considered as a finest choice due to the decisions taken by the intermediate nodes in UCRA.

In the proposed UCRA algorithm, node handling capacity is calculated to construct a unique cluster which ensures reliable data routing, spatially and temporally correlated data are aggregated which ensures energy conservation and reduces delay.

Main Contributions in this work are,

- Framing network energy conservation model based on the cross over distance(COD)
- Finding the data rate and Maximum Available Bandwidth •Find the node handling capacity based on the number of nodes to be covered by a sensor node and neighbors
- Constructing a unique clustering approach to select cluster head by sink based on performance metrics and probability
- Implementing the Forward tree establishment and calculate the probability to become a forwarder based on incoming traffic count
- Cluster updating and route maintenance
- Aggregate spatially and temporally correlated data

II. Limitations Of Existing Work

From the related readings in [5-9], it is inferred that some protocols produced better results in terms of energy efficiency and network lifetime with routing and clustering but data aggregation was not addressed properly. Numerous clustering algorithms were developed with the objective of CH stability and distribution of sensor nodes. CH selection was taken into account only from the point of view of CHs and cluster members and not from the Sink. In most of the clustering and routing protocols, data aggregation was ensured with the mean value of sensor readings and based on threshold value. Spatial-Temporal data was not taken into account for aggregation.

III. UNIQUE CLUSTERING AND ROUTING ALGORITHM (UCRA)

A. System Model

Wireless sensor network deployment is done by considering the following assumptions. The network has 'N' number of nodes with the transmission range 'r' with the initial energy 'e'.

- All nodes in the network are homogeneous.
- Nodes are deployed randomly
- Either the sensor nodes are immobile or the nodes move with random mobility
- Sink will act as a data collector to collect the data from the sensor nodes in the network
- Nodes deployed within the transmission range of the Sink, will send data in direct single hop manner
- Devices use the shared channel to transmit the data.
- All other sensor nodes will communicate with the Sink in a multi-hop manner.
- These sensor devices use other sensor nodes as relay nodes to connect to the Sink
- The sensor device has limited resources such as bandwidth and energy. During the transmission and reception of data both resources will get reduced based on the requirement of the packet they don't possess a guard then there would be chances to miss the announcement and hence departures may in turn get missed.

The energy model adopted here is DE-LEACH [6]. After random node deployment, Sink executes the BS-announcement message. as a broadcast message at fixed time interval and communication established with all the sensors. In this paper, BS and Sink are used interchangeably.

B. Framing and Updating the Cluster

After collecting the information of all sensor nodes, Sink performs the clustering; the proposed clustering approach is centralized and distributed clustering approach. That is the initial clustering process is done by Sink in a centralized manner. The cluster maintenance part is done with all sensor nodes in a distributed manner [10]. The periodical cluster update is done by the Sink to maintain the better connectivity among sensor nodes and Sink. The clustering process is continued with the information collecting phase. The cluster group maintains better hop connectivity because of the clustering aspects such as energy, node connectivity, and bandwidth and traffic pattern of the node.

Algorithm1. Clustering Algorithm

- After receiving all node info, sink node performs clustering
- Sink estimates probability based on
- ETX

If distance(S1, S2) < COD
then $E_{TX} = m.Eelec + m.E_{fs}.d^2$
else if distance(S1, S2) > COD
then $E_{Tx} = m.Eelec + m.E_{mp}.d^4$

$$E_{Avg} = \frac{(w1*A_{ER}+w2*E_{RD})}{2} \quad (1)$$

$$B_{Max} = (\arg\max_{i=1}^{n})[(B_{Total} - B_{Used})_i] \quad (2)$$

$$Rel = (\text{Tot. no. of } Succ_{TX} / \text{Tot. no. of } Attemp_{TX}) \quad (3)$$

$$Node_{HC} = (2*r^2*n\_nbr/ m*n^2) \quad (4)$$

$$CH_{Prob} = \frac{E_{max}*B_N*Rel*Node_{HC}}{E_{Avg\_N}} \quad (5)$$

- while(nodes < = n)

  Calculate CH_{Prob} *for each node*
- End while
- Repeat

  Arrange in Descending order

  Node at 1st position become CH (with max. PCH)

  Select all 1st hop neighbors of selected CH

  Remove those nodes from Prob. List
- Goto step (i)
- Until all nodes to become clusters

Sink performs the centralized clustering for both initial cluster formation as well as the periodical updation. Sink calculates the probability of the node from the node information and stores it in the node probability table. This table is sorted in descending order and from the sorted list the node with higher probability is selected as the first cluster head in the deployment region.

C. FORWARD TREE ESTABLISHMENT

Each cluster in the network selects the forward aggregator to establish the forward tree to complete the sensed data transmission. The same metric which is used to calculate the probability of cluster head is used with little modification to perform tree formation.

$$P_{For\_Node} = \frac{E_{max}*B_N}{I_{TR}} \quad (6)$$

Algorithm2. Forward Tree Establishment

- Sensor node sends Sink_Discovery msg
- Sink_disc msg(msg_type, seq_no, Path_visited, hop_count, ME, AER)
- One hop neighbor receives the discovery msg
- Check for the routing loop

If(Visited Path==node_ ID)
discard packet

- else if(packet== older one)

  discard packet

- If (packet==new)

  check the packet reaches the sink

- If not reached, rebroadcast the packet
- If reached, calculate probability to select the path

Prob. To select a forwarder

$$P_{For\_Node} = \frac{E_{max} * B_N}{I_{TR}} \quad (7)$$

Where I_{TR} *= Incoming Traffic Count*

- end loop

IV. PERFORMANCE EVALUATION

The performance of UCRA algorithm is evaluated using ns-2 simulator and the results are compared against DRINA and EAST, as formerly known best algorithms for routing and aggregation. These two algorithms were chosen from the literature since having the same basic characteristics of UCRA algorithm.

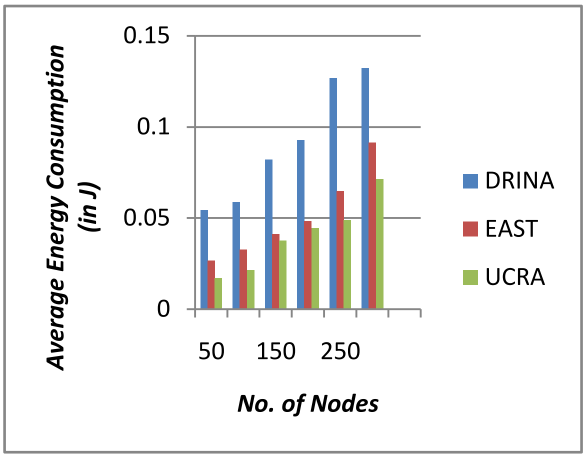
In this simulation, sensor nodes are randomly deployed into a square region of 500 m x 500 m and all nodes have the same transmission radius. Network topology is randomly generated with different number of link nodes from 200 to 350 while confirming the network density leftovers untouched. The default simulation parameters are presented in Table I . Be subject to the evaluation scenario, parameters may get changed.

TABLE I. PARAMETERS USED

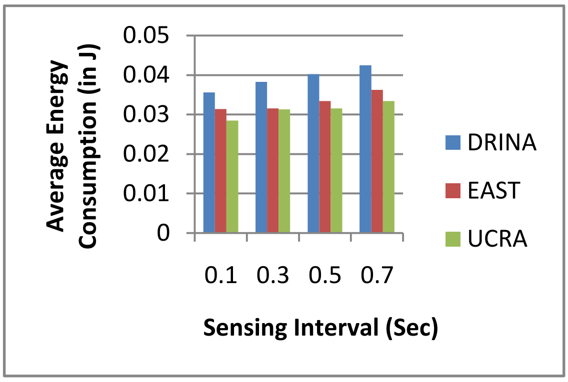
Parameters	Value
Area	500 * 500 m
Number of Nodes	100+1 BS
Initial Energy	100 Joules
Cluster Radius	60 m
Duration	200 Sec
Packet Interval	0.1 to 0.7 Sec
Max. No. of Nodes for comparison	350
W1	0.3
W2	0.7
K	500
Tx Power	0.02 Joules
Rx power	0.01 Joules
Message Size	4000 bits

A. Impact of Energy Requirement on Sensor Nodes

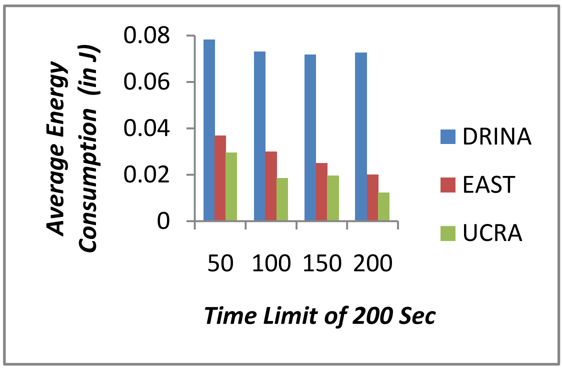
The energy required to transmit and receive packets in UCRA is considerably less when compared with the other well-known existing techniques. Average energy consumption is calculated in three different scenarios: by varying the number of nodes, sensing interval and duration of sensing process and their performance are shown in Figure 1 (a), (b) and (c). Energy consideration is related to half of the node coverage area. Since each node communicates only to nearby cluster head, very less energy is spent for each packet sensing compared to DRINA. When the number of nodes gets increased, the distance to the CH is reduced and thus reduces the energy consumption also. Since node handling capacity is calculated in each 25 seconds, the energy requirement is greatly reduced in UCRA.



(a) Relative Energy based on Nodes



(b) Relative Energy - sensing interval



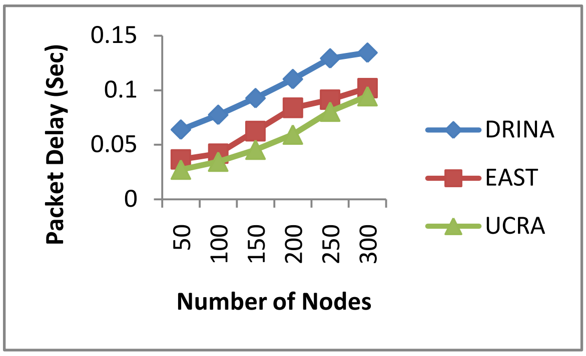
(c) Relative Energy - sensing duration

Fig 1. Energy performances among protocols

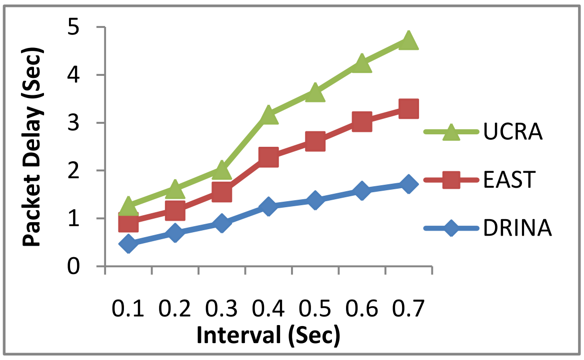
B. Effect of Delay and Data Efficiency

Data packet delay is calculated in three different scenarios: by varying the number of nodes, sensing interval and duration of sensing process and their performance are shown in Figure 2 (a) and (b). Results shown in the given figures predict that the proposed UCRA attained less packet delay compared to existing protocols. Due to the aggregated packets, number of bits transmitted is greatly reduced in

UCRA. Whereas DRINA forwards control messages along with the data packets which increases delay. In EAST, correlation region and error threshold was taken into account but not the forwarder nodes. Hence UCRA gets improved 28% and 12 % against DRINA and EAST respectively in packet transmission delay.



(a) Delay due to increase in node count



(b) Delay by varying sensing interval

Fig 2. Measuring Delay by varying node count and sensing interval

V. CONCLUSIONS AND FUTURE WORK

WSN is an autonomous reconfigurable network which consists of sensor devices which is connected by the centralized device namely Sink. The sensor devices sense the environmental variations and forward the packet to sink by means of data collection and aggregation with forwarding process. In this work, a unique solution is employed to perform the enhanced data forwarding by using the distinctive clustering and routing approach.

This algorithm produces a better performance for small scale environment and when number of nodes get increased, the quality of aggregated data gets decreased slightly since clusters are framed based on the node handling capacity of each cluster head. UCRA provides very promising results and greatly reduces the energy consumption but still it needs to be further improved. To bring the qualified data with reduced energy requirement, scheduling of packets to be implemented before transmitting or receiving the data by the sensor node in a dynamically changing large scale environment.

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