A Cluster Based Weighted Rendezvous Planning for Efficient Mobile-Sink Path Selection in WSN

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Abstract— Data collection and Aggregation is most important task in the large –density applications of wireless sensor network. In the existing system, a mobile-sink node visits Rendezvous Points (RPs), as opposed to all nodes for data collection. Due to processing overhead of Rendezvous point is not appropriate for large scale applications. To overcome this problem, the proposed method is a Clustering Based Weighted Rendezvous Planning (CBWRP) algorithm. The sensor nodes are organized into clusters and each Cluster Head (CH) has a responsibility for collecting data from each sensor node and transmits data to nearest Rendezvous Point. High Energy First (HEF) clustering algorithm is used for selecting node as CH which has more residual energy. The travelling path of Mobile Sink (MS) to visit all Rendezvous point which can be obtained by Weighted Rendezvous Planning (WRP) which can be calculating weight for each sensor node which can be computed by hop distance and number of packets forwarded. An NS2 simulation demonstrates CBWRP reduces energy consumption and increases network lifetime as compared with existing algorithms.

Key words: Clustering; Data collection, Rendezvous point, Mobile sink, Wireless sensor network

I. Introduction

Wireless Sensor Networks (WSNs) is collection of autonomous sensors that absorbs an abnormal physical or environmental condition such as humidity, sound, temperature, pressure, vibration, motion or pollutants, at different locations. The nodes are randomly deployed in sensor network and known its neighbors by GPS and localization techniques. Each sensor node has self-organizing capability for performing sensing, data gathering, and routing. The sensed information of node transmits to the Base Station (BS) via single hop or multi hop manner. In the single hop transmission, a node takes more energy when it farthest from

BS. The lifetime of the network is increased, by avoiding nodes dead due to energy consumption. There are two types of sink can be used, which one can act as Base Station (BS) called static (fixed) sink and other can be act as Mobile Sink (MS). The wide ranging applications are traffic monitoring, forest fire detection, environmental monitoring, agriculture and so on.

II. Related work

In the studies of [1]-[6], mobile sink can collect the information from a sensor node by direct or rendezvous point. This method gathering a sensed event via single hop or multi hop manner. The travelling path of the mobile sink considered as fixed or unconstrained path sink mobility.

In [8], an author proposes Rendezvous Design for Variable Tracks (RD-VT) and Rendezvous Design for Fixed Tracks (RD-FT) algorithms for a rendezvous based data collection. RD-VT constructs Steiner Minimum Tree (SMT) by the source sensor nodes and data collected from originated sources transmits to closest rendezvous points. RD-FT finds shortest tour for mobile element by Travelling Salesman Problem (TSP). Xing et al [7] proposes Rendezvous Planning capability of path (RP-CP) and Rendezvous Planning Utility-based Greedy (RP-UG) rendezvous planning algorithms is developed for overcoming the limitations of [8] algorithms. RP-CP constructs geometric tree for all sensor nodes for RP calculation and its path and RP-UG algorithm finds optimal set of rendezvous points which have maximum energy saving.

Konstantopoulos et al [6] presented Mobicluster protocol is build a multi sized clusters, the size of cluster decreases when distance from base station decreased. This protocol finds Rendezvous Nodes (RN) where node lies near of the travelling mobile sinks. It uses acknowledgment-based communication protocol for RN and MSs. If the cluster size is large then it makes long time data forwarding to RN.

III. CBWRP algorithm

A. Clustering:

In large-density WSN environment, data aggregation is most important for enhancing energy efficiency and prolonging network lifetime. Clustering is an effective method for organizing wireless sensor network in the above context. Clustering is the process of dividing the sensor nodes into different virtual groups and which can be allocated based on geographically adjacent into the same cluster according to some set of rules.

In this clustering structure, a sensor node may be assigned into a Cluster Head or Cluster Member. A Cluster Head can be act as al local coordinator for its cluster member, performing inter/intra-cluster communication and data forwarding to the Base Station (BS).Each sensor node in the cluster can be activated based on TDMS schedule that has given by the cluster head. Our clustering algorithm called High Energy First (HEF) algorithm borrows ideas from the algorithm EECS and LEACH to build clusters. This algorithm constructs a cluster head with have more residual energy.

B. High Energy First (HEF) Clustering Algorithm:

High Energy First (HEF) Clustering is a uniformly distributed and energy efficient which helps in data collection applications of Wireless Sensor Networks. This algorithm selects the cluster head from sensor nodes based upon highest ranking of residual energy while achieving well cluster head distribution. Clusters are formed based on minimum distance between sensor nodes and cluster head which can be calculated by using received signal strength.

Each sensor node has self-organizing capability for calculating its residual energy based on transmitting and receiving packets. In a WSN as G (N, E), where N is set of nodes and E is the set of edges between nodes in N. If sensor node i send k bits to node j then energy consumption calculated for transmitting a packet,

$$E_{TX}(i,j) = k\,(\alpha_1+\alpha_2\times d^{\gamma}_{i,j}) \quad (3.1)$$

Where $d_{i,j}$ is the distance between sensor node i and j, and α_1 energy consumption of the transmitting circuit. The expression $\alpha_2 d^{\gamma}_{i,j}$ is the energy consumption of the amplifier ,α_2 is the energy consumption factor indicating the power incurred by the amplifier circuit and γ is the path-loss exponent. If sensor node j to receive k bits from node i then energy consumption for j can be calculated as,

$$E_{RX}(j,i) = k\times\beta \quad (3.2)$$

where β is consumed energy in the receiving circuit.

In cluster head selection phase, Base Station broadcasts CH Notification to all the nodes at a certain energy level. After receiving the notification, the sensor node compute distance to BS using received signal strength. The candidate nodes for CH election can compare their residual energy with other nodes. Once the energy level is low compared to others then it quiets in competition without receiving any COMPLETE_HEAD_MSG, otherwise it can be selects as a cluster head.

In cluster formation phase, each cluster head broadcasts HEAD_ADV_MSG to its neighbor nodes. After receiving this message, a node decides whether to join that particular cluster head or not based on distance between CH and node. Each sensor node send join request to the CH which have a minimum distance based on received signal strength.

Each cluster head prepares a TDMA schedule and broadcasts to its cluster member, which indicates timeslot for each sensor node to transmitting the packets. The radio component of the sensor node is allowed to turn off at all time periods, except during time of data transmission. Therefore, it reduced an energy consumption of individual sensor node.

The sensor node is turned on at the time of allocated data transmission time and node can be transmits sensed events to its cluster head. A cluster head aggregates the data from its member and send to the nearest Rendezvous point. At the transmission, each node passes data along with the information of residual energy.

At each round, cluster head checks its residual energy comparing with predefined threshold value T(n). If the value of cluster head below of T(n), then the node will persist its position, otherwise cluster head will be changed.

$$T(n) = \begin{cases} p/(1-p\times\left(r\times mod\left(\frac{1}{p}\right)\right) & if\ n\in G \\ 0 & otherwise \end{cases} \quad (3.3)$$

where p is probability of cluster heads and r indicates number of current round.

The cluster heads of ith round cannot became a cluster head of next rounds. It avoids a particular node chosen as cluster-head again and again. The remaining sensor nodes to be a cluster-head by adjusting the threshold T(n), while number of rounds increased.

C. Rendezvous Point Selection:

In delay-sensitive applications, mobile sink node visits rendezvous points instead of all the sensor nodes. Rendezvous point is a point of feasible site and gathering sensed data from the set of nodes in wireless sensor network. The set of nodes should be one or more cluster head electing by the High Energy First clustering algorithm. The node can be selected as RP which have highest weight from the nodes N. The sensor node' weight is calculated hop distance and number of data packets that it transmits to the nearest RP.

Weighted Rendezvous Planning (WRP) is used to determine set of RPs from the sensor nodes N except the cluster head CHi. Then, the weight of node j is calculated as,

$$W_j=NFD\,(j)\times H\,(j,M) \quad (3.4)$$

where NFD(j) is the no. of data packets forwarded to the node j and here $C(j,Tm_i)$ is the function that returns number of children nodes having by the data routing tree(Tm_i) of node j ,which can be calculated as,

$$NFD(j)=C(j,Tm_i)+1 \quad (3.5)$$

Then, H(j,M) is the number of hops of node j from the nearest Rendzvous point in M and it can be calculated as,

$$H(j,M)=\{h_{j,m_i} \mid \forall m_k \in M, h_{j,m_i} \leq h_{j,m_k}\} \quad (3.6)$$

where $h_{j,mi}$ is the hop distance of node j and rendezvous point m_i. The weight is directly proportional to the number of forwarded data packets and hop distance.

D. Mobile-Sink Tour

Mobile sink node needs minimum travelling path to visit all rendezvous point for gathering a sensed data. Each data packet should be delivered to the mobile sink node within maximum allowed packet delay. The cost of the travelling path is calculated by solving the Travelling Salesman Problem (TSP). It can be solved as Delay-aware energy-efficient Travelling Path (DEETP) finds shortest path should not exceeds the maximum tour length l_{max}.A mobile sink node travels with constant speed V (m/sec) and S (sec) is the time for the tour, then maximum tour length l_{max} (meter) can be calculated is,

$$l_{max} = S\times V \quad (3.7)$$

WRP algorithm starts from the static sink node (Base Station) and adds RP (Mi= {m0, m1, m2..,}) to the tour until reach the final destination BS. If the tour length is greater than l_{max} while mi added to the tour then mi should be removed from the tour and RP set.

Fig. 1 shows dotted line indicates shortest path for mobile-sink to visit all rendezvous points. Source node indicated by gray color, which transmits data to its cluster head. Black node indicates CH which sends the sensed data to nearest rendezvous point. It transmits data to mobile sink when it arrives.

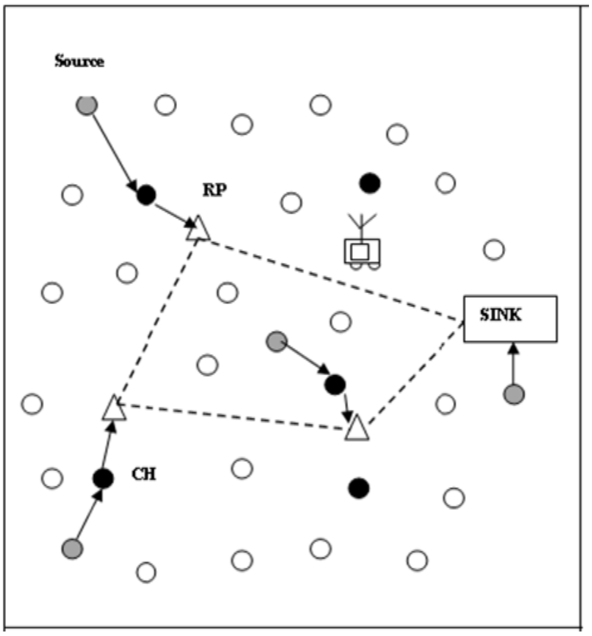

Fig. 1: Movement for Mobile-Sink node by using CBWRP algorithm.

IV. PERFORMANCE EVALUATION

This section describes the performance of rendezvous planning algorithms WRP and CBWRP. This is implemented in NS2 and written in OTcl and C++. The nodes are randomly deployed in 100×100 m^2 sensor field. Table 1 listed simulation parameters for constructing desired topology.

Parameter	Value
Number of sensor nodes (N)	8 to 100
Mobile sink speed (v)	1m/s
Transmission range	15m
Length of data packet	20 bytes
Initial energy of node's battery	50J
Energy consumed at receiving circuit	40mW
Energy consumed in transmitting circuit	25mW
Packet delay (S)	100 to 200 seconds

Table 1:. Simulation Parameters

Fig. 2 shows Network Energy Consumption of WRP and CBWRP. The energy consumption is increased when number of nodes increased. The CBWRP algorithm reduces the energy consumption by 16% compared with existing WRP algorithm. Because of RPs collects a data from the cluster head of each cluster reduces the number of multi hop transmissions.

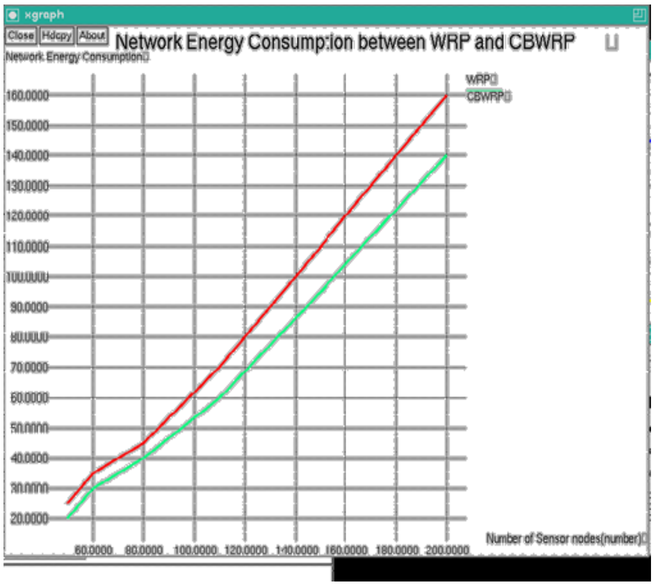

Fig. 2: Network Energy Consumption between WRP and CBWRP.

Fig. 3 shows comparison between WRP and CBWRP based on Network lifetime. The lifetime of the sensor network is increased when number of nodes are decreased. CBWRP algorithm prevents formation of energy holes in network by CHi is selected for each round and distributes energy depletion throughout the sensor environment. The CBWRP algorithm increases network lifetime by 30% compared with existing WRP algorithm.

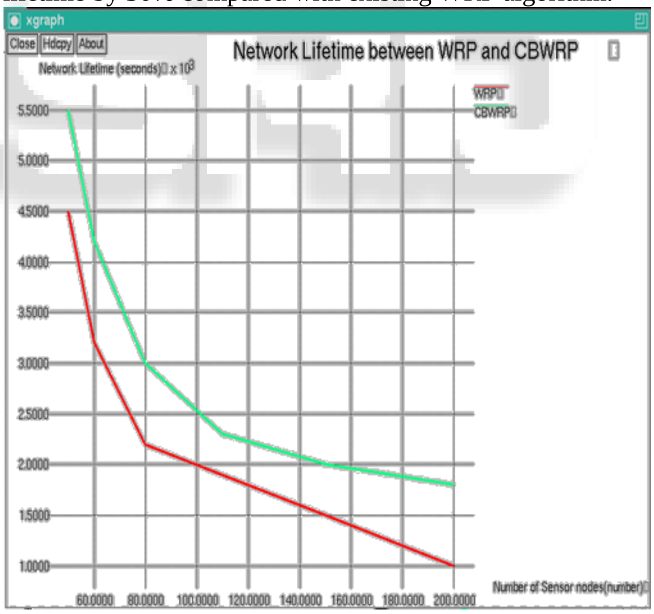

Fig. 3: Network Lifetime between WRP and CBWRP.

V. CONCLUSION

In this system, the proposed CBWRP method determines clusters and set of rendezvous points for mobile sink to collect a data in effective manner. It minimizes energy depletion throughout the network and prevents formation of energy holes. The highest weighted node reduces the number of multihop transmissions in the data collection of the mobile sink. The result of CBWRP is obtained from the computer simulation which indicates Network energy consumption and Maximum lifetime compared with existing WRP algorithm. The future works for this system implementing in urban area applications and measure its performance. To extend CBWRP algorithm to the energy efficient routing protocols for clusters and RPs communication.

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