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Optimal Polling Point Selection and Channel Allotment Scheme for Clustered WSN

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ABSTRACT

Wireless Sensor Networks are constructed to manage the environment surveillance operations. The mobile collector performs the data collection operations at the polling points. The polling point selection is carried out with the cluster head pair details. The data forwarding operations are performed with the distributed load balanced clustering and dual data uploading (LBC-DDU) method. Optimal polling point selection scheme is constructed in the Enhanced Distributed Load Balanced Clustering with Dual Data Upload (ELBC-DDU) method. The bandwidth assignment tasks are managed with the channel allotment scheme. Network area verification and rescheduling process manage the spatial coverage optimization for the data collection process. The data gathering scheme increases the network lifetime with minimum query response delay. Network traffic levels are minimized in the data collection framework.

Keywords: Wireless sensor networks (WSNs), data collection, multi-user multiple-input and multiple –output (MU-MIMO), mobile control, virtual MIMO.

I. INTRODUCTION

Wireless sensor networks (WSNs) are application specific networks composed of small nodes, which can sense the environment, collect the data, do aggregation and every single node can communicate with each other wirelessly via radio link [1]. Today's fast technology improvements in low-power and wireless communication have provided a good condition for WSNs in real-world applications and distributed sensor applications have increased significantly such as wild life and ocean life monitoring, supervising the vibration of structures, automatic warning, supervising the agricultural applications and target tracking.

Nodes have limitations in memory, process and energy; therefore it is difficult to design WSNs. Among the above-mentioned limitations, energy is the most important one because when the sensors are installed their batteries cannot be replaced or charged. Thus, energy considerations are the most prominent factors in WSNs routing. One of the most famous routing algorithms for WSNs is clustering-based hierarchical routing. In this method, all nodes are divided into groups called clusters based on specific methods. In each cluster, one node is selected as a cluster head (CH) and other nodes are considered as normal nodes. Different parameters are taken into account while selecting a CH in various methods. In the major part of clustering algorithms, the main goal is to achieve uniform energy distribution to increase network lifetime. In this type of routing, sensor nodes play different roles and they may have different energy consumption according to their role.

This group of methods is the best class of routing algorithms for WSNs. A CH is able to manage and schedule intra-cluster activities, and as a result nodes may change their state to low-power sleep mode and reduce energy consumption. The nodes might be utilized in a round-robin order and a specific time could be determined for data transmission and receive. Retransmitting is avoided and data redundancy in target region is decreased and medium access collision is also avoided. Nodes alternatively transmit their data to CH. The CH collects the data, compresses it and transmits the compressed data to the base station (BS). Transmission to the BS might be done directly or in a multi-hop process and with the incorporation of other CHs. Since CHs transmit their data over longer distance, the energy consumption rate is higher in CHs. A simple approach to balance energy consumption is to reselect the CHs periodically. In this case, the role of CH is changed. The structure between normal nodes, CHs and BS might be repeated.

II. RELATED WORK

With the emergence of mobile sensors, extensive researches have been promoted on target coverage of WSNs. According to different application scenarios, the existing studies can be classified into three categories: (1) route patrol for collecting data from fixed targets [10], (2) detection of mobile targets [4], [5], [3] and (3) target coverage in dynamic environments [6]. In these studies, mobile sensors move actively to improve the surveillance quality, but the optimization of sensor movement is not explicitly considered. Reactive mobility is exploited to improve the quality of target detection, but the movement of sensors is not considered as the primary optimization objective. Mobile sensors are scheduled to replace failed static sensors in order to guarantee coverage ratio with minimum movement distance. But each sensor concerned cover only one target and the maximum moving distance for each mobile sensor is limited. An optimal velocity schedule is proposed to minimize energy consumption in movement when the road condition is uniform.

Many research efforts have also been made to improve the area coverage with mobile sensors with the aim of maximizing the covered area. In [7], Voronoi diagrams are used to detect coverage holes. Sensors are dispatched to cover the detected holes. As a result, the area coverage ratio is improved. Further, a multiplicatives weighted Voronoi diagram is used to discover the coverage holes corresponding to different sensors with different sensing ranges [8].Voronoi diagram to discover the coverage holes corresponding to different sensors with different sensing ranges. Voronoi diagrams in these studies are constructed according to the position of mobile sensors, and thus need to be recomputed after each round of sensor movement. In [9], mobile sensors are used to improve energy efficiency of sensors in area coverage. When destinations have been determined, mobile sensors are designed to move along the shortest path to minimize the energy consumption.

Given designated destinations, k-coverage is studied. In this work, a competition scheme is proposed to minimize energy consumption in movement. Recently, parameterized algorithms were exploited to find maxlifetime target coverage [11] and min-power multicast paths WSNs. In these studies, destinations of mobile sensors are given in advance and the energy efficiency is considered in the path finding process.

Mobility of sensors could also be exploited to enhance network connectivity after the coverage stage is completed. A triangular deployment strategy is proposed to dispatch sensors to connect the network after deploying mobile routers to maximize the coverage area. In the proposed strategy, sensors move along the shortest path to the corresponding triangular vertices in order to save energy [2]. The authors considered a hybrid network consisting of both static and mobile sensors. It first divides the static sensors into groups as large as possible and then seeks the minimum number of mobile sensors to connect these static sensor groups. A sensor node relocation approach is proposed to maintain connectivity between a region of interest and a center of interest outside the deployment region where a particular event happens.

The originality of this study and differences from the existing work include. (1) In this work, sensors move reactively and each sensor can cover more than one target, which is more general in practice, but also makes the problem more complicated. (2) The Voronoi diagram of targets is adopted to find the nearest sensor, which avoids blind competition among mobile sensors. Besides, because our solution generates the Voronoi diagram according to the position of targets, it does not require re-computation of the Voronoi diagram as the targets are static. This contributes to the lower complexity of the proposed solution. (3) Destinations of mobile sensors are unknown, which should be computed by our algorithms. When mobile sensors move to these destinations, both target coverage and network connectivity are satisfied. (4) In order to investigate the impact of network parameters on the performance of our algorithms, analyses and evaluations are given according to the simulation experiment results, which provides a reference for practical engineering and theoretical basis for the design of mobile sensor networks.

III. SYSTEM METHODOLOGY

3.1 Data Gathering using Joint Virtual MIMO

The joint virtual MIMO and data gathering (vMDG) model is adapted to schedule the nodes. There are n wireless nodes randomly distributed in a planar field. Each node u knows its position denoted by (X_u, Y_u). Each node is equipped with an antenna and can adjust its transmission power arbitrarily. Four important assumptions are considered for problem definition. First, it is assumed that the network is synchronized. Despite some concerns over the infeasibility of the MIMO mode due to lack of simultaneous synchronization, some works a small synchronization error didn't greatly decrease the performance of vMIMO transmission. For example, Nguyen et al. analyzed that the performance degradation increased with the synchronization error and the number of cooperative transmission and reception nodes [12]. The cooperative MIMO system was rather tolerant for small ranges of synchronization error and the degradation was negligible for synchronization error range as small as $0.2T_s$, where T_s was the symbol period. As a result, it is reasonable to assume perfect time synchronization among the network. Second, transmission collision can be avoided. In general, MAC protocols based on adaptive modulation can be used and in particular, the MAC protocol uses a variable-length energy-minimizing TDMA scheme for interference avoidance also used.

Third, this work ignores the cost of sharing the control information for vMIMO transmission in the data gathering. This assumption is based on the following reasons. The control packet is relatively short compared with the data packet. Second, the algorithm will construct a tree. Most of the links in this tree are not long. The energy consumption of additional data exchange procedure will not greatly impact the energy consumption of vMIMO communication. Fourth vMIMO involving two (2) nodes at most based on the following rationale. Sajid et al. have given two conclusions by simulations. The SIMO, MISO and MIMO models are more energy-efficient compared with the SISO mode. Second, the 2 * 2 mode is much more energy-efficient than 1 * 1 (SISO), 3 * 3 (MIMO) and 4 * 4 (MIMO) modes. If more nodes cooperate with others in vMIMO transmission, the management of the cooperative nodes will also become more complex. The vMIMO transmission includes four different communication modes, SISO (1 * 1), SIMO (1 * 2), MISO (2 * 1) and MIMO (2 * 2) respectively. In the SIMO, MISO and MIMO modes, the transmitter or receiver sides may contain two nodes. For convenience, two nodes in one transmitter or receiver side will be referred to as a cooperative node pair.

The joint vMIMO and data gathering (vMDG) problem is to select a set of cooperative node pairs, construct a vMIMO-aware topology and perform vMIMO-aware routing on the topology, so that all nodes will send their sensor data to the base station with vMIMO transmissions. The optimization objective of this problem is to minimize the total energy consumption of data gathering for wireless sensor networks.

IV. SYSTEM IMPLEMENTATION

4.1. Optimal Polling Point Selection Scheme

The polling points are identified to locate the mobile collectors. The mobile collector performs the data gathering process on the selected polling points. The mobile collector makes the communication with the cluster head pairs from the polling points. The clusters are formed with reference to the node location and resource information. The cluster heads are elected with reference to the resource and coverage level information. Cluster head pairing process is initiated to group up the nearest clusters for data collection process. The polling point selection process is integrated with the cluster head pair selection process. Partitioning method is applied to fetch optimal polling points. The vMIMO scheduling scheme is tuned to handle multiple cluster based data collection. The bandwidth allocation is carried out for the mobile collection data communication process.

4.2. Spatial Coverage Analysis

The sensor coverage information is categorized into two types. They are sensing coverage and transmission coverage. The sensing coverage deals with the data monitoring area levels. The transmission coverage indicates the data transmission distance levels. The spatial coverage analysis verifies both the sensing coverage and transmission coverage values. Sensor node deployment is carried out with the coverage values.

The network coverage reflects the entire monitoring area measurements. Data values are sensed and stored in the local storages. The data transmission is carried out through the cluster head to the mobile collector. In the sensing coverage verification the network is compared with the sensing coverage levels. The transmission coverage analysis includes the data transmission process between the node to cluster head and cluster head pair to the mobile collector. Node membership under the clusters is verified for the node to cluster head communication. The mobile collector trajectory plan is composed with reference to the cluster head pairing and polling point selection information. Cluster head pair communication is verified with the mobile collector receive ranges. The cluster assignment and head selection operations rescheduled with the spatial coverage information.

V. PERFORMANCE ANALYSIS

The mobile collector based data distribution scheme for Wireless Sensor Networks (WSN) is designed to perform data collection process. The sensor nodes are grouped with reference to the resource and proximity values. The cluster heads are selected to manage the data transfer process. A three tier framework is constructed to manage data transmission process. The mobile collector collects the data from the cluster heads. The cluster head collects the data values from the sensor nodes. Cluster head pair selection and pooling point selection tasks are carried out for the data collection process. The optimal polling point selection scheme is adapted in the polling point selection process.

The Load Balanced Clustering with Dual Data Upload (LBC-DDU) scheme is employed to perform the cluster head and pooling point selection process. The Multi User Multi Input and Multi Output scheduling scheme is adapted for the bandwidth scheduling process. The Enhanced Distributed Load Balanced Clustering with Dual Data Upload (ELBC-DDU) scheme is designed to handle the spatial coverage optimization, optimal polling point selection and channel allotment process. The system is tested with three performance measures. They are average response time, traffic rate and network lifetime parameters. The average response time measures the time period taken for the data collection process. Figure 5.1.shows the average response time analysis between the Load Balanced Clustering with Dual Data Upload (LBC-DDU) and Enhanced Distributed Load Balanced Clustering with Dual Data Upload (ELBC-DDU) schemes. The analysis result shows that the Enhanced Distributed Load Balanced Clustering with Dual Data Upload (ELBC-DDU) scheme reduces the average response time 30% than the Load Balanced Clustering with Dual Data Upload (LBC-DDU) scheme.

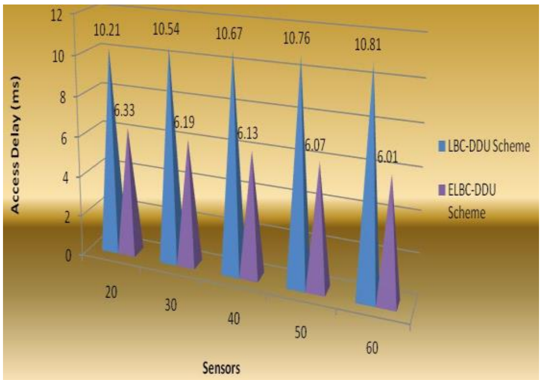

Figure 1. Average Response Time Analysis between (LBC-DDU) and (ELBC-DDU) schemes.

The traffic rate analysis is carried out to measure the message transmission level for the data transmission process. Figure 5.2.shows the traffic rate analysis between the Load Balanced Clustering with Dual Data Upload (LBC-DDU) and Enhanced Distributed Load Balanced Clustering with Dual Data Upload (ELBC-DDU) schemes. The analysis result shows that the Enhanced Distributed Load Balanced Clustering with Dual Data Upload (ELBC-DDU) scheme reduces the traffic rate 20% than the Load Balanced Clustering with Dual Data Upload (LBC-DDU) Scheme.

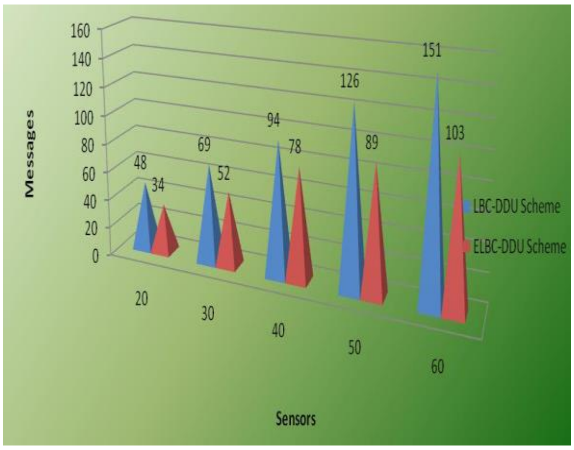

Figure 2. Traffic Rate Analysis between (LBC-DDU) and (ELBC-DDU) schemes

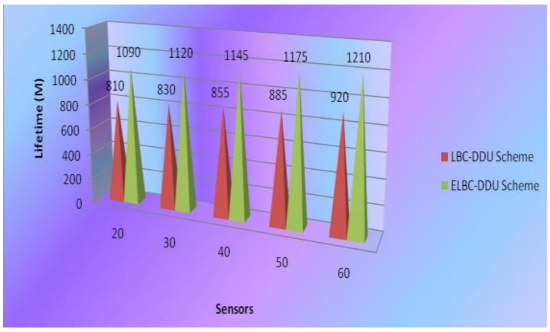

Figure 3. Network Lifetime Analysis between (LBC-DDU) and (ELBC-DDU) schemes.

The network lifetime analysis is carried out to measure the network lifetime for the WSN. Figure 5.3.shows the network lifetime analysis between the Load Balanced Clustering with Dual Data Upload (LBC-DDU) and Enhanced Distributed Load Balanced Clustering with Dual Data Upload (ELBC-DDU) schemes. The analysis result shows that the Enhanced Distributed Load Balanced Clustering with Dual Data Upload (ELBC-DDU) scheme increases the network lifetime 35% than the Load Balanced Clustering with Dual Data Upload (LBC-DDU) scheme.

VI. CONCLUSION AND FUTURE ENHANCEMENT

The environment monitoring operations are managed with the sensor networks. The data capture and transmission operations are managed with mobile collectors. The mobile collector data transmission process is performed with the Distributed Load Balanced Clustering and Dual Data Uploading (LBC-DDU) scheme. The Enhanced Distributed Load Balanced Clustering and Dual Data Uploading (ELBC-DDU) method is build with optimal polling point selection and channel allotment scheme. The ELBC-DDU also supports spatial coverage optimization to cover the entire network area. The network lifetime is increased with minimum energy consumption levels. Response time and traffic levels are minimized in the data collection process. The system can be enhanced with the following features. The system can be improved to handle malicious and anonymous request attacks. The data collection scheme can be tuned to handle mobile sensor environment.

VII. References

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