An Energy-Efficient Cooperative Routing in Wireless Sensor Networks

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Abstract—**Wireless Sensor Network (WSN) is a collection of thousands of wireless sensor nodes which are battery-powered devices. During data forwarding the wireless nodes have limited data processing and transmission power. Thus, energy consumption of wireless devices plays an important role in system design. Our main aim is to reduce energy consumption in WSN by using an effective technique like data fusion and clustering. Nevertheless, the clustering technique leads to extra delay during data aggregation process. When the size of outgoing data is not reduced by in-network data fusion, the network is in great trouble. This problem is effectively overcome by changing the network structure. Therefore, we proposed a modified network structure for energy consumption in WSNs using Cluster based In-Network Data Fusion (CINDF). The proposed modified structure forms the wireless sensor nodes into number of clusters of various sizes; therefore each cluster can make communication with the data fusion center in an interleaved manner. The intra-cluster communication distance is optimized by using an optimization process. The proposed structure is compared with other existing data aggregation structures and the simulation results shown that the proposed approach can effectively reduce energy consumption and delays using data aggregation process.**

Index Terms— **In-network data fusion, Clustering, data aggregation and Wireless Sensor Network.**

I. INTRODUCTION

Wireless Sensor Network (WSN) has gained more attention in the field of research that comprises of thousands of sensor nodes which have low computation cost and storage capacity. These sensor nodes are used to measure, sense and collect information from environment and transmit the collected information to the user or destination using a set of rules. [1,2]. These sensor nodes possess limited amount of memory which are deployed in a difficult accessing locations. In WSN, a radio is implemented to achieve wireless communication to transmitting the collected data to a base station. Battery is the major source of power in wireless sensor nodes. Wireless sensor networks have no or little network infrastructure in which there are two types like structured and unstructured based WSNs are used. [3,4]. Sensor networks possess great potential in several applications like natural disaster relief [7], seismic sensing [10], military and surveillance applications [5,6], hazardous environment exploration [10] and biomedical health monitoring [8,9] etc. But those wireless sensor nodes require more power for data transmission which is a major drawback in WSN. For energy consumption, clustering based in-network data fusion is proposed to effectively reduce energy consumption [11,12].

A. Clustering

In clustering, a typical clustering algorithm is used in which various sensor nodes are split into number of clusters. Each cluster has a cluster head (CH) and cluster members (CMs) which makes connections with the CHs. Basic operation cluster head is to collect information from its cluster members. If the collected data from the cluster members is fusible, then the corresponding cluster head performs data fusion on the collected data and the output of data fusion is the reduced size of collected data. The sensor network has a fusion center (FC) that collect fused data output from each cluster head that will process the further operation of collected fused data. It is necessary to reduce the communication distance and size of transmitted data to reduce energy consumption greatly. If the proposed in-network data fusion does not provide any size reduction in output data, the clustering approach can introduce additional delay and

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energy consumption in the process of data collection [13,14].

B. In-Network Data Aggregation

Data gathering based applications used in-network Data Aggregation in order to reduce considerable amount of communication packets that results increased network life-time. The in-network data aggregation denotes several ways of data forwarding methods to intermediate sensor nodes towards the sink node when combining the collected data from various source nodes. [15,16]. In-network aggregation provides the synchronization of packet transmission among the sensor nodes in which the routing protocol design is a key factor for aggregation of collected data. In data aggregation process, a sensor node does not transmit data packet as soon as it is accessible since it waiting for data from its neighbor nodes which leads to better aggregation of data that finally improves the performance of proposed algorithm by reducing energy. [17]. Size reduction of data involves in combining and compressing the packets received from all its neighbors by a node in order to reduce the length of collected packets to be transmitted.

The rest of this paper organizes

II. RELATED WORK

In this section, existing hierarchical cluster based routing protocols are discussed to compare the performance of the proposed approach. The data aggregation and data fusion are used to reduce total number of messages transmitted to the sink node.

Heinzelman et al. [18] proposed Energy- Efficient Communication Protocol for Wireless Sensor Networks in which Low Energy Adaptive Clustering Hierarchy (LEACH) is explained. LEACH protocol is one of the initial significant developments to existing clustering approaches in wireless sensor networks. Conventional clustering schemes like Minimum Transmission Energy (MTE) which does not result to energy dissipation through the network. LEACH algorithm gives balanced energy consumption in the presence of random rotation of cluster heads.

Loscri et al. [19] presented Two-level hierarchy for low-energy adaptive clustering hierarchy (TL-LEACH) which is an extension of LEACH algorithm. Parent-child combination is supported by this TL–LEACH that has a base station which receives transmitted data in a single hop manner. It classifies the cluster heads into primary cluster head and secondary cluster head and it also uses other sensor nodes as simple detection nodes. At first, the primary cluster head make communication with the secondary cluster head. The architecture of TL-LEACH has two levels which can greatly reduce energy consumption and number of nodes, while base station receives data from source. In measuring the data reliability enhancement of both LEACH algorithm and TL-LEACH algorithm are almost same [20].

J. Hee-Jin et al. [20] proposed a Mobile Agent Based LEACH in Wireless Sensor Networks which is a multi-hop intra cluster algorithm. This technique is used where the clustering approach utilizing mobile agents for data transmission and those are moving dynamically across the network. The clustering approach controls the operation of mobile agents in local management. The characteristics of the participating mobile agents are estimate itself which calculates average transmitted data and shared the data information among the nodes. Thus, the redundant data are reduced and it finds an alternate path when path failure occurs which can give reliable data delivery.

III. PROPOSED METHOD

In this paper, Cluster based In-Network Data Fusion (CINDF) is proposed. At first, set of sensor nodes are randomly deployed in the network. These nodes are formed as clusters in which cluster heads are assigned and the proposed modified network contains a fusion center for data fusion. Initial energy of each sensor node is observed at each cluster in which high energy node is elected as cluster head. The operation of cluster head is to collect or gather data from its cluster member. After data collection process, the network is updated by updating each step size and this updation is denoted by the cluster heads present in each cluster. If the collected data from the cluster members are fusible then the cluster head can perform data fusion on the collected or incoming data which reduces the size of outgoing data. This fused data output is transmitted to the fusion center for further operation.

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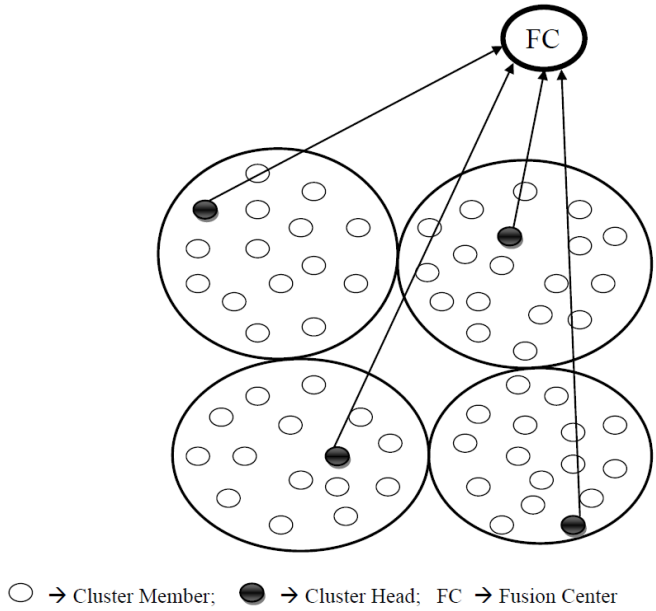

Fig. 1 Proposed Network Architecture

Next, the proposed algorithm concentrates on the transmitting data size, communication distance and energy consumed by a node which must be reduced. The optimization technique is used to reduce the communication distance that reduces energy consumption i.e., if a path to destination is so long, then it consumes more energy for packet transmission. If a path i.e., the distance of destination from source is reduced, then the transmitted packets consume very less energy.

A modified network structure is also proposed which is a tree based network that assures the duration of data aggregation will be greatly reduced, even the in-network data fusion does not provide the packet size reduction on the incoming data to produce reduced size of outgoing data. As mentioned above the sensor nodes are formed into several single-layered clusters with different sizes. Thus, all clusters make communication with the fusion center in an interleaved manner through cluster heads present in each cluster. Figure 1 illustrates the proposed modified network structure.

IV. EXPERIMENTAL RESULTS

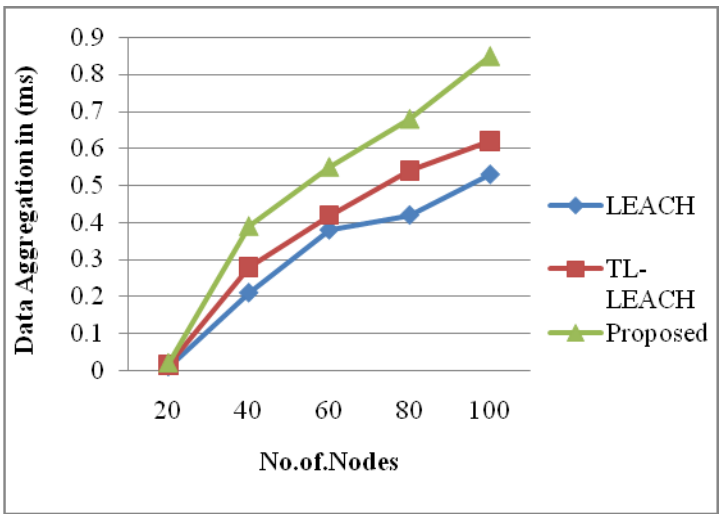

Fig. 2 No. of Nodes Vs Data Aggregation

In Fig. 2, three protocols such as LEACH, TL-LEACH and Proposed protocols are compared. These plots are drawn between No. of Nodes and Data Aggregation. While No. of Nodes is increased the Aggregation of existing protocols (LEACH and TL-LEACH) gets slightly increased and the proposed protocol gets rapidly increased. Generally, the network which has high aggregation provides better performance.

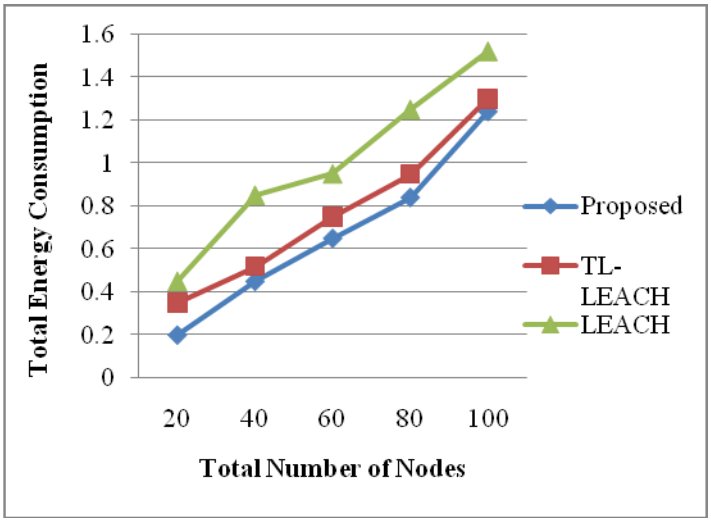

Fig. 3 Total Number of Nodes Vs Total Energy Consumption

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In Fig. 3, three protocols such as LEACH, TL-LEACH and Proposed protocols are compared. These plots are drawn between Total Number of Nodes and Total Energy Consumption. When Total No. of Nodes is increased the Total Energy Consumption of existing protocols (LEACH and TL-LEACH) gets increased and the proposed protocol gets reduced. The network which has low energy consumption can provide increased network life-time.

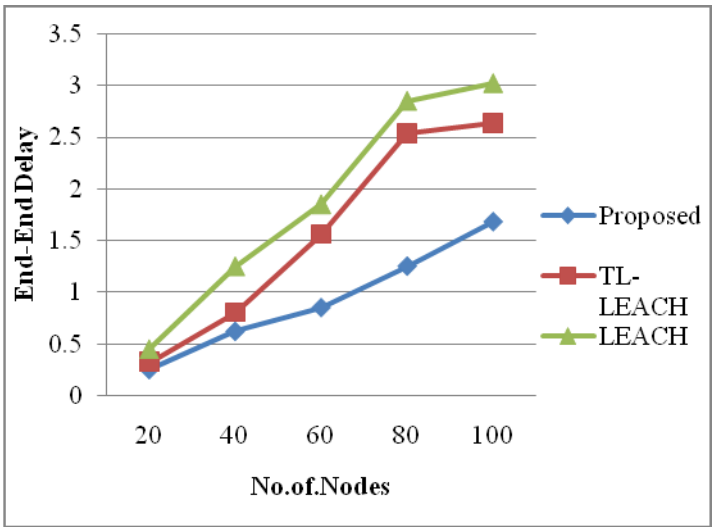

Fig. 4 No. of Nodes Vs End-to-End Delay

In Fig. 4, three protocols such as LEACH, TL-LEACH and Proposed protocols are compared. These plots are drawn between No. of Nodes and End-to-End Delay. While No. of Nodes is increased the End-to-End Delay of existing protocols (LEACH and TL-LEACH) gets increased and the proposed protocol gets reduced. The network which has reduced End-to-End Delay can provide better performance.

V. CONCLUSION

In this paper, Cluster based In-Network Data Fusion (CINDF) with modified network structure is proposed to reduce overall energy in WSNs. The proposed modified network structure forms the sensor nodes into various single layer clusters with different sizes. The design process of each cluster is carefully handled since the corresponding cluster heads make communication with the fusion center (FC) in an interleaved manner which also reduce the data aggregation duration. An optimization process is used to reduce energy consumption by reducing distance of destination. Simulation results are shown the performance of proposed CINDF and it compares with the existing LEACH, TL-LEACH and Mobile Agent Based LEACH. From the result it is shown that the proposed CINDF provides reduced energy consumption which leads to increased network lifetime.

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