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Hierarchical Data Redundancy Elimination Approach (HIDREA) for Wireless Sensor Network with Energy Saving Approach

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Abstract: *One of the critical issues affecting the lifetime of wireless sensor networks (WSN) is Energy consumption. Most of the energy of sensor nodes is spend for the redundant data transmission. Hence, in order to reduce the energy utilization, redundant data must be eliminated and the data aggregation approach has to be applied before transmitting to the base station. In this paper we have proposed a hierarchical approach for eliminating data redundancy in the view of extending the work in the future Internet of Things. The simulation result demonstrates that the proposed technique is efficient while comparing with the existing methods.*

Key words: *Wireless Sensor Networks, Data redundancy, Data aggregation, Hierarchical approach, Internet of Things*

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I. Introduction

Wireless sensor network (WSN) is built of using ahuge number of tiny, low powersensors which are working with built in batteries. The sensors are randomly or manually deployed in the fields where manual intervention is impossible [1]. Recharging or replacing batteries in such nodes is mostly not possible in such regions. WSN have variety of applications in such areas such as environment monitoring, defense exploration, healthcare, surveillance systems and disaster warning systems [2]. However, majority of these applications requiresensor nodes with long duration energy supply to continuethe operation for a longer period of time. WSNs become the integrated component of Internet of Things, where sensor nodes are connected with the Internet dynamically, and use it to cooperate and achieve their goals.

There are three important factors that affect the performance of the WSN: (i) data collection and aggregation (ii) clustering and (iii) routing [3] during the transmission of the sensed data from the sensor nodes to the Base Station. The sensor nodes spend most of their battery power in data collection and transmission which decreases the lifetime of the entire system[3]. Since the sensor nodes are deployed in various places some significant nodes called as the sink nodes are given the responsibility of collecting the data from the other sensor nodes and transmitting the aggregated data to the base station.However, if multiple sensor nodes are sensing the same event, redundant data will be collected at the sink node and it will be huge.Eliminating redundancy is a key challenge in WSNs as too much of redundancy leads to the wastage of energy in the sink node as well as in BS. Hence, we need to develop a technique for data aggregation by avoiding redundant data which can reduce the network traffic, reduction in energy consumption and bandwidth**.**

In this paper we compare the several data collection and aggregation techniques in WSN which are proposed in the literature. We present a hierarchical approach (HIDREA) to prevent redundancy during data collection by comparing the current data with the previous data in a periodical manner. The sensor network is organized in three layers and the redundancy prevention and aggregation is carried outin two stages. This paper is organized as follows: Section 2 describes the literature survey of the existing techniques. Section 3 presents the problem statement and explains the proposed approach. In section 4 we presentthe performance evaluation of the proposed scheme and in section 5 we give the conclusion and future work.

II. Literature Review

In this section we present some of the existing researches dealing with the elimination of data redundancy and aggregation. In WSN data redundancy can be categorized as of two types: (i) spatial redundancy and (ii) temporal redundancy[4]. Spatial redundancy is the process of acquiring data from a particular location/place from several sensor nodes. It depends on the positioning of sensor nodes in the place under monitoring. Since sensors are deployed closely, there will be considerable amount of spatial redundancy. Temporal redundancy means the process of collecting data in a specific time interval, from a particular sensor node. It is also known as time redundancy and is used to improve the exactness of sensor nodes readings. Data aggregation algorithms are further classified into various techniques with the aim of reducing the size of data, eliminating redundancy and minimizing the number of transmission.

The algorithms for data size reduction can be further divided into three types: summarization[5], quantile digest and representative data item. Summarization is the process of finding a single quantity computed from the entire set of sensor readings. We can apply the functions such as sum, average, count, min, max etc. for summarizing the data. Quantile digest[6] involves the segregating of ordered data into identical sized data subsets dynamically, for e.g. finding mean, median or mode of the sensed values. Representative data item is the technique used to select one particular value that represents a particular set of data.

The techniques for data aggregation are designed[7] as per the requirementof the application which either need spatial or temporal redundancy or both.The Secure Reference based Data Aggregation protocol (SRDA)[8] includes both data aggregation and security concept together in cluster based wireless sensor networks. It utilizes the idea of differential data. A reference value for each sensor node is created by the CH. Each sensor node computes the difference between its actual reading and the reference data. Then the difference is encrypted and sent to the CH.Thus, the consumption of energy by the sensor nodes for data transmission is reduced.

A Secure Data Aggregation Watermarking-based scheme (SDAW) is developed by D.E. Boubiche et al.[7] for homogeneous WSNs. The purpose of this algorithm is to secure the data aggregation process and tosave the energy consumption.

The Energy Efficient and Secure Pattern based Data Aggregation (ESPDA)[9] consist of both data aggregation and security schemes to create a technique for energy and bandwidth efficient. To preventthe transmission of redundant data, ESPDA generates pattern codes which present in the sensed data. Then the pattern codes are send to the sensor nodes from CH, and each node calculate its own pattern code and sends back to the CH which picks out the unique pattern code.

Efficient Data Redundancy Reduction (EDRR)[10] is developed by Sampoornam *et al* in which Conjugative sleep scheduling scheme is used with Differential Pulse Code Modulation (DPCM) based redundancy reduction technique for extending the lifetime of the network with continuous communication in the power constrained environment.

M. Kumar and K. Duttain[11] have developed LDAT: LFTM based Data Aggregation and Transmission Protocol for Wireless Sensor Networks. The authors presentedaninnovative scheme for data aggregation based on trust and reputation model to ensure security and reliability of aggregated data. The technique selects secure paths from sensor nodes to the base station and hence the accuracy of aggregated data will be increased significantly.

III. Problem definition and proposed technique

Data aggregation is defined as the process of combining and summarizing sensor data in order to reduce the data transmission in the network. Data redundancy is the global challenge and it can be addressed by data aggregation with the aim of less power consumption, gathering and routing information througha multi-hop network and processing data at the intermediate nodes. It attempts to gather the very important and critical and data from the sensors nodes and send to the Base Station in an energy efficient manner with minimum data latency and minimum possible bandwidth.

In this paper we present a hierarchical architecture in which the sensor network is organized in a three layer structure. In thisthree layer structure, the first or bottom layer consists of the Sensor nodes (s), the second or middle layer comprises the Sector Heads (SH) and the third or top layer includes the Cluster Heads (CH).Sensor nodes are the common sensors which are deployed in the environment to read the parameters. The data generated by these nodes are transmitted to the sector heads which collect the data from all the sensors. SH nodes are responsible for comparing and removing the data redundancy and aggregation. This process is carried out by all the SHs in the network. The aggregated data from all the SH nodes are sent to the cluster heads (CH) which is responsible for forwarding the data to the base station (BS). The proposed scheme is depicted in figure 1. SH nodes are dynamically changed based on their residual energy in order to balance the power consumption and extend the life time of the entire network.

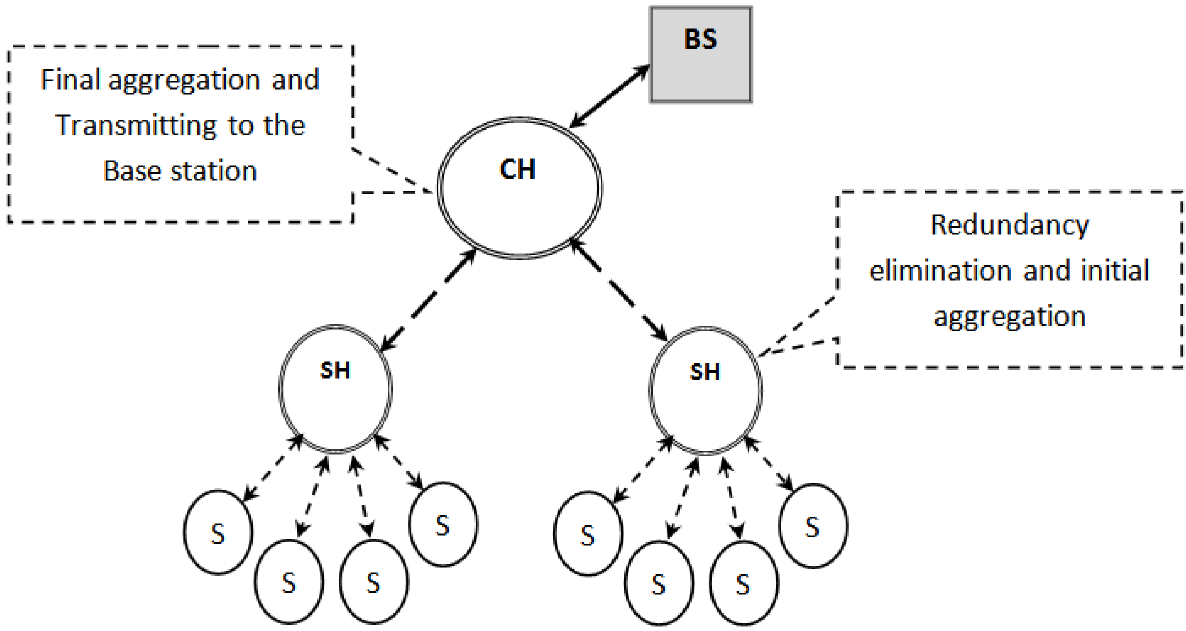

Figure1. Three layer architecture of the proposed WSN

In each sector, the sensor node with the highest residual energy willbe selected as SH and it sends a message to its sector members to inform them with its status. The proposed data aggregation algorithmis executed at the SH nodes. In every SH node a table is maintained with the details all the sensor nodes and their readings with time. The structure of the table is shown in figure 2. The table contains the node id, the time of the reading and the value of the reading. The algorithm which is implemented in the SH node reads the table, compares the data and eliminate the redundant data before aggregation.

Node_ID	Time_stamp	Reading Value
S1	102233	41
S2	102235	42
S3	102235	41
S4	102237	43

Figure 2. Comparison table in SH nodes

We implement an algorithm for redundancy removal which is listed below. Here we compare the sensed data from every node based on the time of sensing since temporal redundancy is purely based on the time as mentioned earlier.

Algorithm I - Redundancy Removal

Start
For every time interval t
{
for c = 1 to k
{
ifenergy_level of S_c> $S_{1\ to\ k}$then
SH ←S /*Assign Sector head */
}
Read the node ID N
Read the time stamp of N : TS_N
Read the sensed data of N : SD_N
for i = 1 to n
{
If TS_{Nt}= TS_{Nt-1}&SD_{Nt} != SD_{nt-1}then
accept SD_N

```
                else if TS_Nt= TS_Nt-1 &SD_Nt = SD_nt-1 then
                accept SD_1and reject SD_2 TO SD_N
                else if TS_Nt!= TS_Nt-1 then
                accept SD_Nfor all N
        }
}
Stop
```

In the above algorithm, S represents a sensor node, TS_Nrepresents the time_stamp of the node N and SD_Nrepresents the sensed data of the node N. For the purpose of simplicity, we have considered the temperature sensors to read the temperature from 10^o Celsius to 50^o Celsius in our testing environment.Initially n number of nodes for each cluster are created and dispersed randomly. All the sensor nodes started with the same energy level and for each sensor node, a temperature between 10 and 50 Celsius is generated randomly. Since the BS is located outside of the network and is connected through wired network we need not bother the energy constraint.

IV. Simulation and Results

The simulation set up of the proposed data aggregation model is designed and implemented in ns2 simulator with TCL. We have applied the sensor radio model used in [12] and [13] and the simulation parameters used in the research work [14][15]. The sensor nodes are arbitrarily deployed in a 100m x 100m area with a base station located at the center (0, 0). The power consumption for sending the data is 24.75mW which is quite nearer to the power consumed for receiving the dataequal to 13.5 mW and the energy level at the initial stage of each sensor node is equal to 2.8J.

The performanceof the proposed approach is analyzed by comparing with the existing protocols LDAT[11], READA[17], SCT[18], EDRR[10] and SDRE[16]. The parameters used for evaluating the performance are accuracy and aggregation gain ratio (AGR),average packet delivery ratio (APDR) and average residual energy (ARE).

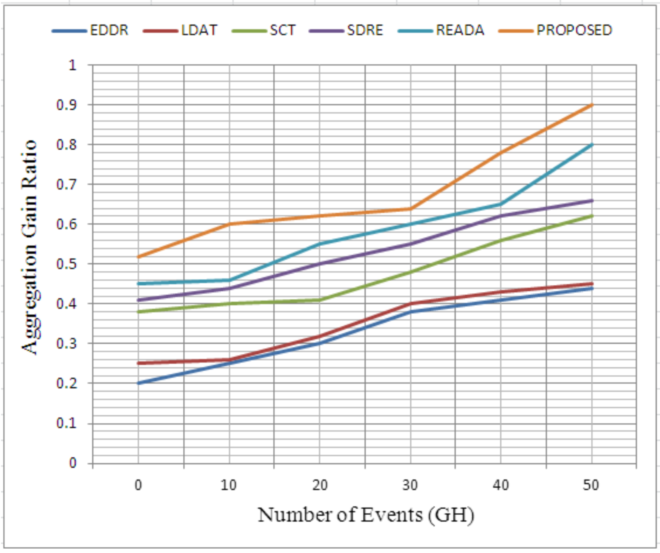

Figure 3 Effect of Aggregation Gain Ratio (APDR) over number of events

The evaluation metrics are defined by using the following relations:

$$APDR = \frac{\text{Total number of packets delivered after aggregation}}{\text{Total number packets transmitted before aggregation}} \quad (1)$$

$$E_{Total}= \Sigma_{i=1} (E_{INIT}+E_{GH}+E_{NGH}) \quad (2)$$

$$ARE = E_{Total} / \text{No. of events} \quad (3)$$

(4)

Accuracy = Σ(Estimated mean – Actual Mean) / Σ Actual Mean * 100

Figure 3 shows the aggregation gain ratio of proposed and under consideration protocols. The proposed model illustrates that the aggregation gain in terms of data collected and aggregated in between the range 0.52 to 0.9, whereas the other standard protocols shows lesser than this level. This is due to the number of cluster heads which collect the data and aggregate them before send to the base station.

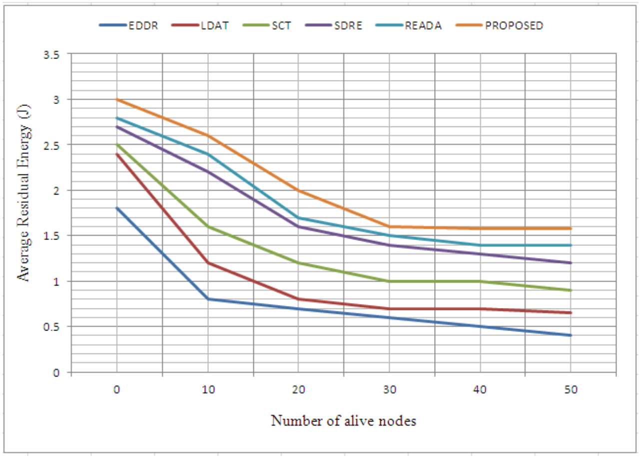

Figure 4 Effect of Average Residual Energy (ARE) over number of events

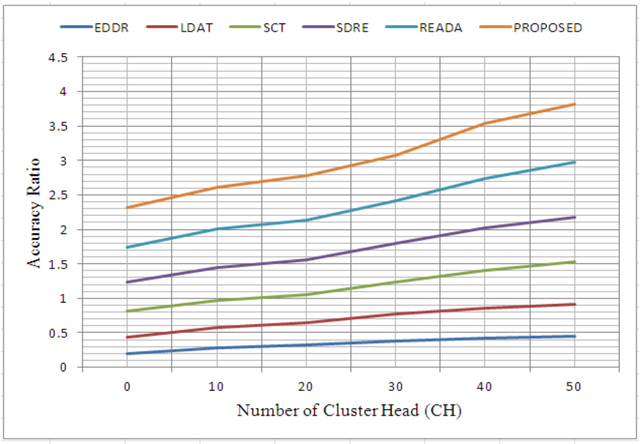

Figure 5. Effect of Accuracy over number of aggregation heads

Figure 4 shows the effect of average residual energy over number of events during the simulation, figure 5 shows the effect of accuracy over number of aggregation heads generated during the simulation. In figure 8 we show the rate of bandwidth utilization with the data redundancy rates.

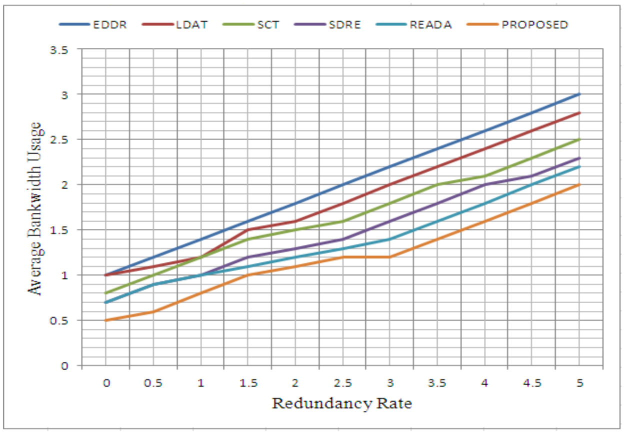

Figure 6. Total of occupied bandwidth rate and redundancy rates

V. Conclusion

Data collection and aggregation are widely used in WSN for reducing energy consumption and to extend the life span of the network. In this paper we have presented a hierarchical model of the WSN and a redundancy removal algorithm which maintains a data base of the sensor data with time stamp. Simulation results illustrate the efficiency of the proposed solution in terms of elimination of data redundancy, aggregation gain ratio, Average residual energy and bandwidth utilization compared with the average bandwidth utilization are better than while comparing with existing technologies.In future, we extend our research for the Internet of Things (IoT), which includes the WSN as a vital part of the network and utilizes the 6LoWPAN protocol to connect with the Internet.

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