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HCIFR: Hierarchical Clustering and Iterative Filtering Routing Algorithm for Wireless Sensor Networks

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Abstract— *The hierarchical clustering and iterative filtering algorithms are combined to form an energy efficient routing algorithm which supports in improved performance, efficient routing at the time of link failure, collusion robust and secure data aggregation. The idea of combining these two algorithms which may lead to improved performance. Initially clusters are formed by neighborhood. The cluster is a combination of one clusterhead, two deputy clusterheads and cluster members. This system uses a Hierarchical clustering algorithm for efficient data transmission to their clusterhead by cluster members. The clusterhead aggregate the collected data and check for trustworthiness. The data is aggregated by clusterhead using the iterative filtering algorithm and resistant to collusion attacks. Simulation results depict the average energy consumption, throughput, packet drops and packet delivery under the influence of proposed algorithm.*

Keywords—Cumulative Credit Point, Hierarchical Clustering, Iterative Filtering, MLE(Maximum Likelihood Estimator), Secure Data Aggregation, TDMA (Time Division Multiple Access).

I. INTRODUCTION

A WSN is a collection of sensor nodes and a small number of data collection devices. The sensor nodes are low cost, low-power, small-size devices, and are used for sensing applications like temperature recording, military surveillance, fire detection etc. The sensor nodes are used for gathering information which is present in environment of their interest. The sensor nodes send their sensed information using a wireless medium to a remote base station (sink). The base station aggregates the collected data and draw conclusions over sensed data.

Routing is an important and challenging design issue need to considered for WSN. “A properly designed routing protocol should not only ensure high message delivery ratio and low energy consumption for message delivery, but also balance the entire sensor network energy consumption, and thereby extend the sensor network lifetime. The main feature of WSNs are: scalability, self-organization, self-healing, energy efficiency, network lifetime optimization, less complexity, less costly, security, routing, size of nodes and connectivity between the sensor nodes. Every sensor node in the network should be a source or destination but not both.

HCIFR protocol has the advantages:

- HCIFR ensures that the energy consumption of the wireless sensor network can be reduced. So that the maximization of network lifetime can be achieved.
- HCIFR algorithm takes routing decisions dynamically. So the data delivery to the clusterhead and finally to the base station.
- HCIFR uses the Iterative Filtering algorithm for secure data aggregation.

Clustering is concept used in the proposed system for the reduction of energy consumption. Clustering means grouping the different set of nodes which are their neighbours. Cluster members can send their sensed data to the clusterhead with less energy consumption. The clusterhead can send the final aggregated data to the base station. The clusterhead is responsible for collecting data, checking for the redundancy and aggregate the remaining data. The aggregated data can be transmitted to the base station.

The data can be aggregated using the averaging technique by clusterhead. Through this technique there are possibilities of security attacks on sensor nodes whose battery power is dead. So to avoid these type of attacks, the Iterative Filtering (IF) algorithms are used.

This paper is coordinated by: section 2: explains literature survey, and different routing algorithms. Section 3: contains methodology of proposed system which includes dynamic hierarchical clustering and iterative filtering. Section 4: depicts the results obtained from evaluation of the proposed system. Section 5: conclusions.

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II. RELATED WORK

Hiren Kumar Deva Sarma, Rajib mall and Avijit Kar proposed a system which is energy efficient and reliable routing for mobile WSN for deploying the sensor nodes, clustering concept is introduced. A cluster consists of clusterhead, two deputy clusterhead, and cluster members. The role selection of the sensor is done by base station using the cumulative credit point [1]. Mohsen Rezvani, Aleksandar Ignjatovic, Elisa Bertino and Sanjay Jha proposed a system which is an improvement of Iterative Filtering algorithm. This algorithm is collusion robust against security attacks. The algorithm used to find the error rate by calculating the bias and variance of each sensor node and eliminate the error rate using the MLE. The malicious nodes are blocked by the clusterhead and send the final aggregated data to the base station. In this workshop [2], H. K. Deva Sarma, A. Kar, and R. Mall proposed a concept called cumulative credit can be used a parameter for the role selection of either clusterhead or deputy clusterhead [3].

In this paper [4], S. Lindsey and C. S. Raghavendra proposed an algorithm called PEGASIS (control proficient assembling in sensor data frameworks), a close ideal chain-based convention that is a changeover LEACH. In PEGASIS, every node connects to its nearby neighbour and alternates transmitting to the base station, in this way decreasing the energy spent per round. In this paper [5] D. B. Johnson, and D. A. Maltz proposed an algorithm routing the packets between the mobile wireless hosts in adhoc network. This algorithm is capable of adapting of frequently changing the paths dynamically at the time of link failure or link unavailability. The paths are changed when there is overhead. In this paper [6] J. N. Al-Karaki and A. E. Kamal have surveyed on the routing challenges, design issues while designing the routing protocols. The basics of the routing, routing types and routing protocols have been covered under this survey.

In this paper [7] A. Manjeshwar and D. P. Agarwal proposed an energy efficient algorithm called TEEN (Threshold sensitive Energy Efficient sensor Network protocol). There are many algorithms based on network classification like reactive and proactive networks. TEEN is been mainly proposed for reactive type of networks. Evaluate the performance of the protocol for a simple temperature sensing application. In terms of energy efficiency, this protocol outperforms from all existing sensor network protocols. TEEN perform much better than LEACH. In this paper [8] “A. Manjeshwar and D. P. Agarwal” has proposed an improvised version of TEEN algorithm called APTEEN (A hybrid protocol for efficient routing and comprehensive information retrieval in wireless sensor networks). This algorithm combines all the best features present in reactive and proactive networks. It collects the data periodically and also give real-time warnings when there are critical events. This algorithm can also be extended further to sensor networks with uneven node distributions.

In this paper [9] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci has done survey on sensor networks. The basics of the sensor networks, network creation, protocol stack, and different types of algorithms for routing the packets in sensor networks. These all concepts is explained in detail. In this paper [10] W. Heinzelman, A. Chandrakasan, and H. Balakrishnan has proposed an algorithm called Energy-efficient communication protocol for wireless microsensor networks. The energy consumption can be reduced by using this algorithm. The clustering concept is used for energy consumptioj reduction and also the load on one clusterhead is been reduced by sharing the load to other clusterheads.

III. PROPOSED WORK

Initially the sensor nodes are deployed in the network randomly. The node sends “Hello” packets to its neighbour nodes, in this same way “Hello” packet will be flooded to the entire network. Based on the neighbourhood, the sensor nodes forms different clusters in the network. After formation of the clusters, the transmission of the data can be sent through the following phases as shown in fig 1.

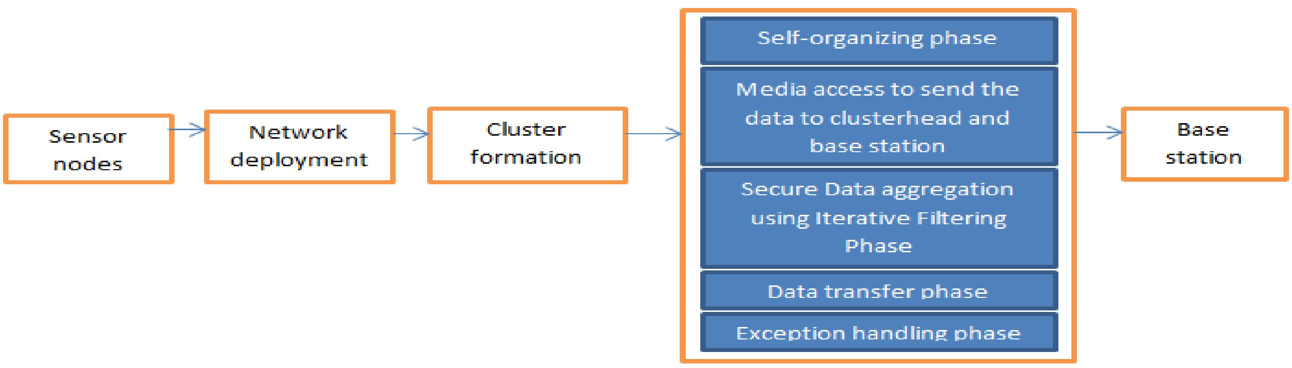

Fig 1: Architecture diagram of Proposed System

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A. Self-Organizing Phase: Once the clusters are formed as per the neighbourhood, the role selection of the sensor node can be clusterhead and deputy clusterheads will be done in this phase. The selection will be done by base station using the Cumulative Credit Point. Cumulative Credit Point is a combination of three values is: energy of the node, node degree and the mobility. The corresponding weight will calculated using these three values. The cumulative credit point of the nodes are arranged in descending order. The first threshold value will be selected as a clusterhead, second and third highest threshold values will be selected as deputy clusterheads. The clusterhead is involved in data collection from their cluster members. The clusterhead shares its data to one of the deputy clusterhead. The deputy clusterhead is involved in data transmission. It will forward the data to the base station by connecting deputy clusterheads of other clusters.

/*Algorithm to find the cumulative credit point of the sensor node*/

Input:

D → Node degree

E→ Energy of the node,

G→ Geographical location of the sensor node.

Output:

CP →cumulative credit point of the node

Variables: N →the total number of sensor nodes shortlisted by the base station.

V_D, V_E, V_M, CP, wt_1, wt_2, wt_3

Step 1: The sensor node degree is calculated as pantile count (V_D).

V_D = [(Total count of contestant nodes which is having lesser degree than the degree of the contestant node interested, in the cluster) / N] × 100

Step 2: The sensor node energy level is calculated as pantile count (V_E).

V_E = [(Total count of contestant nodes which is having low energy level (E) than the energy level of the contestant node interested, in the cluster) / N] × 100.

Step 3: The sensor node geographical location is calculated as pantile count (V_G).

V_M = [(Total count of contestant nodes who have less mobility level than the geographical location (G) of the contestant node interested, in the cluster) / N] × 100

Step 4: Compute the cumulative credit point CP for each node inside the cluster as follows:

$$CP = (wt_1)\, V_D + (wt_2)\, V_E + (wt_3)\, V_G$$

Where wt_1, wt_2, and wt_3 are weight factors given to different constants, for example, node degree of the node, energy level, and geographical location regulated in the below condition:

$$wt_1 + wt_2 + wt_3 = 1$$

B. **Media access to send the data to its clusterhead and Base station:** TDMA (Time Division Multiple Access) is used to send the data from cluster members to its clusterhead, and the clusterhead share its data to deputy clusterhead. The base station also receives the data from the deputy clusterhead in TDMA.

C. **Secure Data aggregation using Iterative Filtering Phase:** The data received from its cluster members will be aggregated using the iterative filtering algorithm. If the sensor nodes send the incorrect data then the clusterhead identifies the node which has sent incorrect data by calculating the Bias value of each sensor node (Error rate is calculated), the Variance value of each sensor node (noise ratio is calculated) and using the MLE (Maximum Likelihood Estimator). The MLE finds the original signal or data from Bias and Variance value. In this way, the clusterhead finds the original data and aggregates with the data sent by other cluster members.

D. **Data Transfer Phase:** this is the phase where the final aggregated reaches its destination called Base station: Finally the aggregated data is shared by clusterhead to its deputy clusterhead. The deputy clusterhead forward the data to the base station by connecting the different and nearest deputy clusterhead of other clusters.

E. **Exception Handling Phase:** This phase specifies how to handle in situations like link failure, and clusterhead is not able to withstand its position. At the time of link failure, alternative routes will are used by the deputy clusterheads or cluster members to send the data. The routes are calculated dynamically. When the energy of the clusterhead is reduced in such a way that it cannot collect the data then the clusterheadship is transferred to one of its deputy clusterhead. The deputy clusterhead for that cluster will be selected by base station.

IV. RESULTS AND DISCUSSION

The NS2 network simulator is used. Consider a sensor network of 82 sensor nodes deployed randomly in the field as shown in below fig. The routing algorithm is verified for different network scenarios. The results of the proposed routing algorithm are also compared with the results of other algorithm. M-LEACH protocol is selected to compare with the proposed protocol by considering the mobility of nodes while routing the packets.

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Initially the 82 nodes are deployed in the network dynamically as shown in fig 2

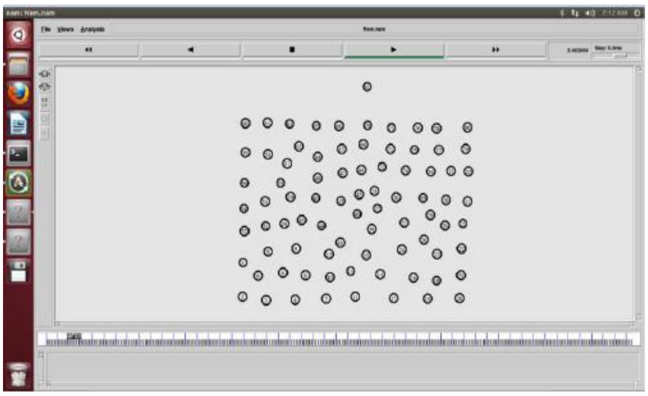

Fig 2: The deployment of sensor nodes in the network

The sensor node 0 is sending the hello packets to its neighbours inturn the neighbours will broadcast the “Hello” packets to its neighbours as shown in below fig 3

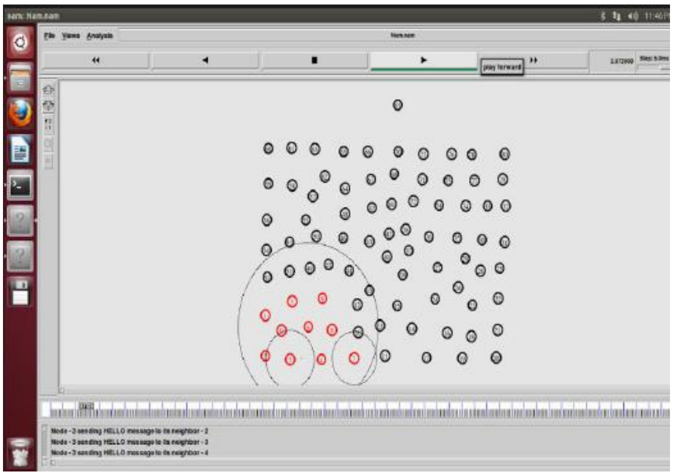

Fig 3: The transmission of “Hello” packet by node 0 to nearest neighbours to find the neighbourhood

The sensor nodes have formed different clusters in which each color represents one cluster as shown in below fig 4.

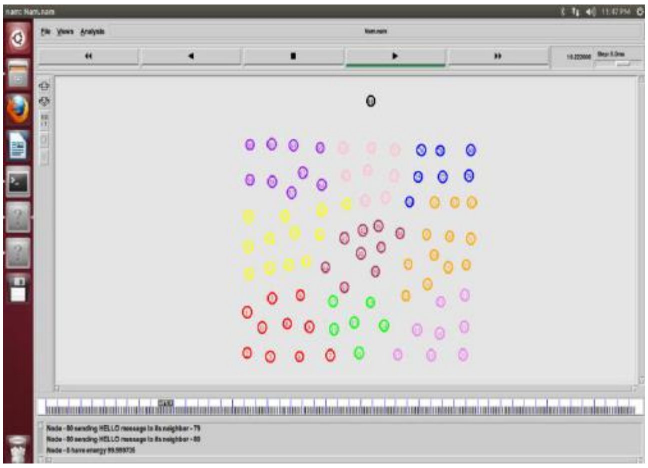

Fig 4: Nodes have formed different clusters

The sensor nodes of each cluster declare its clusterhead and deputy clusterhead1 and deputy clusterhead2 has been selected based on the cumulative credit point. For example the blue cluster which is at rightmost top corner, the cluster consists of 74, 75, 76, 77, 78, 79, and 80. Based on the threshold value of the node 78 is selected as clusterhead. The deputy clusterhead1 is 75 and deputy clusterhead2 74 as shown in below fig 5.

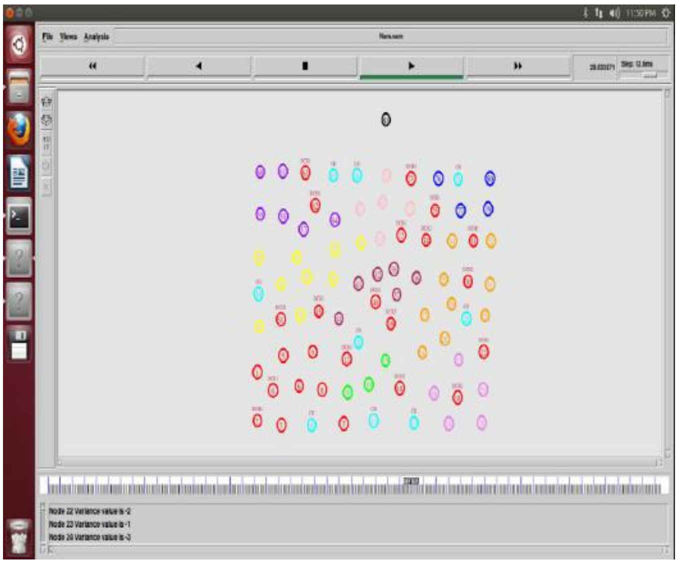

Fig 5: The clusterhead and deputy clusterhead of all the clusters are declared

The iterative filtering algorithm is used to find malicious or misbehaved node in the wireless sensor network. For example node number 1, 2, 14 and so on are malicious node as shown in below fig 6.

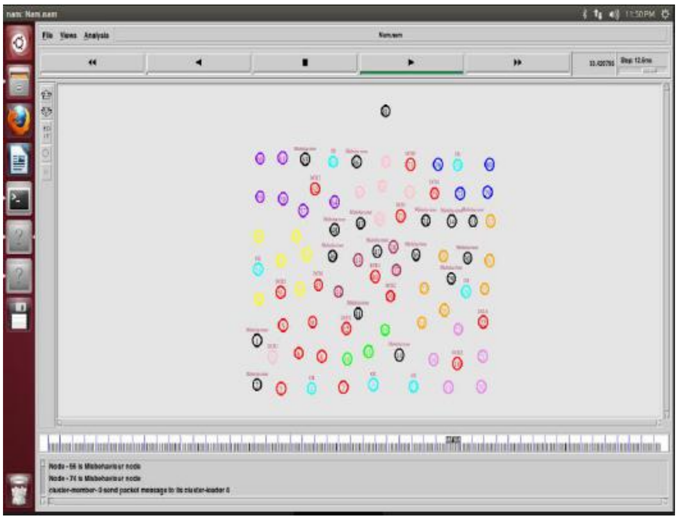

Fig 6: The malicious nodes have been blocked by clusterhead which are in Black color

A. Performance measures

The below mentioned measures are used for comparison of the performance for proposed protocol and existing protocol called M-LEACH protocol based on the below parameters.

- Average energy consumption
- Throughput
- Packet drops
- Packet delivery.

Average Energy Consumption: It means that the average energy required for sending the sensed data to the base

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station. The comparison of both algorithms is shown in the form of graph as in fig 7.

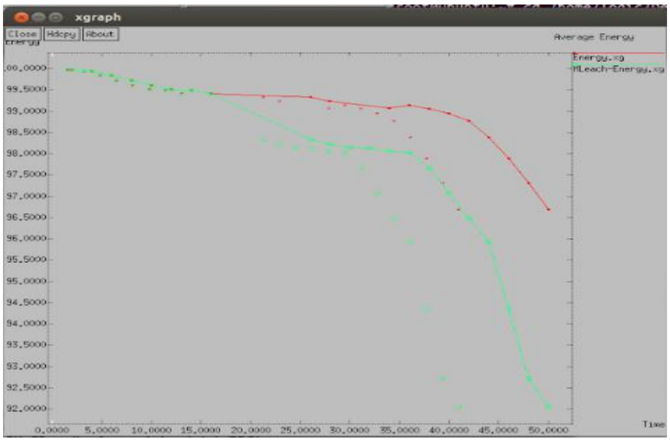

Fig 7: Comparison of M-LEACH algorithm and HCIFR algorithm based on energy consumption

Throughput: It is the ratio between the actual numbers of packets transmitted by the nodes in the system to the numbers of successfully delivered packets at the base station. A protocol with higher throughput is desirable. The graph is shown in fig 8 how the throughput based on speed of delivery is varies from the proposed algorithm to M-LEACH algorithm.

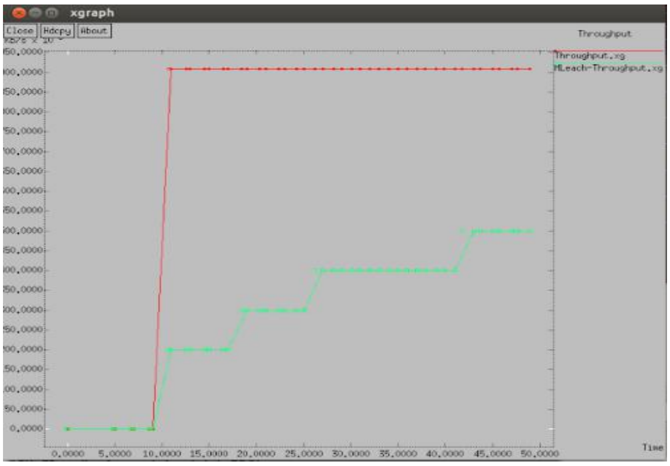

Fig 8: Comparison of M-LEACH algorithm and HCIFR algorithm based on throughput

Packet drops: Packet loss occurs due to the computer network failure while the packets reaching to its destination. The packet drops of the HCIFR algorithm are compared to the M-LEACH algorithm as shown in below fig 9.

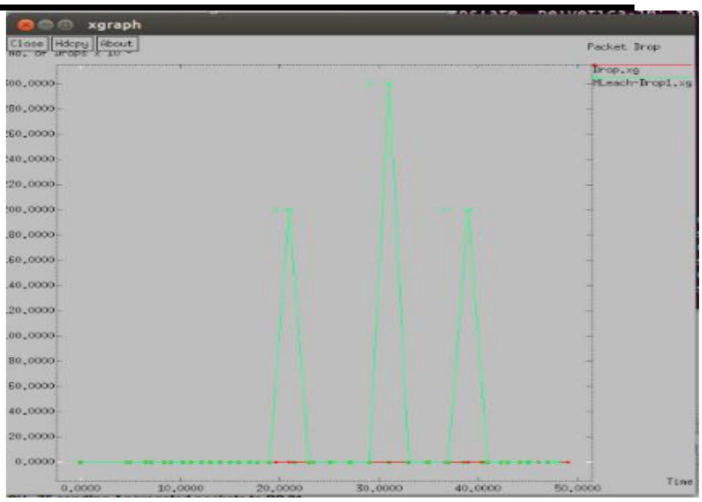

Fig 9: Comparison of M-LEACH algorithm and HCIFR algorithm based on packet drops

Packet delivery: The successful delivery of a packet over a wireless sensor network depends on the routing algorithm used to route the packets. The packet delivery of the HCIFR algorithm is compared to the packet delivery of the M-LEACH algorithm is shown in fig 10.

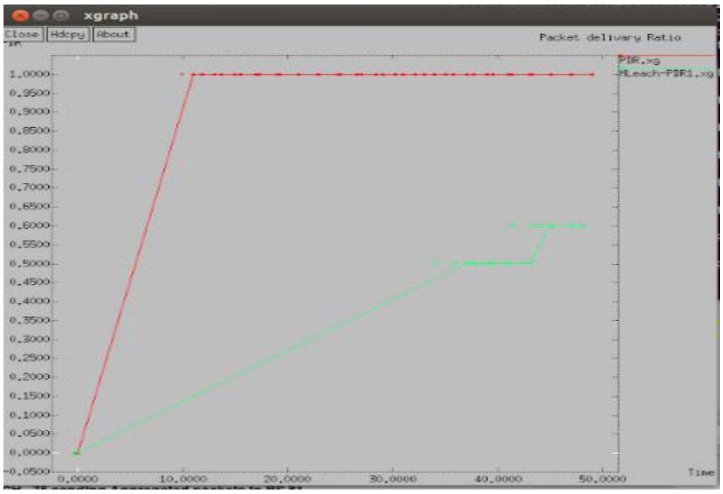

Fig 10: Comparison of M-LEACH algorithm and HCIFR algorithm based on packet delivery to the base station

V. CONCLUSION

An energy efficient routing algorithm is proposed for efficient routing of the sensed data from the cluster members to its clusterhead, then clusterhead aggregates the data using the Iterative Filtering algorithm which is collusion robust and checks for trustworthiness. Then the data from clusterhead shares with its one of the deputy clusterhead and finally to the Base station. The proposed algorithm is also fault tolerant. The proposed routing algorithm outperforms when compared to the M-LEACH algorithm.

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