Fault Tolerance for Chain based Hierarchical Data Gathering Protocol for WSN

Rakesh Kumar **Anjum Sharma**

Abstract

Wireless sensor network nodes are very tiny in size and their cost is also not very high. They are deployed in any geographical region in a random fashion. During the process of data sensing, data gathering and data transmission, the charge of the power unit associated with any node gets low, after certain time, i.e., each node has its life time. The life time of nodes directly affects the life time of the sensor network. As each node is very low in cost, it is unnecessary and difficult too, to recharge them once their energies are exhausted. Therefore, it is very important to conserve the power of the nodes so that the life time of the entire network can be conserved. Hence the requirement of a power efficient data gathering protocol is very important to serve the purpose in wireless sensor network. In the proposed work, it is being tried to change the idea relating to the data gathering and transmission of the existing model, as, chain leaders belonging to certain covering angle will only transmit the gathered data to the another chain leader of the same covering angle and we have implemented the backup chain leader as a fault tolerance mechanism . Our research can provide better efficiency and resource consumption and further can provide good level of fault tolerance.

Keywords: Wireless Sensor Node, Cluster, Cluster Head, Fault tolerance

1. INTRODUCTION

Recent advances in wireless communications and electronics have enabled the development of low-cost, low power, multifunctional sensor nodes that are small in size and communicate unmetered in short distances. These tiny sensor nodes, which consist of sensing, data processing, and communicating components, leverage the idea of sensor networks. Sensor networks represent a significant improvement over traditional sensors. A sensor network is composed of a large number of sensor nodes that are densely deployed either inside the phenomenon or very close to it. The position of sensor nodes need not be engineered or predetermined. This allows random deployment in inaccessible terrains or disaster relief operations. On the other hand, this also means that sensor network protocols and algorithms must possess self organizing capabilities. Instead of sending the raw data to the nodes responsible for the fusion, they use their processing abilities to locally carry out simple computations and transmit only the required and partially processed data. The above described features ensure a wide range of applications for sensor networks. Some of the application areas are health, military, and home. In military, for example, the rapid deployment, self-organization, and fault tolerance characteristics of sensor networks make them a very promising sensing technique for military command, control, communications, computing, intelligence, surveillance, reconnaissance, and targeting systems. In health, sensor nodes can also be deployed to monitor patients and assist disabled patients. Some other commercial applications include managing inventory, monitoring product quality, and monitoring disaster areas.

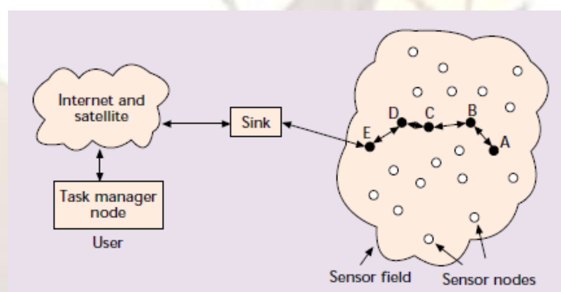


Figure 1: Sensor nodes scattered in a sensor field

The sensor nodes are usually scattered in a sensor field as shown in Figure1.Each of these scattered sensor nodes has the capabilities to collect data and route data back to the sink. Data are routed back to the sink by a multi-hop infrastructure less architecture through the sink as shown in Figure1.

The sink may communicate with the task manager node via Internet or satellite. The design of the sensor network as described by Figure1 is influenced by many factors, including fault tolerance, scalability, production costs, operating environment, sensor network topology, hardware constraints, transmission media, and power consumption.

2. ROUTING TECHNIQUES IN WSN

Wireless sensor networks (WSN) consist of small nodes with sensing, computation, and wireless communications capabilities. Many routing, power management, and data dissemination protocols have been specifically designed for WSNs where energy awareness is an essential design issue. Routing protocols in WSNs might differ depending on the application and network architecture. Overall, the routing techniques are classified into three categories based on the underlying network structure: flat, hierarchical, and location-based routing. Furthermore, these protocols can be classified into multipath-based, query-based, negotiation based, QoS-based, and coherent based depending on the protocol operation. Many routing, power management, and data dissemination protocols have been specifically designed for WSNs where energy awareness is an essential design issue. Routing protocols in WSNs might differ depending on the application and network architecture. Overall, the routing techniques are classified into three categories based on the underlying network structure: flat, hierarchical, and location-based routing. Furthermore, these protocols can be classified into multipath-based, query-based, and negotiation-based, QoS based, and coherent based depending on the protocol operation. Figure 2 shows routing protocols in WSNs.

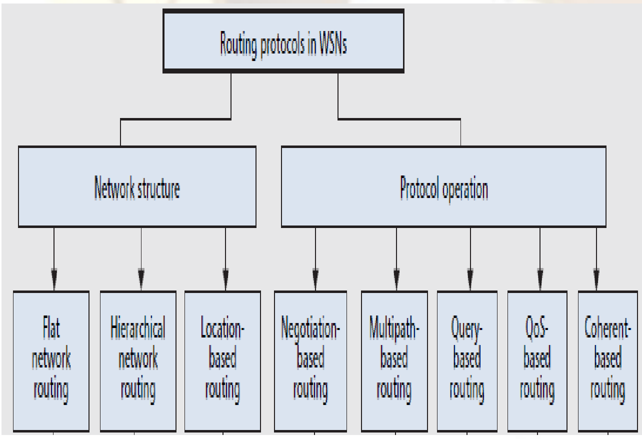


Figure 2: Routing Protocols in WSNs

In flat networks all nodes play the same role, while hierarchical protocols aim to cluster the nodes so that cluster heads can do some aggregation and reduction of data in order to save energy. Location-based protocols utilize position information to relay the data to the desired regions rather than the whole network.

3. RELATED WORK

In general, three strategies are considered for the design of data aggregation techniques in WSNs. They are cluster based, tree-based, and chain-based . In this section, we only review three chain-based routing protocols, PEGASIS, COSEN, and Enhanced PEGASIS, and point out their pros and cons that motivate our research.

A. PEGASIS

PEGASIS is a basic chain-based routing protocol. In which, all nodes in the sensing area are first organized into a chain by using a greedy algorithm, and then take turns to act as the chain leader. In data dissemination phase, every node receives the sensing information from its closest upstream neighbour, and then passes its aggregated data toward the designated leader, via its downstream neighbour, and finally the base station. Although the PEGASIS constructs a chain connecting all nodes to balance network energy dissipation, there are still some flaws with this scheme. 1) For a large sensing field and real-time applications, the single long chain may introduce an unacceptable data delay time. 2) Since the chain leader is elected by taking turns, for some cases, several sensor nodes might reversely transmit their aggregated data to the designated leader, which is far away from the BS than itself. This will result in redundant transmission paths, and therefore seriously waste network energy. 3) The single chain leader may become a bottleneck.

B. COSEN

In contrast to PEGASIS, COSEN is a two-tier hierarchical chain-based routing scheme. In that scheme, sensor nodes are geographically grouped into several low-level chains. For each low-level chain, the sensor node with the maximum residual energy is elected as the chain leader. Moreover, with the low-level leaders, a high-level chain and its corresponding chain leader will be eventually formulated. In data communications, all common (normal) nodes perform a similar procedure as that in PEGASIS to send their fused data, via their respective low-level leaders and the high-level leader, toward the BS. COSEN, compared to PEGASIS, although can alleviate the transmission delay and energy consumption, it still introduces a lot of redundant transmission paths, especially for those nodes which are nearest to the BS but would detour their fused data toward the farther leaders.

C. Enhanced PEGASIS

In 2007, Jung et al. proposed a variation of PEGASIS routing scheme, termed as Enhanced PEGASIS. In their method, the sensing area, centered at the BS, is circularized into several concentric cluster levels. For each cluster level, based on the greedy algorithm of PEGASIS, a node chain is constructed. In data transmission, the common nodes also conduct a similar way as the PEGASIS to transfer their sensing data to its chain leader. After that, from the highest (farthest) cluster level to the lowest (near to the BS), a multi-hop and leader-by-leader data propagation task will be followed. The EPEGASIS although has considered the location of the BS to slightly improve the redundant transmission path and the network lifetime, there are still some problems with that scheme. 1) For large sensing areas, the node chain in each concentric cluster would still become lengthy, and thus result in a longer transmission delay. 2) Since the leader node election strategy is same as that in PEGASIS (by taking turns), it did not consider the node's residual energy. As a node with the least residual energy is elected to act as the leader, the network lifetime would be significantly affected. 3) While the distribution of sensor nodes is not even, the transmission distance between two chain-leaders in different cluster levels might be lengthy, this would consume more energy.

4. CHIRON PROTOCOL

For improving the deficiencies with the aforementioned three schemes, in this section, we thus propose an energy efficient hierarchical chain-based routing protocol, termed as CHIRON. The design philosophy is described as follows.

A. Network model and assumptions

Without loss of generality, in our research, we also consider a WSN of *n* energy-constrained sensor nodes, which are randomly deployed over a sensing field. The BS is located at a corner of the sensing area, and equipped with a directional antenna and unlimited power. As a result, the BS can adaptively adjust its transmission power level and antenna direction to send control packets to all nodes in the WSN. Besides, for easy discussion, we define some notations as follows:

- R: the transmission range of the BS. For simplicity, we use distinct integers (1 … n) to represent various ranges.
- θ: the beam width (covering angle) of the directional antenna. Also, similar to the definition of R, different integers (1 … n) are used to indicate distinct angles.
- Gθ, R : the group id. Theoretically, by changing different values of θ and R, the sensing area can be divided into n * n groups. Those are G1, 1, G1, 2, …, G1, n, …, Gn, 1, …, Gn,, n.
- ni: the node i; the node set N={n1, n2, n3, …, ni}, where 1≤i≤|N|.
- cx,y: the id of a chain which was formed in group Gx,y. the chain set C={c1,1, c1,2, ….}.
- lx,y: the leader node id of chain cx,y. The leader set L={l1,1, l1,2, ….}.
- neighbour(ni): the neighbouring nodes of ni. The neighbouring nodes mean the nodes which are locating in the transmission range of a specific node.
- dis(x, y): the distance between nodes x and y. The BS can be deemed as a special sensor node.

B. OPERATION OF CHIRON

The operation of CHIRON protocol consists of four phases: 1) Group Construction Phase. 2) Chain Formation Phase. 3) Leader Node Election Phase. and 4) Data Collection and Transmission Phase.

1. Group Construction Phase

The main purpose of this phase is ready to divide the sensing field into a number of smaller areas so that the CHIRON can create multiple shorter chains to reduce the data propagation delay and redundant transmission path in later phases. Instead of using concentric clusters as EPEGASIS scheme does, the CHIRON adopts the technique of Beam Star to organize its groups. After the sensor nodes are scattered, the BS gradually sweeps the whole sensing area, by successively changing different transmission power levels and antenna directions, to send control information (including the values of *R* and *θ*) to all nodes. After all nodes receiving such control packets, they can easily determine which group they are respectively belonging to. In addition, by the received signal strength indication (RSSI), every node can also figure out the value of dis(ni, *BS*). A grouping example with *R*=1...3 and *θ*=1..2 is shown in Figure 3.

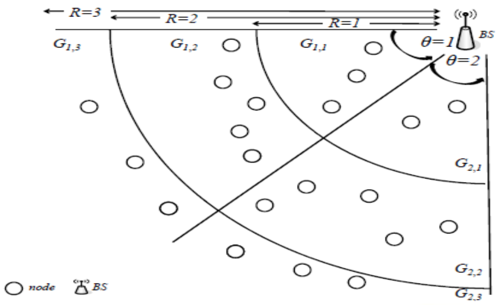


Fig. 3 Grouping example with R=1…3 *and* θ=1…2

2. Chain Formation Phase

In this phase, the nodes within each group Gx,y will be linked together to form a chain cx,y, respectively. The chain formation process is same as that in PEGASIS scheme. For each group Gx,y, the node ni with the maximum value of dis(ni, BS) (that is farthest away from the BS) is initiated to create the group chain. By using a greedy algorithm, the nearest node (to ni) of neighbor(ni) will be chosen to link the node ni, and become as the newly initiate node in next linking step. The process is repeated until all nodes are put together, and thus finally a group chain cx,y is formed. Figure 2 shows all group chains that are constructed from the sensing environment of Figure 2

3. Leader Node Election Phase

For data transmission, a leader node in each group chain must be selected for collecting and forwarding the aggregated data to the BS. Unlike the PEGASIS and EPEGASIS schemes, in which the leader in each chain is elected in a round-robin manner, CHIRON chooses the chain leader (*lx,y*) based on the maximum value *Res*(*ni*) of group nodes. Initially, in each group, the node farthest away from the BS is assigned to be the group chain leader. After that, for each data transmission round, the node with the maximum residual energy will be elected. The residual power information of each node *ni* can be piggybacked with the fused data to the chain leader *lx,y* along the chain *cx,y*, so that the chain leader can determine which node will be the new leader for next transmission round.

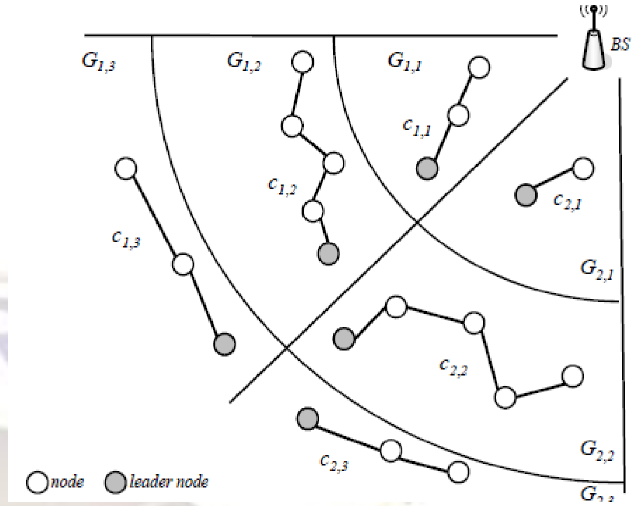


Figure 4: The group chains constructed from Figure 1

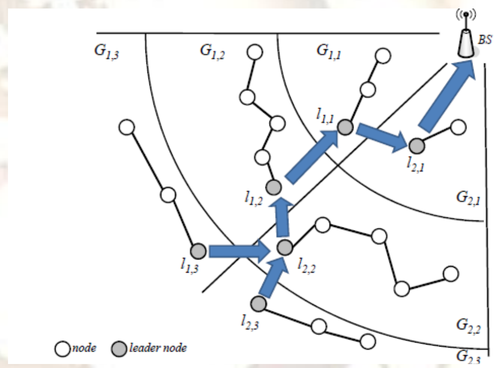


Figure 5: The data transmission flows

4. Data Collection and Transmission Phase

After completed the previous three phases, the data collection and transmission phase begins. The data transmission procedure in CHIRON is similar to that in PEGASIS scheme. Firstly, the normal nodes in each group *Gx,y* transmit their collected data along the *cx,y*, by passing through their nearest nodes, to the chain leader *lx,y*. And then, starting from the farthest groups, the chain leaders collaboratively relay their aggregated sensing information to the BS, in a multi-hop, leader-by-leader transmission manner. In order to avoid a longer transmission distance incurred between two chain leaders, and thus result in a great amount of energy dissipation,

5. IMPROVED CHIRON SCHEMES

CHIRON is used to split the sensing field into a number of smaller areas, so that it can create multiple shorter chains to reduce the data transmission delay and redundant path, and therefore effectively conserve the node energy and prolong the network lifetime. In CHIRON routing is done on the basis of angles. As the routing start from the clusterhead to destination the path changes in angles due to the sensing elements . Due to this sensing the time and power dissipation increases hence the CHIRON has not exact output, when we compare to the real applications. In proposed schemes communication, routing is done between clusterhead (CH) to clusterhead (CH) is done directly or as a straight line. In proposed scheme network is divide into two parts, so only two sensor element are present between two clusterheads (CHs). Hence we have two straight path for routing. Since the number of sensor elements are reduced so sensing time and power dissipation are reduced hence the improvement in CHIRON is possible.

6. SIMULATION AND RESULTS

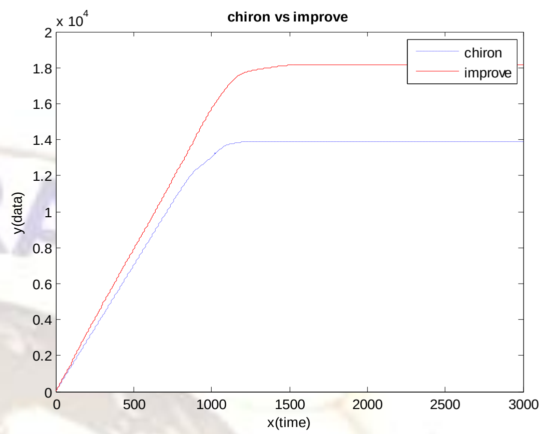
For evaluation the performance and fault tolerance of our proposed CHIRON protocol, in this section, we use a simulation tool MATLAB to conduct several experiments

A. Simulation environment and parameters

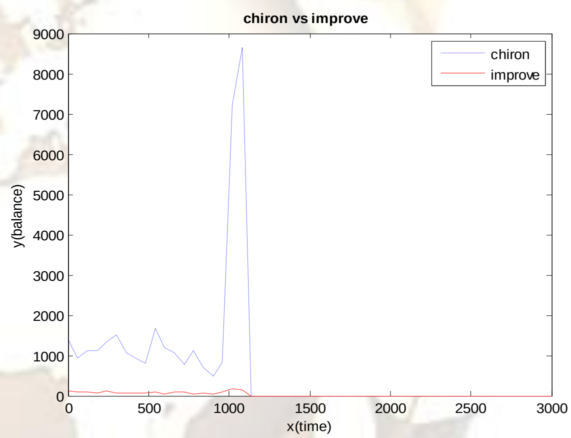
In our simulations, we consider three different sizes of sensing area: 100 m□ *100 m, 200 m□ *200 m, and 300 m□ *300 m, each is with 100 randomly deployed sensor nodes. The BS is located on the corner of sensing field. Every sensor node is initially equipped with 0.5 joules power. We define the average delay ass the average required hops, and the redundant transmission path as the number of detour hops, for one node transmits its sensing data to the BS, respectively. We also define the simulation round as a duration time in which all sensor nodes sent a 2000-bit packet to the BSS. For each simulation scenario, the results are drawn by the average value of 10 runs.

B. Simulation results

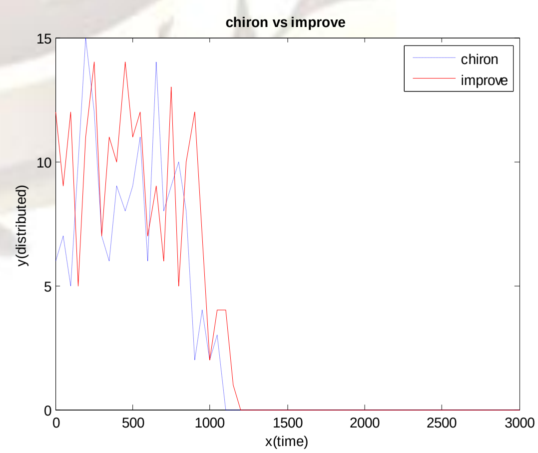
Figure 6 shows the simulation results of average propagation delay and redundant transmission path for two compared schemes. It could be seen that the proposed scheme. In CHIRON routing is done on the basis of angles. As the routing start from the cluster-head to destination the path changes in angles due to the sensing elements . Due to this sensing the time and power.



(a)



(b)



(c)

Figure 6: Improved results for CHIRON.(a) Graph for data on network. (b) Graph for balancing of data on network. (c) Graph for distribution of data on network.

These graph shows the improved result for CHIRON, in which Figure 6.a) shows the data process on the network even when the energy is get zero. Figure 6.b) shows the balancing of traffic using the imroved CHIRON and CHIRON. Improved schemes shows the balancing improvement over CHIRON. Figure 6.c) shows the distributing of traffic using the imroved CHIRON and CHIRON. Improved schemes shows the distributing improvement over CHIRON.

7. CONCLUSION

In this paper, we discuss an efficient hierarchical chain based routing protocol CHIRON, which is suitable for large sensor networks with power and time constraints. In our approaches, we utilize the concept of Beam Star topology to divide the whole sensing field into a number of smaller areas, so that the CHIRON can create multiple shorter chains to reduce the data propagation delay and redundant transmission path and provide better fault tolerance, thus significantly save network energy. dissipation increases. Hence the CHIRON has not exact output when we compare to the real applications. In proposed schemes communication, routing is done between clusterhead (CH) to clusterhead (CH) is done directly or as a straight line. In proposed scheme network is divide into two parts so only two sensor element are present between two clusterheads (CHs). Hence we have sequential straight path for routing. Since the number of sensor elements are reduced so sensing time and power dissipation are reduced.

REFERENCES

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, “A Survey on Sensor Networks,” IEEE Commun. Mag. Vol. 38, pp. 102-114, 2002.

[2] J. N. Al-Karaki and A. E. Kamal, “Routing Techniques in Wireless Sensor Networks: A Survey,” Proceedings of the IEEE Wireless Communications, Vol. 11, pp. 6-28, 2004.

[3] C. Y. Chong and S. P. Kumar, “Sensor Networks: Evolution, Opportunities, and Challenges,” Proceedings of the IEEE, Vol. 91, pp. 1247-1256, 2003.

[4] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, “Energy Efficient Communication Protocol for Wireless Microsensor Networks,” Proceedings of the 33rd Hawaii International Conference on System Sciences, 2000.

[5] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, “An Application Specific Protocol Architecture for Wireless Microsensor Networks,” IEEE Transaction on Wireless Commun. Vol. 1, Issue 4, pp. 660-670, 2002.

[6] E. Altman, T. Basar, T. Jimenez, and N. Shimkin, “Competitive routing in networks with polynomial costs,” IEEE Trans. Automat. Control, vol. 47, no. 1, pp. 92-96, 2002.

[7] J. Choi, C. Conrad, C. Malakowsky, J. Talent, C.S. Yuan, and R.W. Gracy, “Flavones from Scutellaria baicalensis Georgi attenuate apoptosis and protein oxidation in neuronal cell lines,” Biochemica et Biophysica Acta, 1571: 201-210 (2002).