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Energy-Efficient Chain-Based Data Gathering in WSN

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***Abstract*– A WSN is a specialized wireless network made up of a large number of sensors and at least one base station. The foremost difference between the WSN and the traditional wireless networks is that sensors are extremely sensitive to energy consumption. Energy saving is the crucial issue in designing the wireless sensor networks [1]. Since the radio transmission and reception consumes a lot of energy, one of the important issues in wireless sensor network is the inherent limited battery power within network sensor nodes. In order to maximize the lifetime of sensor nodes, it is preferable to distribute the energy dissipated throughout the wireless sensor network. The data gathering schemes should be power efficient. In our proposed work we are changing the idea related to the data gathering and transmission protocol Chiron. The main goal of our research is reduce of energy consumption and improve the lifetime of network as chain leader belonging to the certain covering angle will only transmits the gathered data to the another chain leader of the same covering angle and then we send the data of the another covering angle in sequential manner . So the data is transferred to some angle based chain leader rather than to the nearest chain leader. By this method of data gathering we found that energy consumption is reduced and lifetime is improved significantly.**

***Index Terms* – Base Station, Chain based routing, Data gathering, Energy efficient routing protocol, Life Time, Sensor Node, WSN.**

I. INTRODUCTION

A WSN is a specialized wireless network made up of a large number of sensors and at least one base station. The sensor nodes are small devices that consist of four basic components 1) sensing subsystem, 2) processing subsystem, 3) wireless communication subsystem 4) energy supply subsystem [2]. Fig.1 shows the various components of a sensor node. The sensor nodes have limited battery power, communication range and memory etc. In most cases, the sensors forming these networks are deployed randomly and left unattended to and are expected to perform their mission properly and efficiently. Sensor networks are also energy constrained since the individual sensors are extremely energy-constraint .Therefore the lifetime of a WSN is limited .

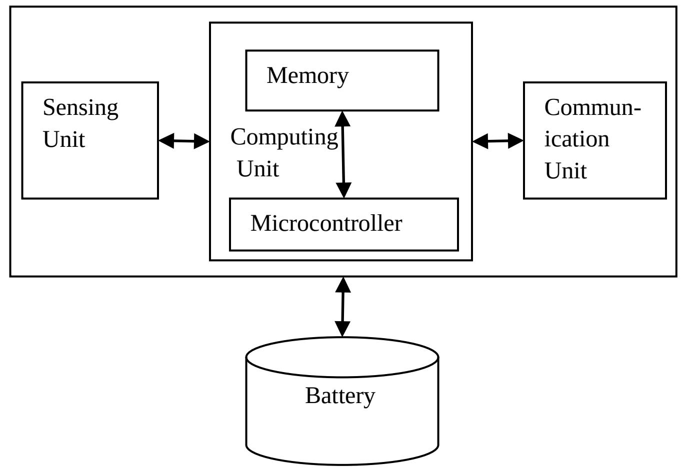

Fig.1: Architecture of a sensor node in WSN

A real and appropriate solution for this problem is to implement routing protocols that perform efficiently and utilizing the less amount of energy as possible for the communication among nodes. Sensor devices in WSNs monitor the same event and report on them to the base station. Sensor networks need protocols, which are specific, data centric, capable of aggregating data and optimizing energy consumption. Sensor nodes deployed in a specified area monitors environmental conditions such as temperature, air pressure, humidity, light, motion or vibration, and so on. The sensor nodes are usually programmed to monitor or collect data from surrounding environment and pass the information to the base station for remote user access through various communication technologies.

Design Constraints for Routing in Wireless Sensor Networks

Due to the reduced computing, radio and battery resources of sensors, routing protocols in wireless sensor networks are expected to fulfill the following requirements:

Autonomy:

The assumption of a dedicated unit that controls the radio and routing resources does not stand in wireless sensor networks as it could be an easy point of attack. Since there will not be any centralized entity to make the routing decision, the routing procedures are transferred to the network nodes.

Energy Efficiency:

Routing protocols should prolong network lifetime while maintaining a good grade of connectivity to allow the communication between nodes. It is important to note that the battery replacement in the sensors is infeasible since most of the sensors are randomly placed. Under some circumstances, the sensors are not even reachable. For instance, in wireless underground sensor networks, some devices are buried to make them able to sense the soil.

Scalability:

Wireless sensor networks are composed of hundred of nodes so routing protocols should work with this amount of nodes.

Resilience:

Sensors may unpredictably stop operating due to environmental reasons or to the battery consumption. Routing protocols should cope with this eventuality so when a current-in-use node fails, an alternative route could be discovered.

Device Heterogeneity:

Although most of the civil applications of wireless sensor network rely on homogenous nodes, the introduction of different kinds of sensors could report significant benefits. The use of nodes with different processors, transceivers, power units or sensing components may improve the characteristics of the network. Among other, the scalability of the network, the energy drainage or the bandwidth are potential candidates to benefit from the heterogeneity of nodes.

Mobility Adaptability:

The different applications of wireless sensor networks could demand nodes to cope with their own mobility, the mobility of the sink or the mobility of the event to sense. Routing protocols should render appropriate support for these movements.

II. RELATED WORK

In general, three strategies are considered for the design of data aggregation techniques in WSNs. They are cluster based [4], tree-based [5], and chain-based [9]. In this paper, only chain-based routing protocols have been reviewed.

A. PEGASIS

Power Efficient Gathering in Sensor Information Systems is

PEGASIS protocol which is improved version of LEACH. Instead of forming clusters, it is based on forming chains of sensor nodes. One node is responsible for routing the aggregated data to the sink. Each node aggregates the collected data with its own data, and then passes the aggregated data to the next ring. The difference from LEACH is to employ multi hop transmission and selecting only one node to transmit to the sink or base station. Since the overhead caused by dynamic cluster formation is eliminated, multi hop transmission and data aggregation techniques are employed, PEGASIS outperforms the LEACH [6]. However 1)In a large sensing field, 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 resulting in redundant transmission paths. 3) The single chain leader may become a bottleneck.

B. EPEGASIS

A variation of PEGASIS routing scheme, termed as Enhanced PEGASIS [8] (we abbreviate it as EPEGASIS later in this paper). 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 nodes 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.

C. COSEN

COSEN (Chain Oriented Sensor Network) operates in two phases - chain formation phase followed by data transmission phase. In the chain formation phase, chains of different levels are formed and in data transmission phase, information is transmitted along with the designated paths. One higher level chain and several lower level chains are formed with the deployed sensors. In each chain, one node is elected as a leader. In every kind of chains, the chain-leader is elected based on some criteria or measures. Lower level leader nodes are responsible to collect information from lower level chains and send the information towards higher level leader [9]. Higher level leader sends the information to BS. The sensor nodes are capable of dynamic power adjustment. Therefore nodes can adjust the amplifier electronics to adjust/accommodate for any required distance.

B. THE NETWORK MODEL

For improving the energy consumption and data transfer rate is a WSN an energy efficient hierarchical chain-based routing protocol, is discussed here. In this article we assume a sensor network model with the following properties:

1. A fixed base station is located at the corner of the sensing field.
2. The BS is equipped with directional antennas.
3. The BS can adaptively adjust its transmission power level and antenna direction to send control packets to all nodes in the WSN.
4. The sensor nodes are energy constrained with a uniform initial energy allocation.
5. Each node senses the environment at a fixed rate and always has data to send to the base station.
6. All sensor nodes are immobile.

C. THE ENERGY MODEL

To transmit m-bit packet to a node with d meters distance from the source.
Then the energy consumed will be,

$$E_{TX} = E_{TXelec}(\mathrm{m}) + E_{TXamp}(\mathrm{m,d})$$

$$= \begin{cases} m \times E_{elec} + \epsilon_{fs} \times d^2 & if\ d < d_0 \\ m \times E_{elec} + \epsilon_{mp} \times d^4 & if\ d < d_0 \end{cases} \quad \ldots(1)$$

To receive m-bit packet, the dissipated energy is given

by, ….(2)

$$E_{RX} = \mathrm{m} \times E_{elec}$$

$$d_0 = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}} \quad \ldots(3)$$

Where E_{elec} is energy required for electronic circuitry, ϵ_{fs} is free space energy model, ϵ_{mp} is the multipath energy model, d_0 is the threshold distance, E_{TX} is total transmitter energy, E_{RX} is receiver energy.
E_{elec} depends upon factors like filtering, modulation, digital coding etc. The various energies that affect the performance of the WSN are described in equations(1),(2),(3) respectively.
$\epsilon_{fs} \times d^2$ and $\epsilon_{fs} \times d^4$ depends upon BER and distance to the receiver. Fig.2 shows the basic radio model used for our simulation this figure shows the various energy parameters that are used in the radio model.

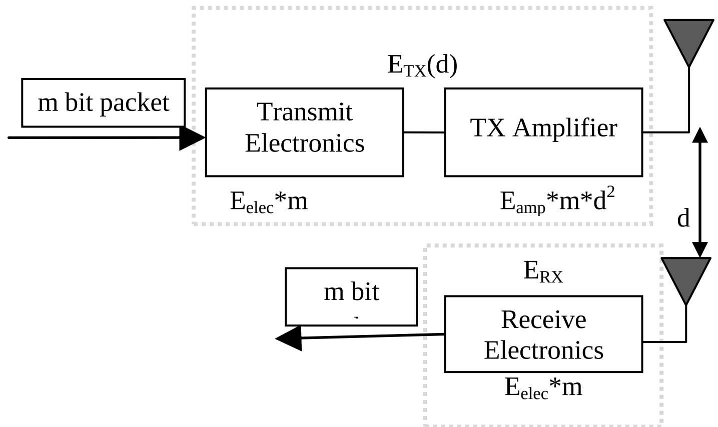

Fig.2: Radio Model showing various energies.

D. THE PROPOSED CHAIN BASED PROTOCOL

The proposed chain based hierarchical protocol has the five phases: 1).Grouping of Sensor Field 2).Formation of Chains 3).Selecting the Chain Leader 4).Data Collection 5).Data Transmission. All these are discussed in the following subsection.

1) *Grouping of Sensor Field*

The sensor nodes are deployed randomly in the required for sensing the particular events in that area. In this phase the whole sensor area is divided in to smaller areas by using the beam star concept. Then RSSI (Received Signal Strength Indication) algorithm is applied to find the distance between the nodes in the area .The RSSI algorithm can also be applies for the localization of the sensor nodes in the wireless sensor network.

2) *Formation of Chains*

In a grouped area the farthest node is taken as the start node for making a chain. This node is linked to its nearest neighbor. Now this newly linked node will search its neighbor with minimum distance from it.

3) *Selecting the Chain Leader*

In this phase chain leader is elected depending upon the residual energy. In a particular subarea the node with highest residual energy is elected as chain leader. But in the first round the farthest node in the subarea is elected as chain leader.

4) *Data Collection*

In this phase the sensor nodes sends the data to their respective chain leader. Each node in the chain collects the data from its neighbor, fuse it with its own data and then send to the chain leader. In this way the data is gathered from the member nodes of the subarea. Now the data is to be transferred to the base station.

5) *Data Transmission*

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In CHIRON protocol the data from a chain leader is transferred to its nearest chain leader neighbor. But in the proposed method the data is transferred from a chain leader to the other chain leader having the same covering angle. By doing this the transmission path and delay is reduced. Hence the lifetime of the network will be increased.Fig.3.shows the data transfer by using the same covering angle.

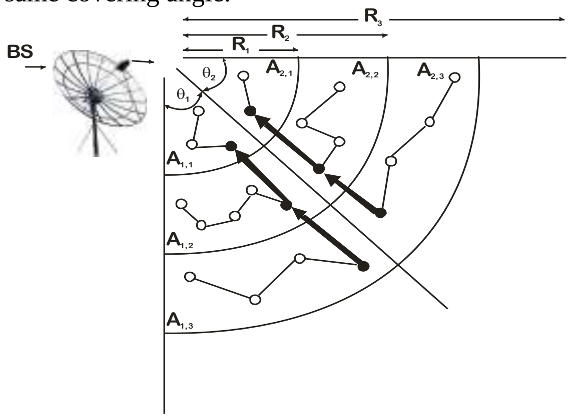

Fig.3: Data transmission path in the proposed protocol

E. SIMULATION AND RESULTS

For evaluation the performance of our proposed protocol, in this section, we use a simulation tool MATLAB [12] to conduct several experiments.

A. Simulation Parameters

In our simulations, we consider three different sizes of sensing area. 120m*120m with 150 randomly deployed sensor nodes. The BS is located on the corner of sensing field (i.e. at 0,0). Every sensor node is initially equipped with 0.56 joules power. We define the average delay as 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 BS. For each simulation scenario, the results are drawn by the average value of 10 runs. The range for different power levels transmitted from the base station is taken as 'R'. The covering angle of the directional antenna is taken as 'θ'.Various other Parameters taken are

E_{elec} =70 n J/bit, ϵ_{fs} =10 p J/bit/m^2 , ϵ_{mp} =0.0013 p J/bit/m^4

E_{DA}=5 n J/bit/signal .Here E_{DA} is data aggregation energy

B. Simulation Results

In Chiron routing is done on the basis of angles with change in the path. But in our case the routing starts from chain leader to chain leader with no changes in the path. So data has to travel with less number of hops so consumption of energy decreases and number of died nodes starts decreasing hence lifetime of the networks improves significantly.

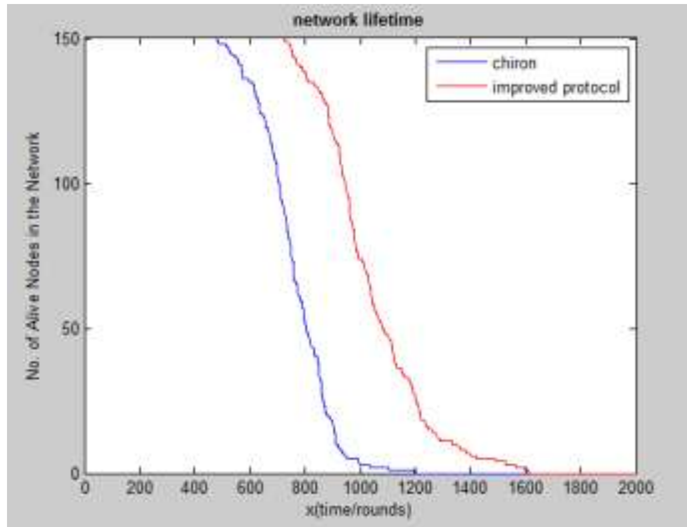

Fig.4: Improved network lifetime

Fig.4 shows the improved network lifetime when the same covering angle is used for data transfer from one chain leader to other chain leader. CHIRON have the lifetime of about 1200 rounds while the proposed protocol have lifetime of about 1600 rounds .There is almost 35% improvement in the lifetime of the WSN if same covering angle is used for data transfer.

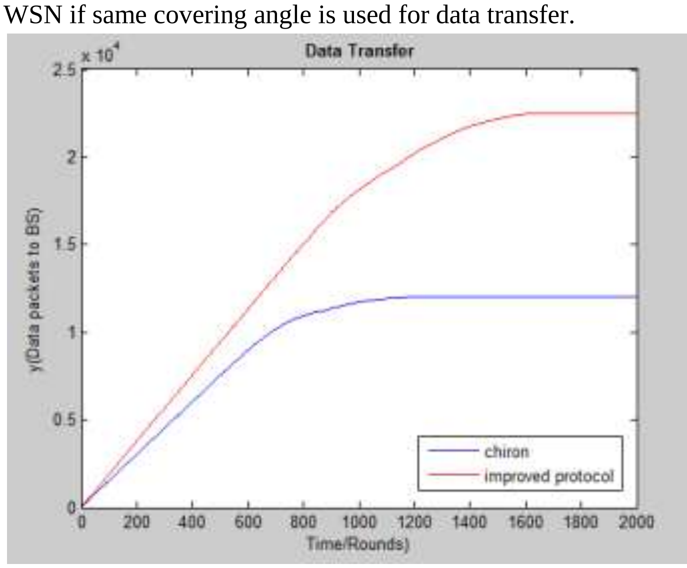

Fig.5: Data transfer vs No. of rounds

As shown in Fig.5, blue line shows the data transfer in Chiron and red line shows the increased data transfer during the same rounds in the improved scheme.

F. CONCLUSION

In this paper, we discuss an energy efficient protocol for large sensor networks with power and time constraints. Energy consumption and network lifetime are the major issues in Wireless Sensor Networks (WSN).Energy consumption can be reduced by using the efficient data gathering protocols. We utilize the concept of Beam Star topology to divide the whole sensing field into a number of smaller areas, so that the it can create multiple shorter chains to reduce the data propagation delay and redundant transmission path, thus it significantly improves the data gathering mechanism and improves the network lifetime as compare to the Chiron because routing is done based upon the angle between chain leader to chain leader and network is divided into two parts so that the chain leader of the same covering angle will transmits the data to the next chain leader but in the same covering angle and in the sequential manner. Hence we have sequential straight path for routing. Since the number of sensor elements are reduced so sensing time and power dissipation are reduced and hence lifetime of the network is improved.

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