A Review of Routing Protocols in Wireless Sensor Networks

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Abstract*- In the recent years, wireless sensor networks have received a remarkable consideration from not only the research communities but also from the actual users. WSNs correspond to the subsequent hi-tech revolution which is distinct from other wireless or wired networks through its potential of interaction with the environment. Though WSNs are endowed with numerous advantages and applications but there are certain hitches also related to it. In this paper a genuine effort has been done to bring under spotlight the vital issue of energy efficiency of battery driven sensor nodes for prolonging network lifespan. We present a systematic and comprehensive taxonomy of the energy conservation schemes discussed in detail and we have proposed a new approach IC-LEACH which not only improves the energy utilization or lifetime of sensor but also to work in non-homogeneous or heterogeneous environment efficiently. We have also tried to compare this new approach with few well-established techniques to show better results.*

Keywords*-* Energy efficiency algorithms, PEGASIS, LEACH, I-LEACH, IC-LEACH

I. INTRODUCTION

Wireless communication is usually thought-about to be a branch of telecommunication. In distinction to the traditional wired networks, sensing element networks gift a robust mix of distributed sensing, computing and communication. WSNs consist of a large number of small sensing self-powered nodes that collect information and communicate in a very wireless manner, with the most aim of handing their processed information to a base station.

Sensor is a small device used to sense the ambient condition of its surroundings, collect data, and process it to conclude some meaningful information which can be further used to identify the phenomena. These sensors can be assembled together using various mesh networking protocols to form a network. These networks use radio frequency channel to communicate wirelessly. The set of these homogenous or heterogeneous sensor nodes is called wireless sensor network (WSN). Wireless Sensor Networks generally consist of a data acquisition network and a data distribution network which are monitored and controlled by a management centre.

- **Microcontroller:** Microcontroller performs tasks, processes information and controls or manages the functionality of other components in the sensor node. A microcontroller is usually the most effective selection for embedded systems as a result of its flexibility to attach to different devices, simple programming. and low power consumption Power may be preserved by programming these devices to travel into a sleep state with solely a part of the controller active. Example of microcontroller Texas Instrument MSP430, Atmel ATMega[7].

- **Transceiver:** Frequencies currently used for wireless sensor systems include 315 MHz, 433 MHz, 868 MHz (Europe), 915 MHz (North America), and the 2.45-GHz Industrial-Scientific-Medical (ISM) band. The 2.45-GHz band provides implementation flexibility owing to the abundance of commercially available RF devices in this band. The functionality of both transmitter and receiver are combined into a single device known as transceivers and are used in sensor nodes. Examples of transceiver are RFM TR1000 family, Chipcon CC1000, Chipcon CC 2400, Infineon TDA 525x family.

- **Power Source:** Data transmission consumes more energy than data processing and thus is more expensive in terms of energy consumption is extremely expensive [5]. The energy cost to transmit a single bit of information is nearly the same as that needed to process a thousand operations in a typical sensor node [6]. The energy cost of transmitting 1 Kb to a distance of 100 m is approximately the same as that for the executing 3 million instructions by 100 million instructions per second/W processor. Batteries, either rechargeable or non-rechargeable, are the key source of power supply for sensor nodes. They can also be classified according to electrochemical material used for electrode such as NiCd (nickel-cadmium), NiZn (nickel-zinc), NiMH(nickel metal hydride), and Lithium-Ion.

- **Sensor:** Sensors are hardware devices that produce measurable response to a change in a physical condition like temperature and pressure. Sensors measure physical information of the area to be examined. The analog signal sensed by the sensors is digitized by an Analog-to-digital converter and sent to controllers for further processing. Characteristics and needs of sensor node ought to be small size, consume very low energy, operate in high volumetric densities, autonomous and operate unattended, and accommodative to the surroundings. This power source typically consists of a battery with a restricted energy budget. Since nodes may be deployed in a hostile or unpractical environment therefore, it may well be not possible or inconvenient to recharge the battery. On the opposite hand, the sensor network ought to have a lifetime long enough to fulfil the application requirements.

The cost of sensor nodes may range from a few pennies to hundreds of dollars, depending on the size and complexity of the sensor network the constraints of size and cost of sensor node results in corresponding constraints on resources such as memory, energy, bandwidth and computational speed.

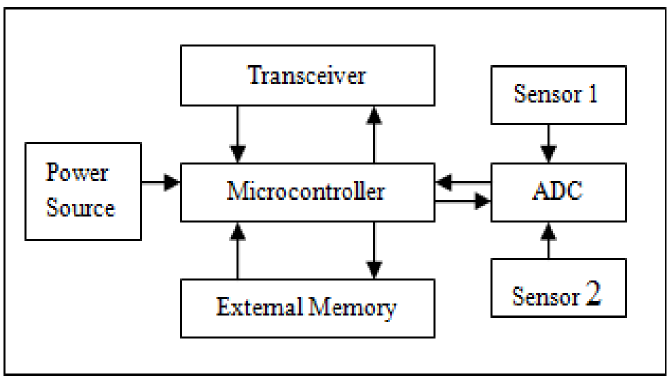


Figure 1 Sensor Node architecture [3]

Applications of Wireless Sensor Network

It provides plentiful applications [3] [4] such as:

- It can be used to monitor microclimates and wildlife habitats [1].
- Monitor the environment, home and business smart environments,
- Better management of cities in areas like traffic control, intelligent transportation, search and rescue, disaster relief, and localization systems.
- Warfare child education, surveillance [8] [9], micro-surgery, and agriculture [2].
- Integrated patient monitoring and diagnostics.
- Drug administration in hospitals, telemonitoring of human physiological data; and tracking and monitoring doctors and patients inside a hospital[19].
- A flood detection system called ALERT system [20] has been deployed in the US. Several types of sensors deployed in the ALERT system are rainfall, water level and weather sensors.

Thus, Wireless sensor networks have lately gained a huge significance since they possess the capability to transform many sections of our economy and life. They have not only helped in environmental monitoring and conservation but have conjointly to be fruitful in manufacturing and business asset management, automation in the transportation and health care industries. These applications involve a huge sum of battery-powered wireless sensors, and are generally designed for long-term deployments with no human involvement. Thus, energy efficiency is one of the major design objectives for these sensor networks. Iyengar and Brooks [16, 17] and Cullerand Hong [18] have given excellent overviews of the breadth of sensor network research topics as well as of applications for sensor networks.

Certain hitches related with sensor network are placement, communication bandwidth, network lifespan, scalability, and power optimization. Of these, energy efficiency for is one in all the foremost important problems so as to prevent connectivity degradation by employing aggressive energy management techniques. The dis-functioning of few nodes can cause significant topological changes and might require re-routing of packets and re-organization of the network. Sensor nodes are battery driven devices with restricted energy resources. So, in order to prolong the lifetime of the sensor nodes, designing efficient routing protocols is critical. The minor sensor nodes are generally remote to the operator once installed, and thus supplementary of the energy source is not feasible.

II. ENERGY EFFICIENT ROUTING PROTOCOLS

The main job of routing in WSNs is to transfer data from source i.e. sensor node to the sink. A number of routing protocols have been exclusively designed for Wireless Sensor Networks where energy efficiency is critical design issue. These routing protocols minimize the used energy, and then extend the lifetime of the WSN.

Depending on the network structure, routing in WSNs can be divided into [15]:

a) Flat-based routing
b) Hierarchical-based routing
c) Location-based routing

In flat-based routing, all nodes are assigned similar tasks. In hierarchical-based routing, nodes will perform dissimilar tasks in the network. In location-based routing, sensor nodes positions are utilised to route data in the network. Out of all these topologies based routing protocols, hierarchal routing protocol technique is much more admired concerning the power saving issue of sensor nodes. In a hierarchical architecture, higher-energy nodes can be used to process and send the information, while low-energy nodes can be used to perform the sensing in the proximity of the target. Several cluster formation takes place and these clusters are responsible to transfer data from node to the sink. A cluster leader or cluster head is formed and then communication with sink can be done with the help of this cluster head; they collect data from neighbouring nodes and send it to another cluster head, which may be responsible for any other cluster and this mechanism continuous until the data reaches to the sink.

The main concern with this method is that cluster heads normally remain active for more time than other nodes in the cluster and thus they lose their energy before other nodes. Another critical issue is that it is complex to preserve the energy level of all sensor nodes at same level, and if cluster head loses it energy first then it may be possible that we might lose one segment of network from our main network topology. These routing protocols are not suitable for large sized networks, since relay the message to find out their neighbours and also to form new clusters by finding new cluster heads. In this process they lose sufficient amount of energy.

W.R. Heinzelman[10]proposed a hierarchical clustering algorithm for sensor networks, called **Low Energy Adaptive Cluster Hierarchy based protocol (LEACH)** which works in the direction to minimize the energy dissipation in sensor networks. The purpose of LEACH is to randomly select sensor nodes as cluster-heads, so the high energy dissipation in communicating with the base station is spread to all sensor nodes in the sensor network. Therefore, the whole purpose is divided into rounds and during each round a different set of nodes are cluster-heads (CH).

The selection of CH depends on decision made by the node by choosing a random number between 0 and 1. If the number is less than a threshold, the node becomes a cluster-head for the current round. The threshold is set as:

$$T(n) = \begin{cases} \dfrac{P}{1 - P * (r \bmod \frac{1}{P})}, & if\ n \in G \\ 0, & otherwise \end{cases}$$

Where P= the desired percentage of cluster heads (e.g. =0.05), r = the current round, and G is the set of nodes that have not been cluster-heads in the last 1/P rounds. Using this threshold, each node will be a cluster-head at some point within 1/P rounds. Nodes that have been cluster heads cannot become cluster heads for a second time for P rounds. After that, each node has a 1/p probability of becoming a cluster head in every round. At the end of every round, every node that is not a cluster head select the nearest cluster head and joins that cluster to transmit data. The cluster heads combine and compress the data and forward it to the base station, therefore it extends the life span of major nodes. In this algorithm, the energy consumption will allocate approximately uniformly among all nodes and the non-head nodes are turning off as much as possible. LEACH assumes that all nodes are in range of wireless transmission of the base station which is not the case in many sensor deployments. 5% of the total nodes play as cluster heads in every round. Time Division Multiple Access (TDMA) is deployed for better management and scheduling. Simulations show that LEACH can achieve as much as a factor of 8 reductions in energy dissipation compared with conventional routing protocols. Also, LEACH is able to distribute energy dissipation evenly throughout the sensors, doubling the useful system lifetime for the networks simulated by them [10].

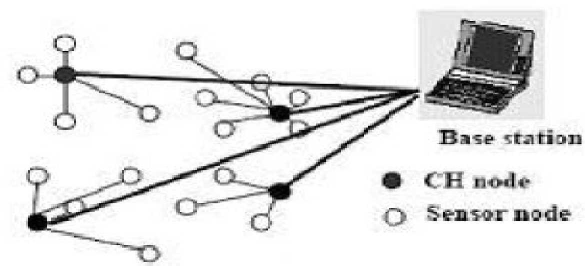


Figure 2 LEACH[14]

Figure 2 shows the communications in LEACH protocol. S. Lindsey and C. S. Raghavendra[11]further proposed a new hierarchical routing protocol **Power-Efficient Gathering in Sensor Information Systems (PEGASIS)** which proved to be an improvement over LEACH protocol. The protocol is a near optimal chain-based protocol for extending the life span of network wherein every node communicates only with the adjacent neighbour by adjusting its power signal to be only heard by this adjoining neighbour. Every node uses signal strength to measure the distance to neighbourhood nodes in order to locate the closest nodes. A leader is selected from the chain formed on the basis of residual energy in every round and that leader collects data from the adjacent node to be transmitted to the base station. Thus, the average energy depleted by every node per round is reduced. In LEACH cluster formation takes place but in PEGASIS chains are formed and they use only one node in a chain to transmit to the BS instead of multiple nodes as in cluster formed by LEACH. This approach reduces the overhead and lowers the bandwidth requirements from the BS. Also the transmitting distance for most of the node reduces in PEGASIS as compared to LEACH.

Simulation results demonstrate that PEGASIS performs better than LEACH by about 100 to 300% when 1%, 20%, 50%, and 100% of nodes die for different network sizes and topologies [11].

But certain drawback of this protocol is when a head node is selected its energy level is not considered. Also, there is no consideration how far the BS is located from the head node. There is possibility of redundant transmission of data as only one head node is selected.

Figure 3 shows that only one cluster head leader node forward the data to the BS.

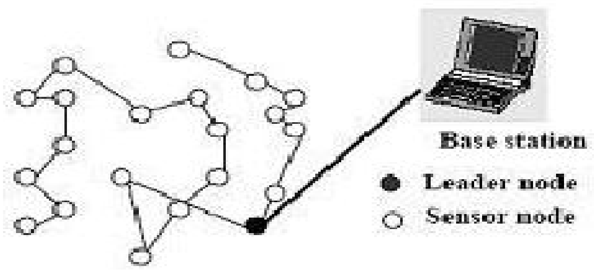


Figure 3 PEGASIS [14]

Naveen Kumar and Jasbir Kaur [16] proposed a new routing protocol named **I-LEACH (improved LEACH protocol)** for WSNs which outperformed LEACH protocol by overcoming the two shortcomings existing in its counterpart which are basically:

1) The selection of CH in LEACH is based on the probability and woks well only if the energy of nodes is uniform i.e. when the WSN is homogeneous. Therefore, residual energy is used to select the CH (Cluster Head) instead of probability so that it can be used for the sensor nodes with different initial energy.
2) There isn't any certainty about the location of CHs whether they are uniformly distributed through the network. So there is possibility that elected CHs will be concentrated in one part of network; hence some nodes will not have any CHs in their neighbourhood and as a result these nodes have to transmit their data to far-distant CHs. Thus, in I-LEACH coordinates are used to form clusters so that there must remain a CH close to every sensor node.
3) Simulation results display that I-LEACH implement the above discussed improvements effectively and efficiently and improves the network lifespan over LEACH. I-LEACH proves to be 15% more energy efficient with 1J/Node energy over a network area of a 100m × 100 m[21] than LEACH and outperforms LEACH with 171 more rounds.

TABLE I

Energy	Protocol	1%	20%	50%	100%
0.25J/Node	LEACH	166	204	232	308
0.25J/Node	I-LEACH	186	232	273	349
0.25J/Node	PEGASIS	335	624	684	779

In this paper we have proposed a new protocol IC-LEACH for sending data from sensor nodes to base station in energy efficient manner so as to improve the lifetime of the network and to maintain a balanced energy consumption of nodes.

III. PROPOSED ALGORITHM

In the proposed protocol IC-LEACH the residual energy concept has been used to select the CHs instead of probability-based selection, so that non homogenous sensor nodes can also perform well with this protocol and coordinates of the x-axis have been used to make sure that distribution of CHs is uniform. It has been made sure that the proposed protocol works for homogeneous as well as heterogeneous WSNs. It is more improved than I-LEACH as the conceptual advantages of chain-formation from the PEGASIS protocols have also been added while designing this protocol, which has been named as **IC-LEACH (Improved Chained- LEACH).** .

The Pseudo Code for IC-LEACH

Initialize

1. 100 Random Nodes← (x,y)
2. Base Station ← Give location of BS (e.g. (50,300))
3. $E_{initial}$← Give value of initial energy (e.g. 0.5 Joule)
4. E_{elec}← 50 nJ/bit
5. E_{amp}← 100 pJ/bit/m^2
6. E_{diff}←5nJ/bit/message

Five clusters are formed, N=5.

Chain is formed in each cluster starting from farthest node.

Main Processing

Repeat after every run *r*

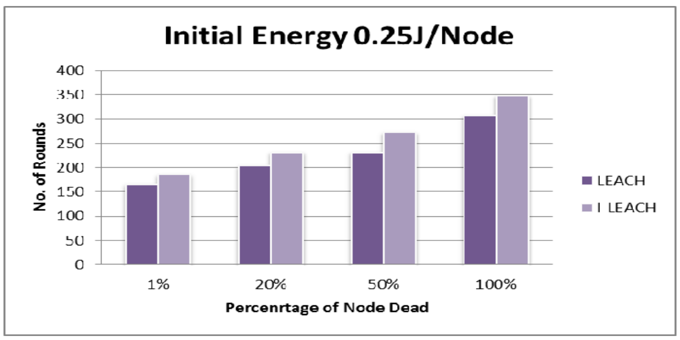
1. Cluster Head (x,y)← max of $E_{(x,y)}$
2. Leader node← Cluster Head of mod (r,N)th cluster
3. d←sqrt[(x(i)-x(i+1))^2+(y(i)-y(i+1))^2]
4. $E_{(x,y)}$←($E_{initial}$-2*r*E_{elec}*k)-(E_{amp}*r*k*d^2)-(E_{diff}*k*r),
   (k =2000,no. of bits in one message)
5. If $E_{(x,y)}$<E_{min}←Dead Node,

E_{min}=2.101*10^(-4); minimum energy required to be a live node.
It has been calculated as:
[E_{min}= (2*50*10^(-9)*2000)+(100*10^(-12)*100* 2000)+(5*10^(-9)*2000)J]

Finalize

1. n(1)← No. of rounds when first node get dead
2. n(2)← No. of rounds when 20 nodes get dead
3. n(3)← No. of rounds when 50 nodes get dead
4. n(4)← No. of rounds when 100 nodes get dead
5. Plot←No. of rounds v/s % of dead nodes

IV. IMPROVED RESULTS GRAPHS



V. COMPARISONS

IC-LEACH performs far better whenever initial energy is incremented. Slope of the curve between number of rounds and number of nodes that are alive, decreases with significant amount as the initial energy is increased

VI. CONCLUSION

Sensor networks present countless challenges, but their flexibility and wide range of applications are eliciting more and more interest from the research community as well as from industry. Sensor networks have the probability of triggering the next revolution in information technology. In our proposed work we have introduced IC-LEACH which acts as a remedy to the shortcomings of LEACH, PEGASIS and I-LEACH protocols and improves the network lifespan. Concept of Chain formation from PEGASIS protocol and concept of residual energy and certainty of CHs formation of I-LEACH protocol have been implemented together. IC-LEACH outperforms all other protocols in terms of number of rounds completed for a given amount of initial energy provided. Another conclusion that has been drawn is that the new proposed protocol IC-LEACH works satisfactorily for heterogeneous as well as homogeneous environment, while the other protocols works only for homogeneous environment.

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