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Comparative Analysis of Routing Protocols Based on Energy Efficiency in Wireless Sensor Network

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Abstract— Wireless sensor networks consisting of no. of small sensor nodes, sense the surroundings and report what is happening in the region in which they are deployed. In wireless sensor networks sensor nodes continuously transfer the information to base station and most of energy of the nodes consumed in transmitting and receiving the data. Hence because of limited and non rechargeable power resource their energy get drained. This results in reducing the lifetime of whole network. In wireless sensor networks sensing nodes are not rechargeable and also their used up batteries can not be replaced. Thus the energy efficiency is most significant requirement in these type of wireless networks. Based on energy efficiency this paper concentrates on comparative analysis of routing protocols: LEACH, PEGASIS, Multi chain PEGASIS; as well as finding most energy efficient routing protocol in wireless sensor network. So that highly energy efficient protocol can be used to increase lifetime of network.

Keywords— Sensor Nodes, LEACH, Cluster Head, PEGASIS, Chain, Multi Chain PEGASIS, Energy Dissipation.

I. INTRODUCTION

Wireless Networks are the networks where there is no physical wired medium between sender and receiver. Wireless sensor networks consisting of large no. of small sensor nodes monitor physical and environmental conditions such as sound, pressure, temperature etc. and passes this acquired data to central node. All the sensor nodes are wirelessly connected to each other in wireless sensor networks. As sensor nodes are not rechargeable less power consumption is must in these networks. Wireless sensor networks work as long as power supply is on. When the power supply is drained off, these network ceases to operate. So energy efficiency is critical requirement in small sensor nodes [1]. This paper concentrates on comparative analysis of routing protocols : LEACH, PEGASIS, Multi chain PEGASIS; based on energy efficiency in wireless sensor network. In wireless sensor network total energy dissipation is directly proportional to Length of data, distance between sender and receiver, energy consumed in transmitting and receiving data. So in order to dissipates less energy in network these factor should be minimized. This paper also present comparative simulated Results of all above routing protocols based on energy efficiency. All the simulation have been done using MATlab.

First Order Radio Model

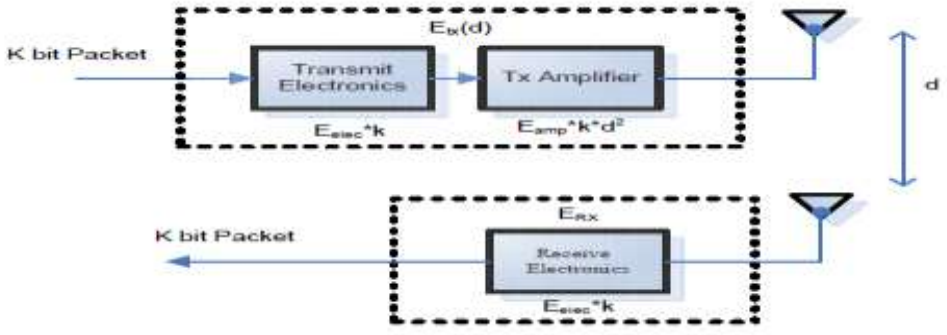


Figure 1: Radio Model

All routing protocols uses this Radio Model for transmission and reception of data. Radio signal Propagation model assumes two model for transmit Amplifier. One is free space Model and other is Multipath fading signal model [3].

Energy Consumption calculation can be done as follows

If the distance between sender and receiver is less than threshold distance($d_{0=Efs/Emp}$), Transmit Amplifier assumes free space model. If the distance between sender and receiver is greater than threshold distance(d_0), Transmit Amplifier assumes multipath model. The formula for energy consumption (ETx) during transmitting data and energy consumption (ERx) during receiving data is written below.

$$E_{Tx}(L,d) = \begin{cases} LE_{elec} + L\varepsilon_{fs}d^2, d \le d_0 \\ LE_{elec} + L\varepsilon_{mp}d^4, d > d_0 \end{cases}$$

$$E_{Rx}(L) = LE_{elec}$$

In the above equation Efs denotes free space energy which is Amplification Coefficient for free space model and Emp denotes multipath energy which is Amplification Coefficient for multipath model. L is length of data to be transmitted [3].

II. PREVIOUS WORK

1.Wendi Rabiner Heinzelman, Anantha Chandrakasan, and Hari Balakrishnan, " Energy-Efficient Communication Protocol for Wireless Microsensor Networks" made the conclusion about LEACH that it minimizes global energy usage by distributing the load to all the nodes at different points [4]. LEACH reduces consumption of energy by as much as 8x compared with direct transmission and minimum transmission-energy routing.The first node death in LEACH occurs over 8 times later than the first node death in direct transmission,and minimum-transmission-energy routing and a static clustering protocol, and the last node death in LEACH occurs over 3 times later than the last node death in the other protocols[4].

2.Sunita Rani, and Tarun Gulati, "An Improved PEGASIS Protocol to Enhance Energy Utilization in Wireless Sensor Network" describe about PEGASIS, that it is chain based hierarchical routing protocol that is near optimal for a data-gathering problem in sensor networks. PEGASIS perform better than LEACH by eliminating the overhead of dynamic cluster formation, minimizing the connected distance between nodes, limiting the number of transmissions and reception among all nodes and using only one transmission to the BS per round[8].

3. Mukesh Prajapat, and Dr. N. C Barwar, "Reduction of Energy Dissipation in WSNs Using Multi-Chain PEGASIS" propose a multi-chain PEGASIS that uses token passing approach for increasing energy efficiency and lifetime of wireless sensor networks[9].

III. ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORK

1. LEACH: Low Energy Adaptive Clustering Hierarchy Protocol

Its Goal is to minimize energy consumption. LEACH is Time Division Multiple Access based self organizing adaptive clustering hierarchical protocol that utilize the randomized rotation of high Energy Cluster Head to evenly distribute the energy load among all the nodes in Network. Here each Cluster Head compress the data coming to it from nodes and send it to Base Station reducing energy dissipation thus increasing network lifetime. Nodes organize themselves in clusters with one node acting as the cluster Head of particular cluster. Clusters Heads randomly changes such that in order to not drain the battery of single sensor node. Data is transmitted hierarchically from nodes to Cluster Head and then Cluster Head to Base Station [4] .

Operation of LEACH:- Operation of LEACH is broken down into different rounds where each round starts with Cluster Set up Phase followed by Steady State Phase [5].

1) *Cluster Set up phase* – It consist of 4 steps. In this phase Cluster Formation takes place.
   a) Cluster Head Selection Step- In the network Architecture when clusters are being created each node decides whether to become or not to become the Cluster Head for the current round.
   Each node takes this decision based on required percentage of Cluster Heads for the network and number of times the node has become Cluster Heads in preceding Rounds [3]. After taking the decision of becoming Cluster Head, node

select a random number between 0 & 1 and compare the selected number with some threshold value T(n) given by the equation written below

$$T(n) = \begin{cases} P/(1 - P\,(r * \bmod (1/p)), & n \epsilon G \\ 0 & \text{otherwise} \end{cases} \qquad (1)$$

If the random number is less than T(n) node will become CH for current round otherwise not. In the equation (1) P is probability of node to become the Cluster Head, r is current round, p represents required percentage of CH in the network and G is collection of nodes that have not become Cluster Head(CH) in last 1/P rounds. Using this threshold value T(n) all the nodes will be CH once in every 1/P rounds. Node as a CH in round 0 can not be CH for the next 1/P rounds. Due to this, the probability of remaining nodes to become CH increases thus reducing burden on single node and not draining battery of that node results in increase in energy efficiency [4]. After 1/P-1 rounds all node which have not been Cluster Head will be selected as Cluster head with probability 1. When 1/P rounds finished all the nodes returns to same line. After every 1/P rounds nodes can be eligible to become the Cluster Heads again [3].

b) Advertisement Step- Using Carrier Sense Multiple Access Protocol, node after becoming Cluster Head broadcast the advertisement containing its status to all the ordinary nodes. During this step the non CH must keep their receiver on in order to hear advertisement sent by all Cluster Heads [5].

c) Cluster Joining Step- Based on received signal strength of advertisement and CH which require minimum communication energy each ordinary node decided to which cluster it wants to belong for current round. Using CSMA MAC protocol, each node send the message to CH for obtaining its membership. CHs must keep their receiver on during this step [4].

d) Schedule Creation Step- After cluster joining step each CH creates Time Division Multiple Access (TDMA) schedule for all the sensor nodes in its cluster. TDMA schedule permit radio component of all sensor node to be switched off excluding their transmit time. Thus less energy dissipation takes place in individual sensor nodes [4].

2) *Steady State Phase-*

a) First Step- Ordinary nodes are able to know at what time they can transfer the data. So all nodes send data to Cluster Head without collisions.

b) Second Step- After receiving data from all sensor nodes in its cluster, each Cluster Head fuse(compress) data and send aggregated data to global Base Station [5].

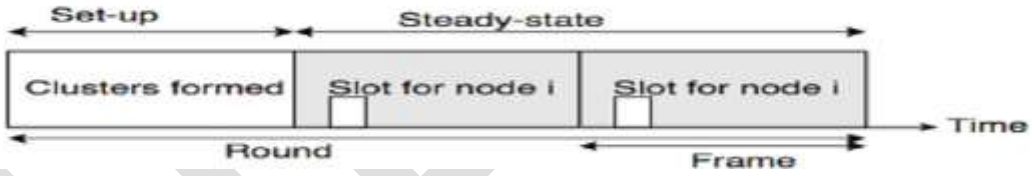


Figure 2: Time line operation of LEACH Protocol [6]

Advantages:- Data fusion helps to reduce the amount of data transmitted to BS resulting in less energy dissipation compared to previous protocols.

Disadvantages:-LEACH have long transmit distance between sender and receiver. As the energy consumption is directly proportional to distance hence more energy dissipation takes place. There is burden on Cluster Head to acquire data of all nodes in clusters. Thus results in energy dissipation of one CH. Whole network need to depend only on CH whenever it dies whole network get failed.

2. PEGASIS: Power Efficient Gathering in Sensor Information System

PEGASIS gathered the sensed information in energy efficient manner due to which sensor network work for a long time. It is improvement over LEACH protocol and overcomes the drawbacks of LEACH protocol like long transmit distance and burden on CH (single node) to acquire the data. It distribute the energy load evenly among all the nodes in network. It is optimal chain based hierarchical routing protocol in which all the immobile nodes participate to form chain.

Base Station is fixed and positioned far away from immobile nodes. Using Global position System (GPS) each node knows its own location and its neighboring sensing nodes . In this protocol chain is build up among all the sensor nodes in the network before starting of rounds. In PEGASIS greedy approach has been used in forming the chain [7]. Chain is started from the End node which is placed

at farther distance from Base Station. End node select the closest node as subsequent node then chain is formed b/w End node & next node. Similarly each node find the distance between itself and the closest neighboring node not connected in chain and connect it with the same method mentioned above . After forming chain data is gathered and fused from node to node & eventually designated node transfer data to Base Station. As each node is gathering and compressing the data and taking turns to become leader node for transmitting data to base station, thus average energy dissipation by each node per round get decreased[8].

Advantages:- Short transmit distance due to which Energy dissipation (Energy dissipation is directly proportional to square of distance) is less compared to LEACH protocol. Less overhead, load is distributed evenly among the network results in less energy consumption.

Disadvantages:- The main drawback of PEGASIS is that chain has to be reconstructed again as it does not execute its functions whenever any leader node in chain dies. It takes long time to reconstruct a long link chain due to which delay occur in data transmission and unnecessary energy dissipation occur in forming chain again. Delay in data transmission thorough long link chain decrease performance of PEGASIS.

3. Multi-Chain PEGASIS: Multi-Chain Power Efficient Gathering in Sensor Information System

In Multi-chain PEGASIS multiple chain are formed in 4 regions in the similar way as in PEGASIS. In this mobile Base Station is employed. It uses token passing approach in data transmission. Chain formation Procedure: Base Station find out the far node by comparing the distances of all nodes from itself in first region. Base Station send the hello packet to all nodes in order to get the information regarding all nodes [9]. The chain construction is started from end node which is far away from the Base Station. End node find the closest neighboring node and make the chain between End node and closest neighboring node. Similarly each node find the distance between itself and the nearest node not connected in chain and connect it with the same method which mention above. The same procedure of chain formation is apply in all four region [10].

Data Transmission:-First Chain leader transmit token to End node then End node after sending its data pass token to next node. In the same way all nodes after sending its data pass data to next node and at last data is transmitted to leader node which transmit all the data to base station. Each node receives the data of its child node and compress it using DCT. Each node combine its data with received one by compressive sampling and send data to parent node. As each node is compressing and sending aggregate data to next node in each and every chain, Energy dissipation evenly distributes among all nodes [9].

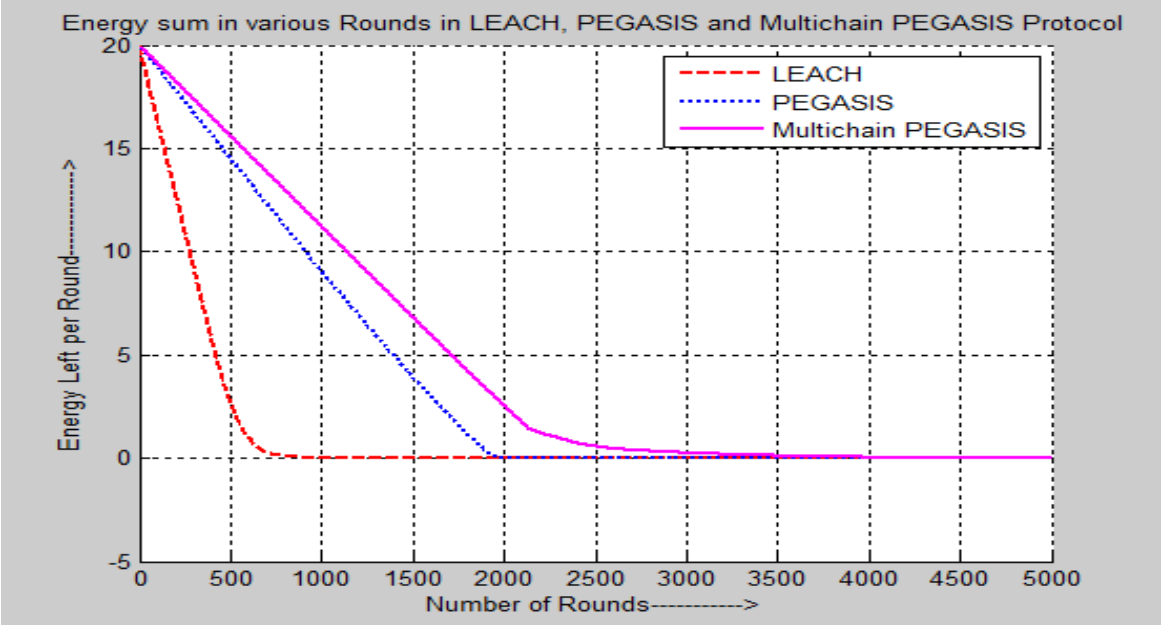
Advantages:- Less overhead and minimum delay in data transmission. Mobile Base Station and short link chains lead to increase in energy efficiency of network and thus increasing network lifetime. As less amount of data is transmitted by each chain so very less Energy dissipates.

IV. COMPARATIVE ANALYSIS OF ROUTING PROTOCOLS

Routing Protocols	***Approach used***	***data transmission***	***Overhead***	***Base Station***	***Delay in Data Transmission***	***Energy Efficiency***
LEACH	Clustering Approach	Cluster formed for data transmission	More overhead	Fixed	Maximum Delay	Less energy efficient Protocol
PEGASIS	Greedy Approach	Single long link chain formed for data transmission	Less overhead	Fixed	Maximum Delay	More energy efficient protocol
Multi-chain PEGASIS	Token Passing Approach	Multiple small link chain formed for data transmission	Very less overhead	Mobile	Minimum Delay	Most energy efficient Protocol

V. SIMULATED RESULTS OF ROUITNG PROTOCOLS BASED ON ENERGY EFFICIENCY

Input Parameters	Values
Number of Nodes	100
Initial Energy of each Node	0.2 Joules
ETx	50*10^(-9) Joules
ERx	50*10(-9) Joules
Free space Energy	10*10^(-12) Joules
Multipath Energy	0.0013*10^(-12) Joules
Data Aggregation Energy	5*10^(-9) Joules



Sum of Energy of Nodes Vs Number of Rounds

Energy of Routing Protocols	15 J	10 J	5J	Energy reaches to zero
LEACH	180 round	280 round	420 round	950 round
PEGASIS	400 round	900 round	1380 round	1990 round
Multi Chain PEGASIS	600 round	1200 round	1700 round	4900 round

All simulations have been done using MATlab. Our simulation results shows that PEGASIS is 100 to 200% more energy efficient than LEACH. Multi-chain PEGASIS has minimum delay in data transmission and 30 to 100% more energy efficient than PEGASIS. As compared to LEACH Multi-chain PEGASIS is 200 to 500% more energy efficient. Multi-chain PEGASIS is most energy efficient.

In LEACH all energy dissipates in 950 rounds while in PEGASIS all energy reaches to zero in 1990 rounds. Energy reaches to Zero in multi chain PEGASIS in 4900 rounds.

VI. CONCLUSION AND FUTURE SCOPE

PEGASIS dissipates 100 to 200 % less energy as compared to LEACH protocol because in PEGASIS gathering and compression of data is done by all nodes in chain due to which energy load is evenly distributed. PEGASIS minimize the overhead , transmit distance between connected nodes . Multi chain PEGASIS has 30 to 100% better energy efficiency than PEGASIS. As compared to LEACH Multi chain PEGASIS is 200 to 500% more energy efficient. Multi chain PEGASIS dissipates least energy & maximize network lifetime with the induction of sink mobility [8]. It also diminishes the delay in data delivery due to short chains and decreases the load on leader node. So most energy efficient protocol is Multi-chain PEGASIS protocol. In future its performance can be made better by periodically changing the chain leader of chain in wireless sensor network. Other future works can involve different routing protocols and different optimizing algorithms.

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