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PEGASIS AND ITS DESCENDANTS: A REVIEW

Gaganpreet Kaur
Lecturer, Department of Computer Science
Thapar Institute of Engineering and Technology, Patiala, Punjab, India

ABSTRACT

In Wireless Sensor Network, one of the most critical issue is power consumption during routing. Various routing protocols have been proposed by the researchers to reduce the consumption of energy of sensor nodes which results in prolonging network life time. Routing protocols are classified into various categories such as Flat based routing protocol, Hierarchical based routing protocol, and location-based protocol. Chain based routing is the category of routing protocols which reduces the power consumption by connecting the nodes of the network in form of chains. PEGASIS is one of the popular chain-based energy efficient hierarchical routing protocol which prolongs the network life time by reducing energy consumption. This paper discusses the various modified versions of PEGASIS and compare them on the basis of different parameters such as criteria used for selecting chain head nodes, no. of chains formed, type of communication among BS and chain head node etc.

Key word: LEACH, PEGASIS, Base Station, WSN, COSEN, CHIRON.

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1. INTRODUCTION

Generally, in most of the applications of networking data throughput and bandwidth are the main factors of concern but in case of WSN these factors are secondary.

WSN is type of network in which sensor nodes are deployed in the target field which is mostly unreachable. Sensor nodes senses the target environment and sends the collected data to the base station periodically. BS is mostly located at far distance from the target environment. Sensor nodes are fitted with irreplaceable battery units so important factor is utilizing the energy efficiently.

At any instant of time sensor node operates in one of the four modes such as transmitting, receiving, ideal or sleeping. In transmitting mode, node consumes maximum amount of energy. In receiving or ideal mode, sensor node consumes little less energy but in sleeping mode it consumes least amount of energy. In order to use energy efficiently no. of transmissions must be reduced which saves significant amount of energy and leads to prolonged network life time. [2, 11, 13, 14]

Lifetime of WSN depends mainly on the routing scheme used. Many routing protocols have been proposed. This paper attempts to review the chain-based routing protocols. This paper starts with detailed description of first and the most popular chain-based protocol PEGASIS then different descendants of PEGASIS are discussed. At last PEGASIS and different PEGASIS's descendants are compared on the basis of some metrics.

2. PEGASIS

Nodes are disseminated in the target area; sensor nodes are of self-organizing nature. They organize themselves in form of a chain and each sensor sends the collected data to its neighboring node. One of the sensor nodes act as header node which sends data to the base station. This algorithm works in two phases: Chain construction and Gathering Data. [1,2]

2.1. Chain Construction Phase

In this phase sensor nodes organize themselves in a form of chain using greedy algorithm. The chain formation starts from the node which is at maximum distance from the base station and each node adjust its signal strength so that only one node can receive the messages send by it. Chain is reconstructed when any node dies.

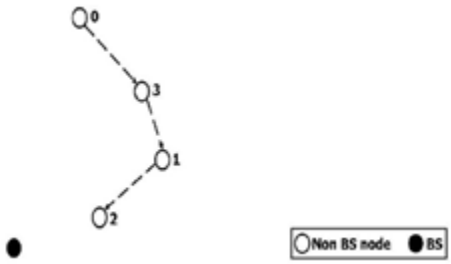

Figure 1 Chain Construction

2.2. Data gathering Phase

In this phase all the nodes send their sensed data to their neighbor nodes, nodes aggregate their own data with the data received from neighbor node and transmit it along the chain. At any time only one node out of all sensor nodes act as header node and this node takes the responsibility of finally transmitting the data to the base station. Sensor nodes take turn to act as header node to balance the amount of energy. [10]

3. DESCENDANTS OF PEGASIS

3.1. COSEN: Chain Oriented Sensor Network

This protocol has two phases. First phase is Chain formation phase. In this phase sensors organize themselves into no. of lower level chains of fixed length, leaders of these chains in turn form one higher level chain. One leader out of these lower level leaders act as higher-level leader. Lower level leaders are chosen on basis of remaining energy. Leaders are chosen after k rounds where k=M/L (or M/L+1), M is no. of nodes and L is length of chain. Higher level leader is chosen by considering the factors like distance of node from BS, remaining energy of the node and whether the node acted as higher-level leader in the last *M/L* (or *M/L+1*) rounds or not. For equal energy distribution chains are formed whenever 20% of initial deployed sensor nodes die. Second phase is data transmission phase in this phase data travel from normal nodes to their chain leaders and from lower level chain leaders to higher level chain leaders which finally send this aggregated data to the base station. [3]

3.2. The Concentric Clustering Scheme for Efficient Energy Consumption in the PEGASIS/Enhanced PEGASIS

This protocol works in four phases. In level assignment phase all the sensor nodes are assigned a level no. by considering factors like no. of sensor nodes and their distance from the base station etc. Nodes of each level construct a chain among themselves. Higher is the level no. more is the distance from the base station. From each level one node is selected as head node. Each head node aggregates the data received from the nodes of its own level and immediate upper level head node and finally lowest level head node transmits the data to the Base station. [4]

3.3. An Energy Efficient Chain-Based Clustering Routing Protocol

This protocol works in two phases: cluster and chain setup phase and data transmission phase. In cluster and chain set up phase sensor nodes arrange themselves in form of clusters and then nodes of each cluster organize themselves in form of a chain. Each cluster has a cluster-head node. In data transmission phase, all non-cluster head nodes send their data to their respective cluster heads and cluster heads send the aggregated data to the base station. [5]

3.4. CHIRON Protocol

The working of CHIRON protocol is divided into four phases. In first Group Construction Phase nodes are arranged in different groups based on their distance from BS and their angle with the base station. In Chain Formation Phase, the nodes within same group form chain. In Leader Node Election Phase in starting the farthest node is selected as chain leader and afterwards the node having highest residual energy is selected as chain leader and in data Collection and transmission phase nodes pass their sensed data to their respective chain header node through neighboring nodes along the chain. Chain Header nodes send their aggregated data to BS in multihop manner. [6]

3.5. Improved CHIRON

To further reduce the propagation delay and redundant transmission path one more restriction is applied that data is transmitted only cluster head to cluster head and chain leader which are at present at same angle will transmit data in sequential form along the straight path this reduces the sensing time and power dissipation. [6]

3.6. Chain-Cluster based Mixed routing (CCM)

In this protocol nodes organize themselves in two-dimensional array. The nodes of each horizontal row construct a chain among themselves and choose one node as chain leader. Then these chain leaders are organized in the form of cluster. During the data transmission phase, the nodes of each chain send their data to their respective chain leader along the chain and these chain leaders organize themselves in form of cluster. The chain leader having maximum residual energy becomes cluster head. All chain leaders transmit their aggregated data to the cluster head which in turn transmit data to the base station using the same mechanism as LEACH protocol. [7]

3.7. An Energy-Efficient Chain-Based Routing Protocol (EECB)

Nodes make a chain among themselves using greedy algorithm. Chain is constructed in the way that nodes on the chain are not revisited and long links among the nodes are avoided by using concept of threshold distance. Chain constructed in this way can have more than two ends. In this protocol chain heads are selected by considering the remaining energy of nodes

and distance of nodes from the base station. Data transmission is performed in the same way as in PEGASIS i.e. by using token. [8]

3.8. EAPHRN: Energy-Aware PEGASIS-Based Hierarchical Routing Protocol for Wireless Sensor Networks

In this protocol chain is constructed in such a way that the long links between nodes can be avoided. For the formation of chain all the nodes compute distance threshold (DTH). Before computing value of DTH each node computes LDTH (Local distance Threshold) which is average of distances between the node and closest k nodes to it where n is constant which depends on the total no. of nodes in the network. The formula used for calculating value of LDTH is given as follow:

$$\boldsymbol{LDTH = \frac{\sum_{i=0}^{n} dst(i)}{k}}$$

All the nodes send calculated value of DTH to the base station. Base station computes the value of DTH using the following formula.

$$\boldsymbol{DTH = \sum LDTH/n}$$

where n is the no. of nodes in the network. Once the value of DT is available with all the nodes, chain formation starts with the farthest node. This node considers all the nodes lying within range of DT distance and connect to any random node. This process continues with the next connected node finally a chain is constructed. For election of chain leader each node calculates the amount of power consumed if it acts as chain leader, then node which results in minimum ratio of power consumption act as chain leader. All the nodes send their data to the chain leader along the chain which finally transmit it to the base station. [9]

3.9. An Energy Efficient Cluster-Chain based Protocol (ECCP)[2012]

In this protocol sensor nodes organize themselves firstly in form of clusters. For making clusters, each node broadcast its residual energy and its current location. Each node receives the information and update neighborhood table. Each node calculates its weight using following equation.

$$\boldsymbol{W_i = ResE_i * \sum_{j=1}^{numberofneighbors} \frac{1}{d^2(v_i, v_j)}}$$

Where

$ResE_i$=residual energy of node i;

$d(v_i, v_j)$ = distance between node i and node j.

The node with maximum weight is chosen as cluster head. Then cluster head broadcast this information using advertisement message the nearby sensor join this cluster head and form cluster. Proceeding in this way the whole network is divided into clusters. According to this protocol clustering is not performed in each round. When any of the sensor node dies, respective cluster head inform the base station and then clusters are reformed in the starting of next round.

Once clusters are formed, nodes of each cluster arrange themselves in form of chain and cluster heads act as chain leaders for these chains. Cluster heads also form a chain among themselves. Cluster head having minimum distance to base station become chain leader. During data transmission the sensor nodes send their data to their respective cluster heads using chain-

based routing and cluster heads send aggregated data to their leader (cluster head acting as leader of cluster heads chain) and finally that chain leader sends the aggregated data to the base station. [16]

3.10. An Energy-Efficient Chain-Based Routing Protocol (EECRP)

In this protocol the whole network is divided into strips ifthe length of the network is l and height of each strip is h. The network consists of n strips where

$$n = l/h$$

One node from each horizontal chain act as chain head. Chain heads are selected by considering theresidual energy of nodes and their distance from upper level head. Base station computes the chain head selection value for each node of every strip by taking ratio of the residual energy of each node and their respective distance to upper level chain head.

$$X = \frac{residual\ energy}{distancetoupperhead^2}$$

The node with highest value of X is selected as the chain head for that strip. Nodes of each strip make a chain among themselves called horizontal chain. These selected chain heads construct a chain among themselves called vertical chain. Chain head of first strip nearer to base station act as the leader of vertical chain. During data transmission phase sensor nodes of each horizontal strip send their data to their respective heads and then these heads transmit the aggregated along the vertical chain finally chain leader of vertical chain sends this data to the base station. [12]

3.11. P-LEACH: Energy Efficient Routing Protocol for Wireless Sensor Networks

Energy Efficient Routing Protocol for Wireless Sensor Networks: This protocol overcomes the drawbacks of LEACH and PEGASIS by combining best features of both in one protocol. In this protocol dynamic clusters are using the approach used in LEACH protocol. Then all nodes send their location information, energy level to the base station. In each cluster, node with maximum energy is selected as cluster head for that cluster. All the cluster heads form a chain among themselves. The cluster head nearest to base station act as leader of the chain. During data transmission all the cluster nodes send their data to their respective cluster heads. These cluster heads fuse this data and send it to the base station along the chain. [15]

Table 1 Comparative Study of Chain Based Routing Protocols in WSNs

Protocol	Criteria for selection of Chain Leader	Frequency of selection of Chain leader	No. of chains	Transmission from chain head node to BS (Singlehop/Multihop)	Drawbacks of PEGASIS overcomed	Advantages of Protocol
PEGASIS [2002]	Turn wise each node of chain act as chain leader	Every Round	One	Singlehop	N.A.	N.A.
COSEN [2006]	Remaining Energy in each sensor nodes	After k rounds k=M/L Where M=no. of sensor nodes And L= Length of the chain	k lower chains and one higher level chain. k=M/L Where M=no. of sensor nodes And L= Length of the chain	Multihop	One chain header node leads to energy imbalance and becomes bottle neck. Delayed transmission	Multiple chains with their chain leaders reduces energy imbalance among sensor nodes. Speed up the transmission rate

Protocol	Criteria for selection of Chain Leader	Frequency of selection of Chain leader	No. of chains	Transmission from chain head node to BS (Singlehop/Multihop)	Drawbacks of PEGASIS overcomed	Advantages of Protocol
Enhanced PEGASIS [2007]	Level wise header nodes are elected using same approach as PEGASIS. Head node of lowest level i.e. level nearest to base station act as head node of chain constructed among head nodes of different levels.	Every round	N+1 Where N= no. of concentric clusters i.e. N chains (nodes of each concentric circle form chain among themselves so total N chains if network consist of N concentric circles.) and one chain among heads of each concentric circle chain.	Multihop	One chain header node leads to energy imbalance and becomes bottle neck. Delayed transmission. During selection of chain head location of base station is not considered.	Network divided into concentric cluster and level wise chains are formed among members and chain leaders are selected which also organize themselves in form chain and reduces energy imbalance among sensor nodes. Speed up the transmission rate Chain header node of lowest level i.e. level nearest to base station is selected as leader of chain constructed among head nodes of different levels.
An Energy Efficient Chain-Based Clustering Routing Protocol [2009]	Using threshold value Each node chooses a random number between 0 and 1. Only if number <threshold, node declare itself as cluster head for that round. Each cluster head act as chain header for the chain constructed among nodes of its cluster.	Every round	N Where n is no. of clusters formed	Multihop	One chain header node leads to energy imbalance and becomes bottle neck. Delayed transmission.	Cluster members of each cluster form chain among themselves and cluster heads act as chain leader and take responsibility of transmitting data to the base station which reduces energy imbalance among sensor nodes. Speed up the transmission rate
CHIRON [2009]	In starting the farthest node is selected as chain leader afterwards for each group, node with maximum residual energy act as chain leader for that group. Chain header nearest to base station act as chain leader for the chain of chain headers.	Every round	N+1 Where N = no. of groups.	Multihop	One chain header node leads to energy imbalance and becomes bottle neck. Delayed transmission.	Nodes are divided into no. of groups and nodes of each group form a chain among themselves which reduces energy imbalance among sensor nodes. One node is elected as leader from each chain. These chain leader send data to base station in multihop manner. Speed up the transmission rate
EECB [2010]	F=residual energy of nodedistance to BS Node having highest value of F is selected as chain leader.	Each phase	One chain with multiple ends	singlehop	Long links among nodes During selection of chain header node energy of nodes and their distance from base station is not considered.	• Avoid long links among nodes by making use of threshold distance. • Residual Energy and distance among nodes taken into consideration.
EAPHRN [2011]	R=consumed EnergyresidualEnery Node with minimum value of R is selected as chain leader	Every round	One chain	Single hop	Long Links among nodes All the nodes turnwise act as chain header	• Avoid long links with use of threshold distance • Node which results in minimum energy consumption is elected as chain leader.
Improved CHIRON [2012]	In starting the farthest node is selected as chain leader afterwards for each group, node with maximum residual energy act as chain leader for that group. Chain header nearest to base station act as chain leader	Every round	N+1 Where N = no. of groups.	Multihop	One chain header node leads to energy imbalance and becomes bottle neck. Delayed transmission.	Nodes are divided into no. of groups and nodes of each group form a chain among themselves which reduces energy imbalance among sensor nodes. One node is elected as leader from each chain.

Protocol	Criteria for selection of Chain Leader	Frequency of selection of Chain leader	No. of chains	Transmission from chain head node to BS (Singlehop/Multihop)	Drawbacks of PEGASIS overcomed	Advantages of Protocol
	for the chain of chain headers.					These chain leader send data to base station in multihop manner. Speed up the transmission rate
ECCP [2012]	Cluster head of each cluster act as chain leader for chains consisting of cluster nodes. Cluster head nearest to base station act as chain leader for chain consisting of cluster Heads	In every round	nc+1 Where nc=no. of clusters; If network is divided into nc clusters, nodes of each cluster form chain among themselves leads to nc chains and One chain among the chain heads of each chain.	Multihop	One chain header node leads to energy imbalance and becomes bottle neck. Delayed Transmission.	Cluster head of each cluster act as chain leader for chains consisting of cluster nodes. Cluster head nearest to base station act as chain leader for chain consisting of cluster heads Speed up transmission rate
CCM (Chain-Cluster based Mixed routing) [2012]	Turn wise each node of chain act as chain leader. Chain leader organizes themselves in form of cluster. Chain leader with maximum residual energy act as act as cluster head.	In every phase	N=L/H Where N=no. of chains L= Length of the network H=height of each strip	Multihop	One chain header node leads to energy imbalance and becomes bottle neck. Delayed Transmission. Energy of nodes is not considered during selection of chain header node	Nodes are organized in 2D array form. Nodes belonging to same row construct a chain among them. Chain leaders of all rows construct a cluster among themselves. Node with maximum energy act as cluster head. Speed up the transmission rate
EECRP [2013]	For horizontal chains the node with highest value of X is selected as the chain head. X=residual energydistancetoupperhead2 For vertical chain, the chain header of the strip nearest to base station is selected as chain header.	Every round	n horizonal chains and one vertical chain n=l/h where l= length of network and h= height of each strip	Multihop	One chain header node leads to energy imbalance and becomes bottle neck. Delayed Transmission. Energy of nodes is not considered during selection of chain header node	Nodes are organized in form of horizontal chains. Chain header nodes of these chains construct a vertical chain among themselves. Chain header are selection by taking into consideration residual energy of nodes and their distance from base station. Speed up transmission rate
P-LEACH [2016]	Node with maximum energy is selected as chain leader.	When energy level of CH becomes less than maximum energy level then other node with second maximum is selected as CH which leads to change in chain leader also.	one	Single hope	One chain header node leads to energy imbalance and becomes bottle neck. Delayed Transmission. Energy of nodes is not considered during selection of chain header node	Nodes are organized in form of clusters so they can transmit their data to their respective heads at the same time. Speed up transmission rate. Nodes with maximum energy act as cluster heads. Cluster head nearest to Bs is selected as chain leader.

4. CONCLUSION

PEGASIS is one of the chain-based energy efficient protocol. In this paper various modified versions of PEGASIS protocol have been discussed and compared. It is observed that each version addresses specific problems of PEGASIS protocol and improved the PEGASIS protocol in some manner. These protocols increased life time of the network as compared to PEGASIS. These modified versions are different from each other in the way chains are formed, criteria used for selecting chain head nodes etc. Location awareness, nature of environment, WSN Applications, control message and QoS are still open issues for researchers for developing novel protocol in WSNs.

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