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Performance Evaluation and QoS Analysis of EEPB and PDCH Routing Protocols in Wireless Sensor Networks

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Abstract : *EEPB (Energy-Efficient PEGASIS-Based protocol) is a chain-based protocol. It has certain deficiencies such as it ignores the nodes energy and distance between nodes to BS when selecting the leader. It causes overhead, maximize the overall network delay and consumes more energy because of more number of transmission and receives among all nodes. Aiming at these problems, PDCH (PEGASIS with Double Cluster Head) is proposed in this paper. PDCH uses a double cluster head instead of single cluster head to distribute energy load among all nodes to increase the network lifetime. Also PDCH uses a dynamic cluster formation to eliminate overhead and reduce the distance of transmission by choosing appropriate node based on residual energy and neighbor nodes. The simulation results show that PDCH has a better performance than EEPB on the efficiency of energy consumption, minimizing network overhead, increasing the network lifetime and balancing load of the network.*

Keywords: *Double Cluster Head, EEPB, Hierarchical Routing, PDCH, PEGASIS, Wireless Sensor Network*

I. Introduction

Wireless Sensor Networks (WSNs) [1] have been identified as one of the most important technologies of recent years. WSN consists a large number of dispersed and dedicated sensors in order to sense the physical conditions of the environment like sound, temperature, humidity, pollution levels and pressure and so on. WSN has empowered the advancement of low cost, low power, multi-functional smart sensor nodes. On the other hand the nodes have limited amount of communication capacity and computing power. So how to optimize the transmission distance and route, load balance, network lifetime and energy efficiency has become an important issue of routing protocols.

Routing protocols in WSNs are broadly classified as, Hierarchical routing protocols (HRP) [2], Quality of service based routing protocols, Location Based routing protocols and Flat based routing protocols. HRPs are broadly used for their great energy efficiency and good expandability. Hierarchical routing is an efficient method to less energy consumption within a cluster and by performing data collection and fusion in order to limit the number of transmitting messages to the BS. LEACH [3] and PEGASIS [4] are the hierarchical based routing protocols. PEGASIS is a chain based routing protocol, which is an enhancement of LEACH protocol. It saves a huge amount of energy compared with the LEACH by upgrading the delivery method of information. However, the PEGASIS also has so many issues requiring solutions.

II. The Current Situation Of WSN

For efficient use of power, researchers have proposed many routing algorithms. Among them, PEGASIS is a typical chain based algorithm. Many other algorithms based on PEGASIS are EEPB [5], IEEPB [6], PEG-Ant [7] and MH-PEGASIS [8] et al.

2.1. PEGASIS Algorithm

The concept of PEGASIS is for each node to receive from previous neighbor and transmit to next closest neighbor on the chain. And alternately leader in each round takes turns transmitting to the BS in the chain. This balances the energy among an overall network. The nodes randomly placed in the network area and form a chain using a greedy algorithm. On the other hand, base station (BS) forms this chain and broadcasts it to all the nodes in the network. Main advantage in PEGASIS is single node manages the data gathering and data fusion and also leader will receive maximum two messages from the neighbors. On other hand probability of long link chain is very high and increase the time delay using greedy approach.

For chain formation, we assume that all sensor nodes are aware of the network and the greedy methodology. In this process, the chain formation done before the first round of communication. To form the chain, we begin with the furthest node from the BS in order to make sure that sensor nodes far away from the BS have near neighbor nodes. Distances of neighbors will increase moderately in greedy approach since nodes already in the chain cannot be revisited.

PEGASIS uses a greedy algorithm to construct a chain. When a node in chain looks for a downstream node, a node chooses the closest node to itself as downstream node. In local area, the greedy algorithm can guarantee the distance of a pair of nodes is shortest. Therefore, sensors can consume least energy in this condition. But in the opinion of a global network, the greedy algorithm will result in a dangerous mechanism "long chain". "Long chain", also known as Long Link (LL) means the distance between a pair of nodes is much longer than other pairs. The occurrence of "LL" is not due to some nodes far away from the main body of the network. An upstream node uses a greedy algorithm to find nearest node in all disjointed nodes as its downstream node. But in some phase, an upstream node cannot find the nearest node in its neighbors. In this case it has to choose a node from far away nodes as its downstream node. Therefore, "LL" is inevitable.

III. EEPB Algorithm

A new algorithm EEPB introduced a new method to avoid long chain between the nodes. It is an enhancement of PEGASIS algorithm. That says the distance between sensor nodes is the first aspect. It first calculates the distance between each node from the formed chain. After that "thresh" is calculated from the average distance of the formed chain. The distance from the closest node to its upstream node is longer than the distance "thresh", the closest node is the "far node". If the closest node combines the chain, it will result in the emergence of LL. In this scenario the "far node" will search a nearer node on formed chain. Through this approach LL is evaded efficiently. This not only balances the energy consumption of nodes, but also conserves energy on sensors. EEPB overcomes several problems over PEGASIS but still has deficiencies as follows.

- While EEPB choose the leader node, it ignores the node energy and distance between the nodes to BS, which improves the leader selection depending on different environment conditions.
- EEPB minimizes the LL between the neighbor nodes in chain by applying the distance threshold "α" which is predefined by the user. This threshold makes a different impact on the chain formation. If the "α" is too small, it is possible that the link distance between the nodes will be greater than the "α", hence LL creation is unavoidable. If the "α" is too large, then it won't be able to judge and restrain the link distance and LL will be formed. And finally in extreme case, if "α" is infinite the chain formation of EEPB will be same as PEGASIS. This analysis concludes that determining the value of "α" is very complex. Also EEPB considers remaining energy of the node and its distance from the BS to select the leader. This method is inappropriate for balancing the energy consumption according to different application requirements.

In EEPB, there are mainly 3 phases: (i) Node selection phase, (ii) Chain construction phase, (iii) Data Transmission phase.

3.1. Node Selection Phase

- Initialize 100 nodes, energy and location of all nodes.
- A source node S announce a route request message to obtain the distance of each node from source node S. For nodes s0, s1, s2….. s99. Compare d (s0), d (s1), d (s2)…. D (s99) from a source node (S). Where, d (s) is the distance of a neighbor from the Source node.
- At the source node S, the neighbor with shortest path is selected for transmitting the data.
- The selected neighbors will act source for other nodes which have not joined the chain yet.

3.2. Chain Construction Phase

- Let us consider that an upstream node wants to search a new node for communication. If the distance from the upstream node to the closest node is longer than the $D_{threshold}$, it will possibly lead to the formation of LL. $D_{threshold}$ is calculated from the average distance of the formed chain.
- Let N be the Number of nodes, such that S_k (k = 1, 2, 3 …N).
- The distance between two nodes is given as (D_{ij}, h) where h is the hop number of the formed chain.
- The distance of every segment in the formed chain is given by D_p, where (p=1, 2, 3 …h).
- $D_{average}$ is the average distance in the formed chain that is calculated by,

$$D_{average} = \sum_{p=1}^{h} \left(\frac{D_p}{h}\right)$$

- $D_{thresold}$ is the threshold distance that is calculated by,

$$D_{thresold} = \alpha * D_{average}$$

- Where α is a user defined constant.
- Let us assume that node S_m chooses node S_n as its downstream node. S_m intimates S_n to join the chain and to look for other nodes to participate in the chain.
- When S_n receives the data packet from S_m it starts computing $D_{average}$.

- On the basis of $D_{average}$, it will calculate $D_{thresold}$.
- S_n will then send the chaining request to all the other nodes that haven't yet joined the chain.
- S_n then select a node whose $D_{i,j}$ will be minimum.
- Let us assume that S_t is that node. Hence min ($d_{i,j}$) = $d_{n,t}$. Then compare $d_{n,t}$ with $D_{thresold}$.
- If $d_{n,t} < D_{thresold}$, it is clear that S_n is not far away from S_l. Hence, when S_t joins the chain, it will not lead to formation of LL. Thus S_n will choose S_t as the downstream node and ask S_t to continue the chain formation.
- If $d_{n,t} > D_{thresold}$, it indicates that S_n is far away from S_t. In this case if S_t joins the chain it will lead to the formation of LL.
- S_t will consume more energy for data transmission, therefore it will look for any other node who is nearer to S_n than itself. If it finds such node than S_n will be the end node on that data chain and S_t will join the chain through the nearer node and finish the chain formation process. But if S_t fails to find such node than LL is unavoidable. Thus S_t will join the data chain directly through S_n and terminate the chain process.

3.3. Data Transmission Phase

- Once the chain is done, the end node starts the transmission of data.
- Each node collects the data from the downstream node with its own data and then sent to the upstream node.
- Every node in the chain repeats the procedure until all nodes are traversed. At last the leader node sends the data to BS.

IV. PDCH Algorithm

Based on the above analysis, this paper presents a new PEGASIS based routing protocol called PDCH. PDCH uses double cluster head instead of single cluster head to distribute energy load among all nodes to increase the network lifetime. Also PDCH uses a dynamic cluster formation to eliminate overhead and reduce the distance of transmission by choosing appropriate node based on residual energy and neighbor nodes. PDCH is an improved routing algorithm over EEPB. In PDCH, there are mainly 4 phases: (i) Cluster Formation phase, (ii) Chain construction phase within a cluster, (iii) Cluster Heads Selection phase, (iv) Data Transmission phase.

4.1. Cluster Formation Phase

- In PDCH [10], network is created using random node deployment and BS is plotted at the given location. After that the distance from BS to all other nodes in the network is found using the Euclidean distance formula.

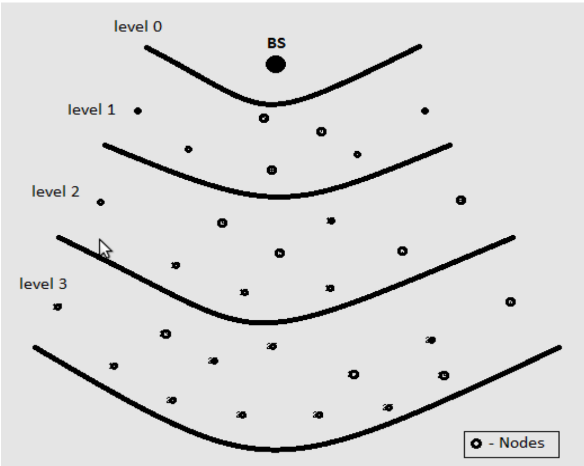

Fig. 1. Level formation

$$d_i=\sqrt{(x_{bs}-x_i)^2+(y_{bs}-y_i)^2}$$

Where,
d_i is the ith node distance from BS
x_{bs} & y_{bs} are the coordinates of the BS
x_i & y_i are the coordinates of the ith node

- Now distance of every node to the BS is decided the level which node belongs to.
- Every level has a unique ID. The first level 0 belongs to BS. The second level is 1, in which nodes are closest to BS and so forth. For example, the nodes which are less than or equal to 250 meters comes under

first cluster (level id = 1). 250 meters to 350 meters come under second cluster (level id = 2), 350 meters to 450 meters come under third cluster (level id=3) and 450 meters to 600 meters come under fourth cluster (level id=4).

- Note that the cluster level formation always runs at the start, and once it is done, it will not be changed in the whole process. So this can save energy compared to frequently level forms in every round. Figure 1 shows the level formation in PDCH.

4.2. Chain Construction Phase

- After cluster formation, we use the EEPB algorithm for chain construction in every cluster level.
- Nodes with same level id can only involve in same chain.
- Nodes with different level id cannot involve in one chain.

4.3. Cluster Head Selection Phase

In PDCH, we use the double cluster head method. One is the main cluster head (MCH) and another is the secondary cluster head (SCH).

4.3.1. Selection of MCH

- Initially set up a parameter 'n' on every node N(i), where i indicates number of nodes. If node N(i) haven't join in the chains, then n=0, when node N(i) was selected by N(i-1) to join the chain, we set n=(n+1), every time when a new node join in a chain, the parameter 'n' of select node automatic increment by 1. When chain construction is complete, we will analyze the parameter n, if n>2, we consider that N(i) has branch chain.
- Node having a branch chain has a bigger chance to be selected as CH than other nodes in every chain.
- Node having the highest neighbor to be selected as MCH.
- If more than one node have the same number of neighbors, than from them, node with high energy to be selected as MCH. Figure 2 shows chain formation and branch chain concept.

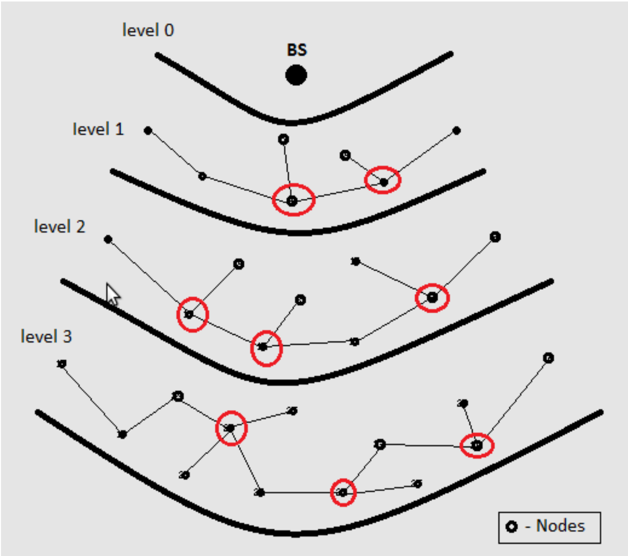

Fig. 2. Chain formation

The marked nodes show that the number of neighbors is more than 2. These nodes have one or more than one branch chain, so they have greater opportunity to be selected as MCH in every level.

4.3.2. Selection of SCH

- If only MCH is responsible for gathering local level data and transmitting this data to upper level, then it becomes a burden for main node. So we choose SCH in every level.
- If MCH has exactly 3 neighbors, then there is only single branch chain, we will select a node belong to the branch chain as the SCH.
- If the neighbor of MCH more than 3, then there is more than one branch chain exist with main CH. In this situation, we will select the node belong to the branch chain which is more closer to the BS or minimum distance from BS as the secondary CH. Figure 3 shows the double cluster head method.

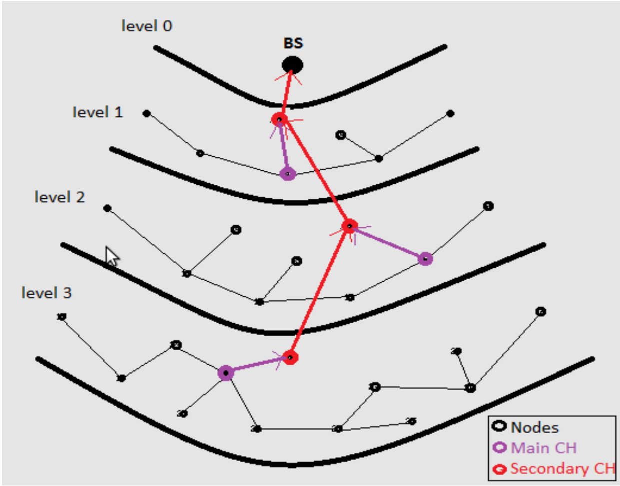

Fig. 3. Double cluster head method

4.4. Data Transmission Phase

4.4.1. Function of MCH

- The main function of MCH is to collect the local level data from all the nodes in the cluster and aggregate this data.
- After that, MCH transmits these aggregated data to the SCH in the same level. In figure 3, purple line shows the transmission from MCH to SCH.

4.4.2. Function of SCH

- The function of SCH is to receive gathered data from MCH and transmitting this data to BS.
- For sending the data to BS, we should chain up all the SCHs, and transmit it to BS through this chain. In figure 3, red line shows the chain of secondary CHs.

V. Simulation And Result Analysis

Simulation is performed to evaluate and compare the performance of EEPB and PDCH protocols. The network model is described in section 5.1. The performance metrics and results are used to compare their effectiveness are given in section 5.2.

5.1. Network Model

In this paper, WSN has the following properties:

- 1000m × 1000m network area in which 100 nodes scenarios are densely deployed.
- The sensor nodes are static. Once sensor nodes have been deployed, they work in the environment without movement.
- The sensor nodes are homogeneous in that they have equal capabilities (initial energy, data processing, wireless communication).
- Sensor nodes have sensing range up to the 250 meters.

Table 1 shows the value assigned to different network parameters.

Table 1. Network Model

Parameters	**Value**
Network Area	1000×1000 m^2
Sensor Nodes	100
Node Sensing Range	250 meter
Data Rate	512 kbps
Initial Energy	100 J
Transmission Power	0.9 J
Receiving Power	0.8 J
Sensing Power	0.0175 J

5.2. Simulation Results

This paper uses NS2 as a simulator to evaluate the performance of PDCH comparing with EEPB. The simulation focuses on delay, energy consumption, dead nodes, network overhead, packet loss ratio and throughput which are important indicators to measure end to end performance of different routing algorithms.

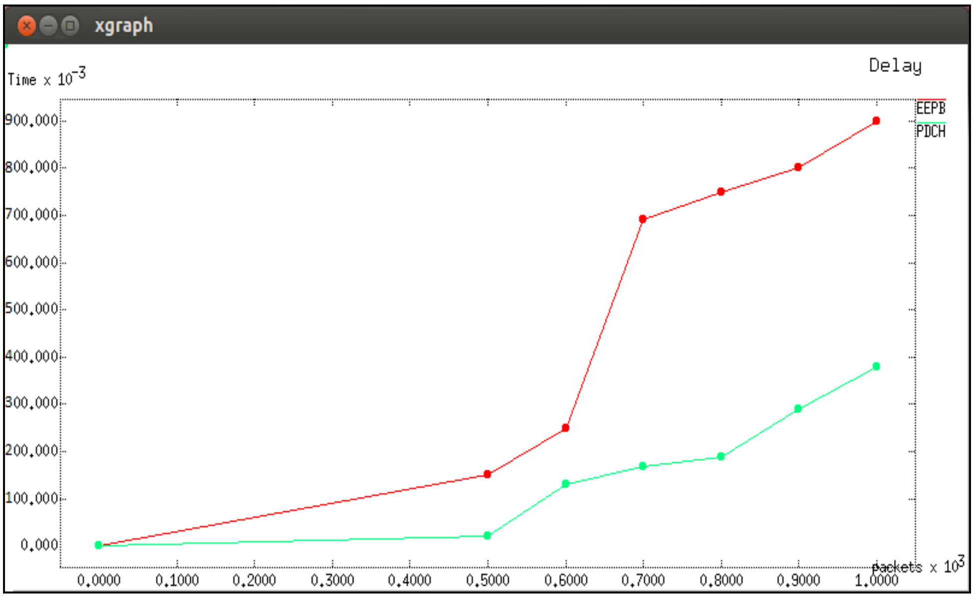

Fig. 4. Delay

Figure 4 shows the delay of EEPB and PDCH protocols in terms of completion of one round of communication. The graph indicates PDCH has 57.77 % less delay compare to EEPB.

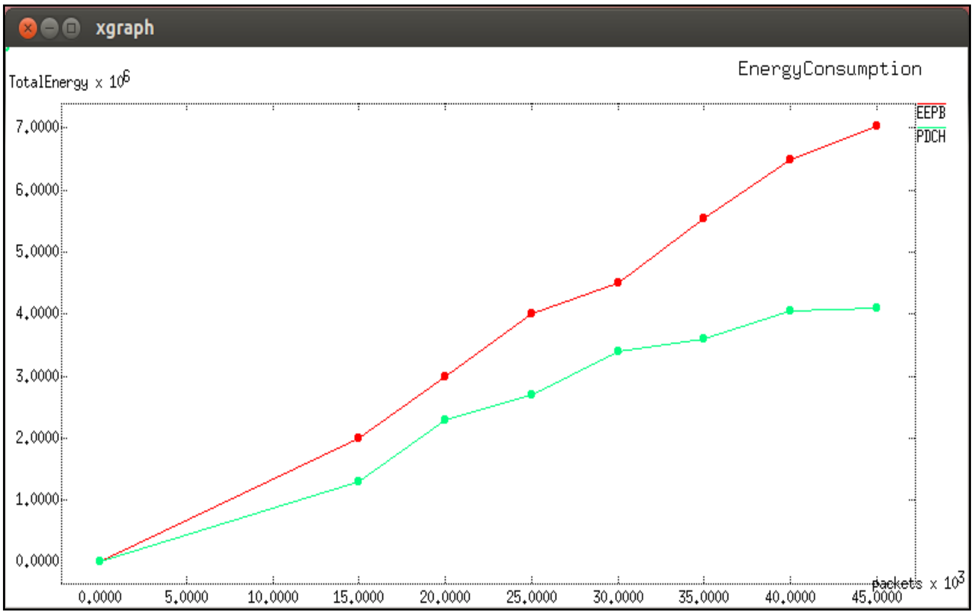

Fig. 5. Energy consumption

Figure 5 indicates energy consumption ratio of both the protocols. For the maximum number of packets transferred, PDCH consumes 41.42 % less energy than EEPB. It shows that PDCH has better lifetime compare to EEPB.

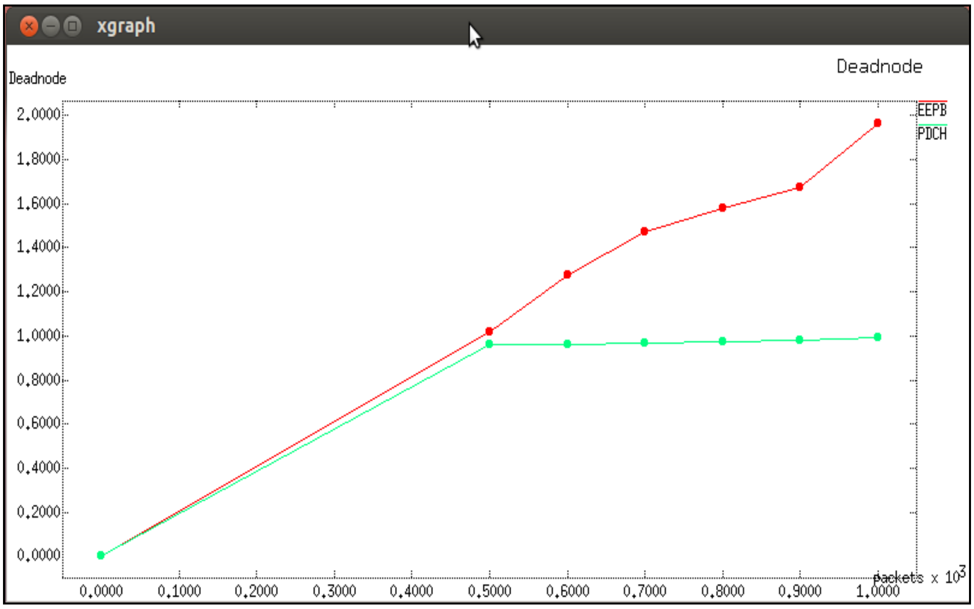

Fig. 6. Dead nodes

In figure 6 the dead node of both protocols is shown. It is clearly seen that percentage of nodes dead in EEPB is very high than PDCH. As per simulation result PDCH has 50 % less dead nodes than EEPB.

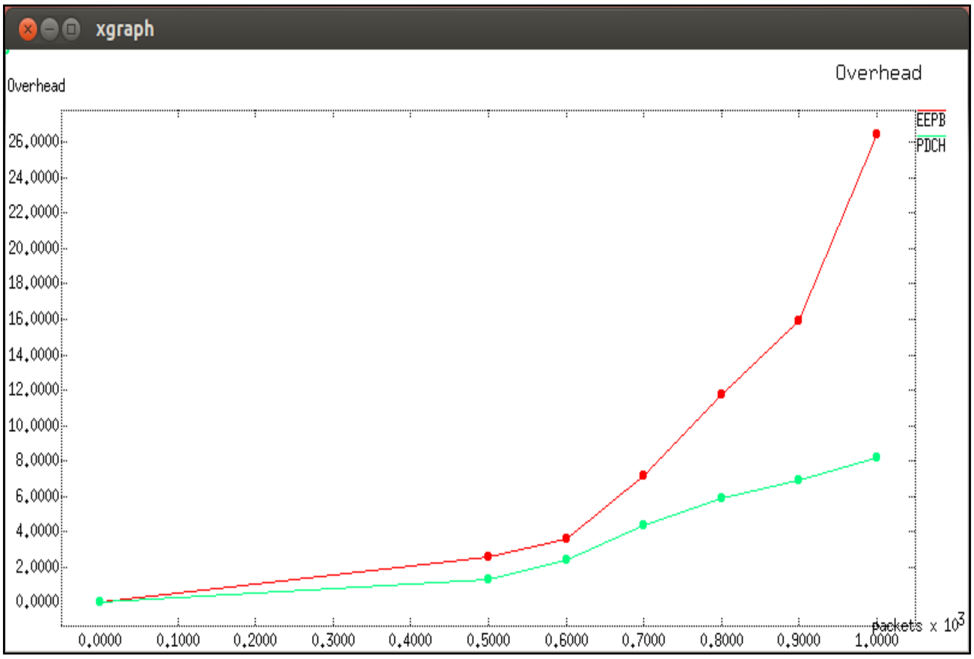

Fig. 7. Network overhead

Figure 7 shows the overall network overhead of both protocols. Overhead in terms of extra data to route packets at the destination. The graph clearly indicates that PDCH has 69.12 % less overhead compare to EEPB.

Figure 8 shows throughput of both protocols. It shows that throughput of PDCH protocol is better than EEPB protocol. Throughput is measured in terms of the number of data packets received with respect to time. The graph shows that PDCH has 16.66 % higher throughput than EEPB protocol.

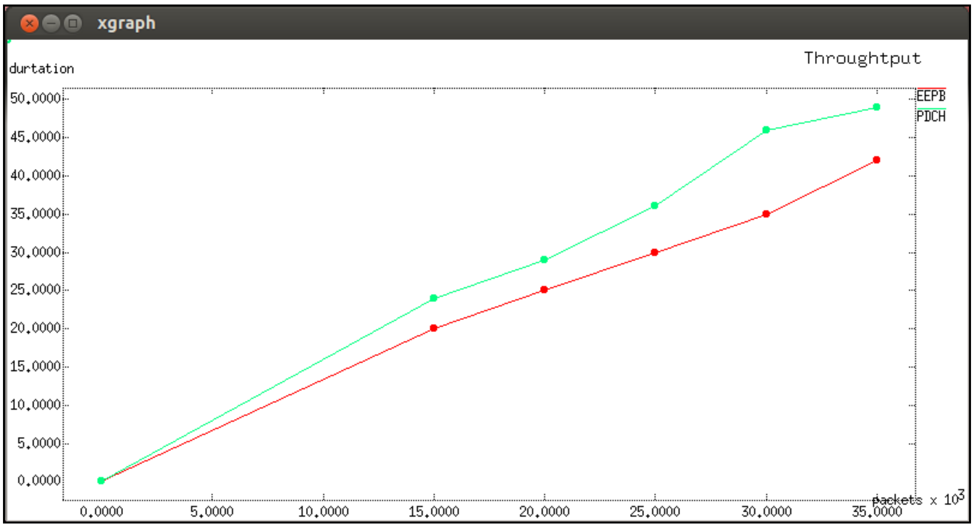

Fig. 8. Throughput

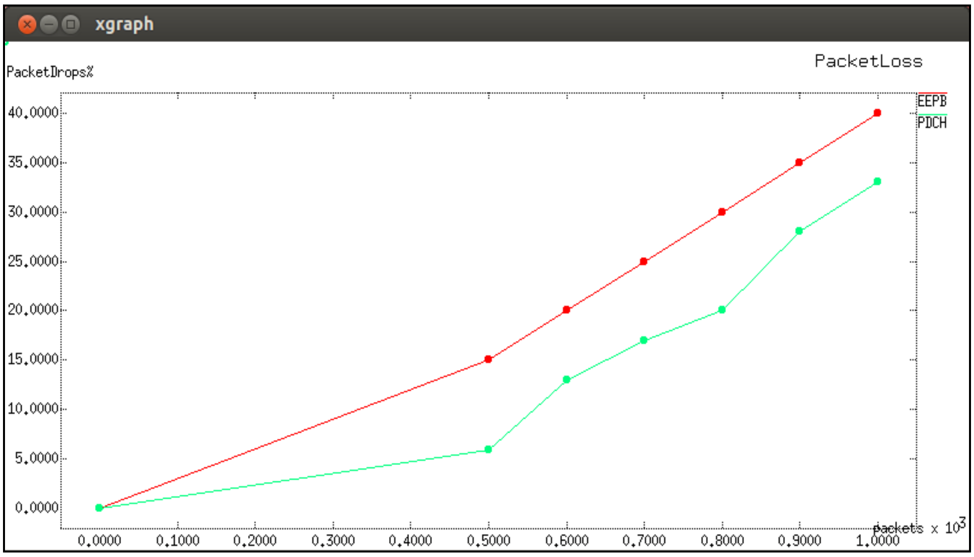

Fig. 9. Packet loss ratio

Figure 9 shows the packet loss ratio of EEPB and PDCH protocols. The graph shows PDCH drops less packets than EEPB protocol. As per result PDCH has 17.5 % less packet loss ratio than EEPB protocol.

VI. Conclusion and Future Work

This paper proposes the methodology of PDCH protocol in order to improve the deficiencies of EEPB protocol. The novel protocol adopts a new distance based cluster selection method as well as double cluster head method in every cluster to balance the overall network load. This technique improves the performance of the overall network. Comparison between PDCH and EEPB protocol is performed and QoS is improvised. Simulation results show that PDCH outperforms EEPB by 57.77 %, 41.42 %, 50 %, 69.12 %, 16.66 % and 17.50 % in terms of delay, energy consumption, dead nodes, network overhead, throughput and packet loss ratio respectively. Thus, it is concluded that PDCH has the better end to end performance than EEPB protocol. In future, PDCH protocol can be compared with other PEGASIS based protocols and QoS can be analyzed.

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