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A Hybrid Optimized Protocol in WSN to Improve Network Lifetime

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Abstract— *Wireless Sensor Networks (WSNs) is an invented automation which is used in recent years to perform multiple tasks in various domains intelligently. In order to increase its efficiency various probabilistic models and approaches have been introduced in the preceding years. In WSNs, large numbers of Immobile Sensor nodes (SNs) which may be homogeneous or heterogeneous are deployed in a gigantic network area. These SNs have mainly three components i.e. processor, sensor and wireless communication device. SNs use its power throughout for collecting, combining, monitoring and transmitting data and they have restriction in terms of transmission power and battery life. Knowing this, many protocols have been developed based on probabilistic approach to overcome this issue. In this paper, we propose a new hybrid optimized protocol to reduce the energy consumption of SNs and increase the lifetime of WSNs. Then the proposed protocol is implemented and compared with the existing routing protocols in MATLAB and found that it outperforms better in terms of stability, network lifetime and gives better solution for energy efficiency as compared to other existing routing protocols in hierarchical heterogeneous WSNs.*

Keywords— Wireless Sensor Networks (WSNs), Sensor Nodes (SNs), Cluster Member (CM), Cluster based routing, Multipath routing, Energy Efficiency, Network Lifetime, Simulated Annealing(SA), Ant Colony Optimization (ACO), PEGASIS

I. INTRODUCTION

In WSNs with the advancement of Micro-Electro-Mechanical-Systems (MEMS), multi-functional SNs are deployed unattended in a large hostile area which have the capacity of sensing, processing and transmission the collected data to the Base Station (BS) [1]. But these SNs have limited supply of power, computational and transmission capability and also it is impossible to replace the batteries of these SNs. The basic Architecture of SNs is as shown in Figure 1 below [2].

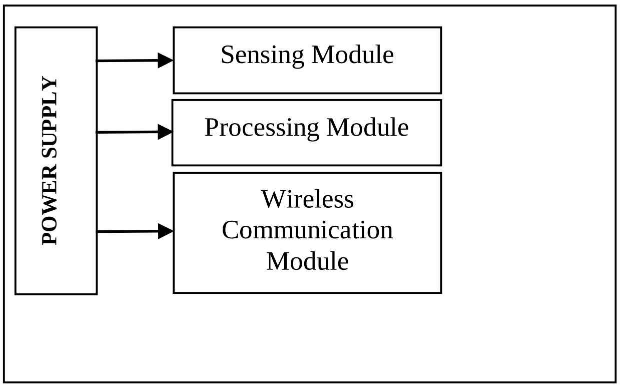

Fig.1. Architecture of SNs

So, energy of SNs used for wireless data transmission has the crucial impact on WSNs. In addition to that WSNs also faces many more challenges [1] like scalability, reliability, cost, mobility, energy efficiency, link failures, power consumption etc. Due to this, WSNs prohibit the deployment of SNs in large network area.

Routing is one of the energy efficient techniques that are used in WSNs to overcome this burden of energy communication of SNs [3]. In routing, Cluster based routing techniques are widely used to provide better data aggregation and scalability in the network due to their energy efficiency and load balancing nature [4]. In this, SNs are grouped together to form a clusters and from that group a node is selected as Cluster head (CH) according to some defined Probability equation. Then all joined SNs transmit their data to CH in their respective clusters. After that all CHs aggregates the collected data and transmit it to BS from some reliable path. In this transmission of data to BS, we can consider two types of communication i.e. Single-hop communication if distance of CH to BS is small or it can be Multi-hop communication if the distance is increases, to overcome energy consumption of SNs [3]. Then the BS collects all those data and forwards it to the user via Internet.

Also in WSNs, two types of approaches are used i.e. Probabilistic Approach and Deterministic Approach. In first approach, CH is selected randomly which results in early energy dissipation of SNs like in LEACH [5], SEP [6]. But in later approach, a fixed CH selection concept is used which depends upon the remaining energy of each SN in order to consume energy efficiently like in DEC [7]. The major drawback of DEC routing protocol is that if BS is located far away from CH then in that case they are transmitting data directly to the BS which results in more energy dissipation of CH.

Further, due to limitation in resources and unreliable low power links between SNs, it is difficult to design an energy efficient routing algorithm [8]. Also, SNs requires an appropriate energy efficient and reliable path for transmission of data, so that retransmission of data cannot take place because it results in more congestion and energy consumption of SNs. That's why; the main concern of WSNs is the energy consumption of SNs and network lifetime.

WSNs are used in various applications like military surveillance, pollution monitoring in air, water and land, health care etc [3, 9]. The advantages of WSNs include low cost, flexibility and centralized monitoring etc.

1.2 ROUTING PROTOCOLS IN WSN: Many routing protocols have been proposed for WSNs. These have been classified into three categories, namely:

- Data-centric protocols

- Hierarchical protocols

- Location-based protocols

Data-centric protocols are query-based and use the concept of naming of desired data to eliminate many redundant transmissions. Hierarchical protocols cluster the nodes so that cluster heads can aggregate and reduce the data to save energy. Location-based protocols use position information to send the data to only the desired regions rather than to the whole network. The more important ones among these are SPIN, LEACH, PEGASIS, TEEN and APTEEN.

Rest of the paper is divided into following sections: Related work is described in Section 2. The Proposed algorithm, its basic assumptions, data aggregation and energy dissipation model is defined in section 3. Section 4 gives the simulation setting and results. Lastly, Section 5 concludes the whole paper.

II. RELATED WORK

In WSNs, many researchers have not only discussed the issues and challenges faced by them but also provide innovative ideas of low energy architectures to overcome them. Like, Routing may be defined as a process of determining a suitable path from source to the destination for transferring of data or information. For this purpose, various routing protocols are introduced in WSNs to enhance the lifetime of the network and for transferring correct data to the BS [5]. Clustering is of the technique which is used to reduce the energy consumption, collision, interference and redundancy of the network while improving the scalability and lifetime of the network. There are various clustering techniques that are used to manage, emphasize and focus on the requirement of SNs. Clustered Sensor Network can be of single hop communication or multi hop communication.

Single hop communication means that all the collected data at CH should be transferred to BS directly and Multi hop communication means that all the collected data should reach the BS in number of hops. LEACH [6], SEP [7] routing protocols comes under the category of single hop communication while MR-LEACH [10], M-LEACH [11] comes under the multi hop communication category. Also when transmission distance increases then single hop communication protocols consumes lot energy while Multi hop communication consumes less energy.

LEACH (Low Energy Adaptive Clustering Hierarchy) [6] is one of the most common and traditional clustering technique used in homogeneous WSNs, in which the role of CH and SNs inside each cluster are changing periodically for every round to balance the energy consumption perception. This change of role is determined by the predefined percentage in the network. Here, each SN generates a random number between 0 and 1 and if this generated number is less than the predefined threshold value then that SN will be CH for the current round. Then elected CH will broadcast an advertisement message to rest of all SNs in the network that they are the CH for current round. And, all SNs send their collected information directly to the CH which is associated with them. But if SNs are far away from CH and they does not come under the range of CH then it results in the loss of SN energy. Also it uses single hop communication due to which it cannot be used for large area network which results in large overhead and long latency.

SEP (Stable Election Protocol) [7] is an advancement of LEACH protocol and is used to study the impact of energy heterogeneity of SNs in two level heterogeneous hierarchical networks. In SEP, two different types of SNs called Normal SNs and Advance SNs are used and also they have different initial energy level. M numbers of Advanced SNs are used and they have α time more energy as compared to Normal SNs. So Advance SNs have more chances to be CH as compared to Normal SNs. Here, CH is selected on the basis of weighted election probability equation. Due to this, the CH is elected randomly and distributed based on fraction of energy of each SN assuring uniform use of nodes energy. This results in increased overall network lifetime and decreased instability period as compared to LEACH.

Multi-hop Routing with Low Energy Adaptive Clustering Hierarchy (MR-LEACH) [10] is used to prolong the network lifetime by partitioning the whole network into different layers of clusters. CHs of each network layer collaborate with each other to transmit the data to the BS. Here, upper layer CH acts like super CH for lower layers and finally reaches the BS. The transmission of aggregated data from CHs to BS follows multi-hop routing to conserve energy.

Multi-hop LEACH [11] protocol is also a cluster based routing protocol whose working operation is almost similar to that of LEACH. But, here two changes are done and that is Multi-hoping concept is used for both inter cluster communication as well as for intra cluster communication. Inside each cluster, one CH is there and rests are cluster member SNs. All the member SNs send the collected sensed data to their respective CH which aggregates it and send it to the BS through multi-hop manner by forming a tree between CHs and BS which act as a root.

O-LEACH [12], also called as orphan node LEACH is a special kind of routing protocol which is used to cover those SNs where CH is not able to concentrate and those SNs cannot reach to CH for transferring their data. Those special kinds of SNs are called as Orphan SNs. So, O-LEACH routing protocol is used to overcome this issue. O-LEACH uses two kinds of Scenarios to solve this problem. First scenario is that, a cluster member SN which is closer to those Orphan nodes plays the role of gateway and allows the joining of those orphan nodes. So in this way, the gateway node act as CH' for orphan nodes. With this orphan SNs send their data to CH' and which then performs data aggregation and send the aggregated data to main CH. Second scenario says if that area which is not covered contains some important SNs and if cluster member SN are superior to number of orphan SNs, then in that case a Sub-cluster is created to cover those entire orphan SNs. Here, first orphan SN which reaches the cluster member SN will act as a CH'. Then this CH' will aggregates all collected data from Orphan SNs and send the aggregated data to main CH. So, here O-LEACH routing protocol for homogeneous WSNs is evaluated to minimize orphan nodes and increases the network connectivity.

In [13], Stephanie Lindsey and Cauligi S. Raghavendra described PEGASIS, a greedy chain protocol that is near optimal for a data-gathering problem in sensor networks. PEGASIS outperforms LEACH by eliminating the overhead of dynamic cluster formation, minimizing the distance non leader-nodes must transmit, limiting the number of transmissions and receives among all nodes, and using only one transmission to the BS per round. Nodes take turns to transmit the fused data to the BS to balance the energy depletion in the network and preserves robustness of the sensor web as nodes die at random locations. Distributing the energy load among the nodes increases the lifetime and quality of the network. Simulations show 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. PEGASIS shows an even further improvement as the size of the network increases.

Motivated by all these studies, we proposed the PEGASIS protocol with the designed simulated annealing modal for heterogeneous WSNs that provides better network lifetime, energy efficiency and provides more stable region by electing CH on the basis of new Probabilistic equation, creating Sub Cluster for far way SNs and by using the concept of Multi-hop communication when CH is located far away from BS. This results in reduced energy consumption, increased network lifetime and improved stability period.

III. EXISTING ALGORITHMS

PEGASIS is a near optimal chain-based routing protocol that is an improvement over LEACH. The main idea in PEGASIS protocol is for node to receive from and transmit to close neighbors and take turns for being the leader for transmission of data to BS. This approach distributes the energy load evenly among the sensor nodes. The nodes randomly placed in the field, organize themselves in the form of chain using greedy algorithm. [14] Alternatively, BS computes this chain and broadcasts it to all the nodes. For data gathering, each node receives the data from one neighbor, fuses its own data and transmits it to the next node in the chain. In a given round, a simple token passing approach is initiated by the leader to start the data transmission from the ends of the chain. Here the cost is very less because the size of the token is very small. The fig 6: shows node C2 as the leader. It passes the token to C0. C0 sends its data to C1. C1 fuses its own data with C0's data and sends it to leader C2. C2 then transmits the token to C4. C4 sends its data to C3. C3 fuses its data with C4's data and then transmits it to leader C2. C2 waits to receive data from both the neighbors and then it fuses its data to neighbor's data. The leader then transmits only one message to the BS.

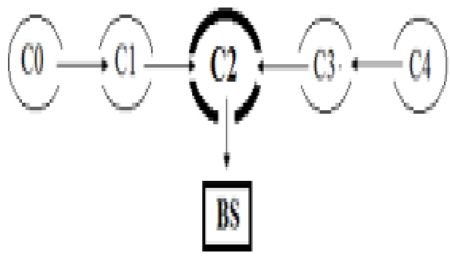

Fig.2: Token Passing

Thus in PEGASIS, each node receives and transmits one packet in each round and be the leader at least once in n rounds (n are no of nodes). PEGASIS improves on LEACH by saving energy at following stages. First, in the local gathering, the distance that most of the nodes transmits is much less as compares to CH in LEACH. Second, the leader receives at most only two messages from the neighbors which is not in the case of LEACH (in the network of 100 nodes, it receives 20 messages if there are 20 nodes per cluster). Finally, one node transmits the message to the BS in each round of communication.

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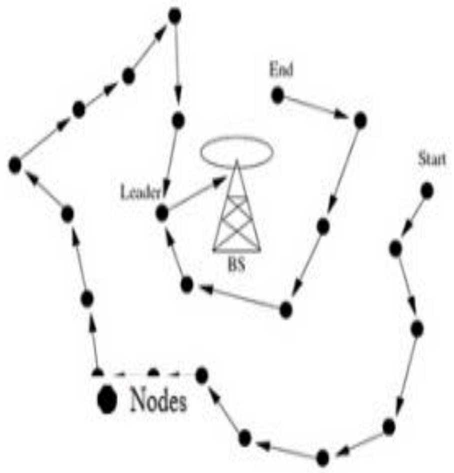

Fig 3: Illustration of PEGASIS Protocol

PEGASIS protocol has its major applications in environment monitoring. The nodes sense various environmental factors such as temperature, humidity, pressure, etc. Each node fuses its sensed data with the adjacent node. The CH finally has all the sensed data, which it then sends to the BS.PEGASIS protocol has its main application in characterizing and monitoring the quality of environment [15].

3.1Optimization Algorithm: There are various Optimization algorithms to get the optimal results. In this work, we are working on ACO as it provide better results than other algorithms.

Ant Colony Optimization (ACO): ACO is a probabilistic method for evaluating optimal paths in thoroughly connected graphs by a guided search, by making utilization of pheromone data. This process can be utilized to resolve any computational issue that can be diminished to evaluating right paths on a weighted graph. In an ACO algorithm, ants transfer by way of a search space, graph, which includes nodes and edges [16].

IV. PROPOSED ALGORITHM

In the existing work the researchers have improved the performance of PEGASIS protocol with the a dynamic way selecting cluster head on the basis of sorting algorithm i.e. the node containing the highest energy will be selected as cluster head and remaining neighborhood nodes will be the part of that cluster. In the existing technique, PEGASIS protocol is applied with ACO technique. This technique also has some disadvantages as its probability distribution is changes with iterations. Moreover sequence of random decision is not independent. Therefore, it degrades the performance of the network and decrease energy efficiency of the network. But will not be able to increase the performance of existing PEGASIS protocol in a very significant manner so in the proposed work our aim is design a protocol over which the cluster head will selected on basis random search technique so that we will be able to improve the performance of existing PEGASIS protocol to significant level in terms of energy efficiency. To improve network efficiency a hybrid technique is proposed based on the PEGASIS, ACO and Simulated Annealing.

4.1 Simulated annealing (SA): SA is a random-search method which achieves a similarity among the way in which a metal cools and restrictions into a least energy crystalline structure (the annealing process) and the search for a minimum in a more general system; it forms the basis of an optimization technique for combinatorial and other problems. SA's major advantage over other methods is an ability to avoid becoming trapped in local minima. The algorithm employs a random search which not only accepts changes that decrease the objective function f (assuming a minimisation problem), but also some changes that increase it. The latter are accepted with a probability

$$p = \exp(-df / T) \quad (1)$$

where df is the increase in f and T is a control parameter, which by analogy with the original application is known as the system "temperature" irrespective of the objective function involved. The implementation of the basic SA algorithm is straightforward.
The aim of the research is to develop an effective aggregation technique for the wireless sensor network i.e used in air quality monitoring application to protect the human health from toxic gases. The methodology for this research is shown in following figure.

To apply the hybrid algorithm, named Simulated Annealing Ant Colony Optimization PEGASIS (SAACOP). on the clustering the following steps should be repeated:
Step 1: Generate an initial network.
Step 2: Generate cluster of the networks
Step 3: Determination of the next path.
To determine the next path, at first, the neighborhood of Pi is determined by
simulated annealing as follows:
Step 1: Select an initial solution P and an initial temperature T.
Step 2: Find another solution, namely Pnext , by modifying the last answer P
Step 3: Calculate the energy differential

Step 4: If < 0 go to Step 9.
Step 5: Generate a random number, namely R, between 0 and 1.
Step 6: If R<exp ( ) go to Step 9.
Step 7: Repeat Steps 2–6 for a number of optimization steps for the given temperature.

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Step 8: If no new solution, Xnext is accepted and go to Step 10.
Step 9: Decrease the temperature T, replace X with Xnext and go to Step 2.
Step 10: Reheat the environment with setting T to a higher value.
Step 11: Repeat Steps 1 through 10 until no further improvement obtained.
After that, SA finds the best local solution(Y), and then new cluster head is updated.
Step 12: After all ant colonies (Pi) updated, find next path for communication.

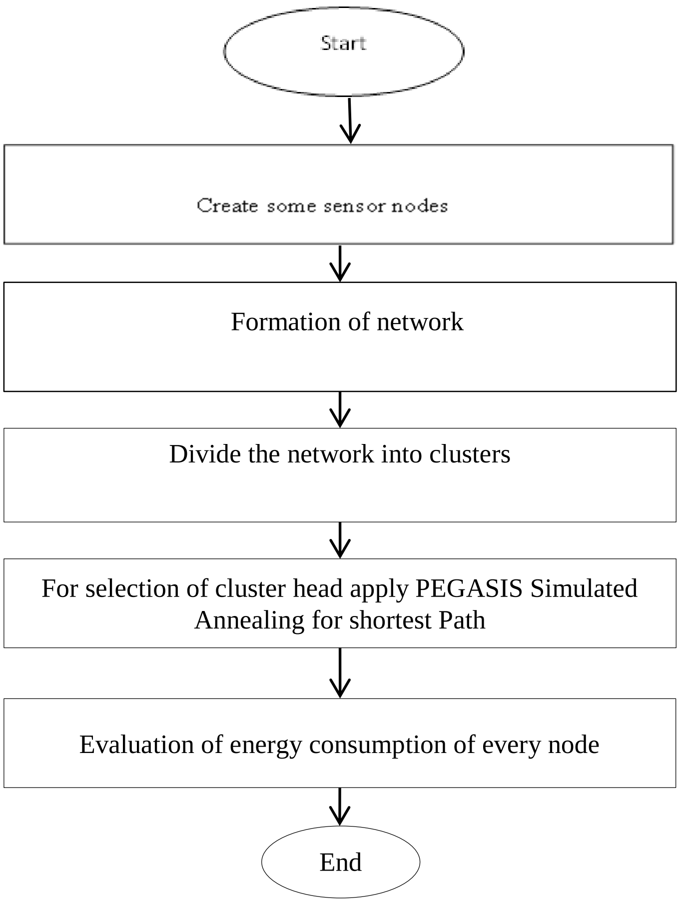
4.2 Performance Metrics: Given below are some key parameters considered for performance of WBAN. Definition of performance metrics is given in following subsections.

1. Network lifetime: It represents the total network operation time till the last node die.

2. Number of alive Nodes: It represents the active nodes of the network for path establishment and data transfer.

3. Number of dead nodes: It represents inactive nodes. These nodes are unable to participate for path establishment.

4. Total Network Energy: It represents the total energy consumed by the network.



V RESULTS AND DISCUSSIONS

In this section, we illustrate the simulation in MATLAB. In this work, we have taken following attributes.

Table 1 Parameters with its attributes

Parameters	Values
Simulation	MATLAB
Number of nodes	100
Network size	100x100, 50x50
Initialization Energy	1J
Packet Transmission Size	250 bytes

Table 2 Lifetime of network size 100X100

Number of dead nodes	Protocol	
	PEG-ANT	SAACOP
1	1100	345
10	1253	855
50	1520	4215
70	1870	7005
100	2670	8999

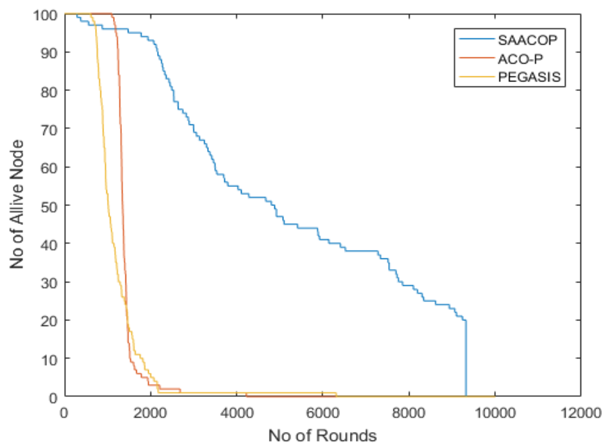


Fig.5: Number of Alive Nodes

Fig.5 depicts that number of alive nodes are more in proposed work as compared to the existing technique. Here blue line represents Simulated Annealing Ant Colony Optimization PEGASIS (SAACOP).Similarly ACO-P(Ant colony Optimization PEGASIS) has medium number of alive nodes whereas PEGASIS has minimum number of alive nodes.

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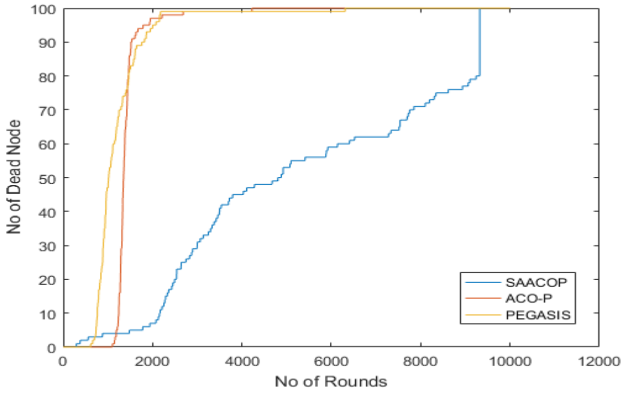

Fig.6. Number of dead nodes

Fig.6. depicts that number of dead nodes are less in proposed work with increase of rounds as compared to the existing technique. Here blue line represents Simulated Annealing Ant Colony Optimization PEGASIS (SAACOP).Similarly ACO-P has more number of dead nodes whereas PEGASIS has medium number of dead nodes.

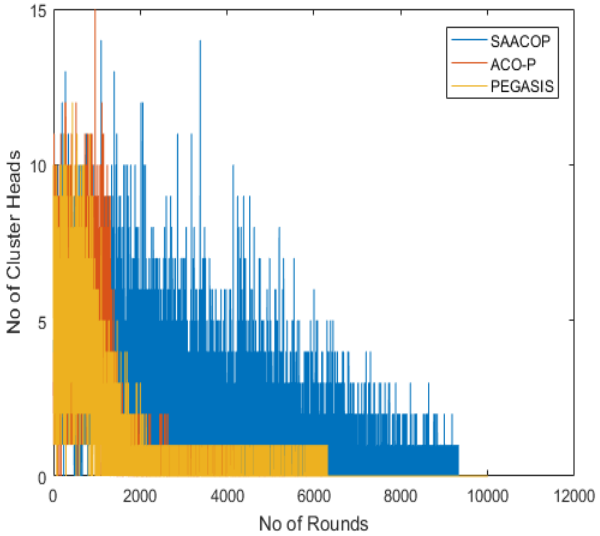

Fig.7 Number of Cluster heads

Fig. 7 depicts that number of Cluster heads are more in proposed work with increase of rounds as compared to the existing technique. Here blue line represents Simulated Annealing Ant Colony Optimization PEGASIS (SAACOP).Similarly ACO-P has minimum cluster heads whereas PEGASIS has medium number of cluster heads.

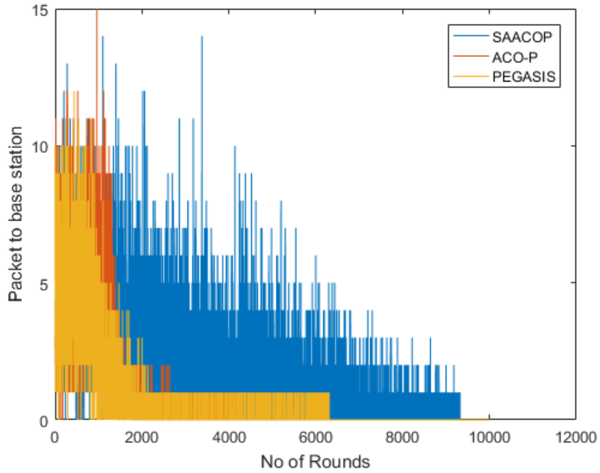

Fig.8 Packet Delivery

Fig.8 depicts that transmission of packets to base station is more in proposed work with increase of rounds as compared to the existing technique. Here blue line represents Simulated Annealing Ant Colony Optimization PEGASIS (SAACOP).Similarly ACO-P has minimum transmission whereas PEGASIS has medium transmission of packet transmission.

6. Conclusion

From the experiment results, it is concluded that proposed hybrid technique is better than existing one. In this work, we compared with the hybrid PEGASIS which uses Ant Colony Optimization algorithm to build the chain, our protocol, PEG-hybrid, can obviously more prolong the time when the first node dies. Existing protocol has good lifetime and efficiency but it has some limitations also. Hybrid PEGASIS provides better performance in terms of number of alive nodes, dead nodes, network lifetime and cluster heads. Hence it helps to improve performance of the network and consume less energy as compared to PEG-ANT.

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