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PEGASIS-E: Power Efficient Gathering in Sensor Information System Extended

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Abstract- In this paper, an improved energy efficient PEGASIS based protocol (PEGASIS-E) has been proposed. PEGASIS-E uses average distance among the sensor nodes as the criteria for chaining, thereby providing better performance in terms of energy dissipation and amount of information sent to BS. The simulation results obtained show that PEGASIS-E gives an increase in the network lifetime as compared to PEGASIS.

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Strictly as per the compliance and regulations of:

PEGASIS-E: Power Efficient Gathering in Sensor Information System Extended

Vibha Nehra [α] & Ajay K. Sharma [σ]

Abstract- In this paper, an improved energy efficient PEGASIS based protocol (PEGASIS-E) has been proposed. PEGASIS-E uses average distance among the sensor nodes as the criteria for chaining, thereby providing better performance in terms of energy dissipation and amount of information sent to BS. The simulation results obtained show that PEGASIS-E gives an increase in the network lifetime as compared to PEGASIS.

I. Introduction

Advances in wireless communication have made possible the development of wireless sensor networks consisting of devices called sensor nodes. Sensor nodes are low power, small size & cheap devices, capable of sensing, wireless communication and computation [1,2]. Applications of wireless sensor network include monitoring of harsh inhospitable, remote geographical locations like toxic urban industrial locations or a surveillance field. Other applications may include office automation, robot control, smart homes, interactive toys, identification and personalization [3].

A sensor network consists of hundreds & thousands of sensor nodes deployed in a geographical region. These nodes collectively form a high level description of event being sensed, which is further forwarded to a distant base station (BS), so that end user can access the available information. Energy awareness and computational feasibility are the key parameters that need to be addressed while designing protocols in resource constrained sensor networks. Variation in distance of nodes from BS and differences in internodal distances are primary antecedents causing unequal energy dissipation among the nodes. Thus, energy difference among the nodes increases with time resulting in deterioration of network performance [4]. PEGASIS (Power Efficient GAthering in Sensor Information System) is a chain based protocol [5] which has certain deficiencies like long chaining time in the process of greedy chain formation, inevitability of long links as well as abrupt death pattern of nodes in the network.

In recent years, researchers have proposed numerous improved algorithms based on PEGASIS such as PEG-ant [6], EEPB [7], IEEPB [8]. Among these EEPB adopts a threshold for chain formation to avoid the formation of long links LL, but this threshold is still uncertain and complex to determine, which induces LL, if not valued appropriately [7]. Likewise, IEEPB compares distance between the nodes twice, finds the shortest path to link two adjacent nodes & avoids the formation of LL between the neighbors [8]. The work in this paper introduces a PEGASIS based routing protocol called PEGASIS-E. PEGASIS-E computes average distance among the nodes and sets it as radio range for the farthest node from the BS. Then, it chains all the nodes in the radio range. Further, it compares the distance of all the chained nodes to find the nearest next end node to continue the chaining process. The simulation results show that PEGASIS-E outperforms PEGASIS.

The rest of the paper is organized as follows: section II explains the radio energy dissipation model, section III gives the network model and assumptions used followed by section IV which describes PEGASIS-E. Section V lists the performance metrics used for the simulation. Section VI describes the results obtained. Section VII concludes the paper.

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II. Radio Energy Dissipation Model

In the radio energy model [9, 10], the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics as shown in Figure 1.

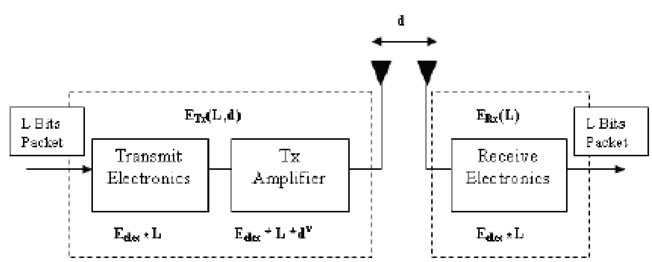


Figure 1 : Radio Energy Dissipation Model

Here both the free space (d^2 power loss) and the multipath fading (d^4 power loss) channel models are used, depending on the distance between the transmitter and receiver [9, 10]. Power control can be used to invert this loss by appropriately setting the power amplifier—if the distance is less than a threshold d_o, the free space model is used; otherwise, the multipath model is used. Thus, to transmit an L-bit message a distance, the radio expends

$$E_{Tx}(L, d) = \begin{cases} L.\,E_{elect} + L.\,E_{fs}.d^2 & \text{if } d<d_o \\ L.\,E_{elect} + L.\,E_{amp}.\,d^4 & \text{if } d>=d_o \end{cases}$$

The electronics energy, E_{elec}, depends on factors such as the digital coding, modulation, filtering, and spreading of the signal, whereas the amplifier energy, $E_{fs}.d^2$ or $E_{amp}.d^4$, depends on the distance to the receiver and the acceptable bit-error rate [9, 10]. Value of threshold distance d_o is given by

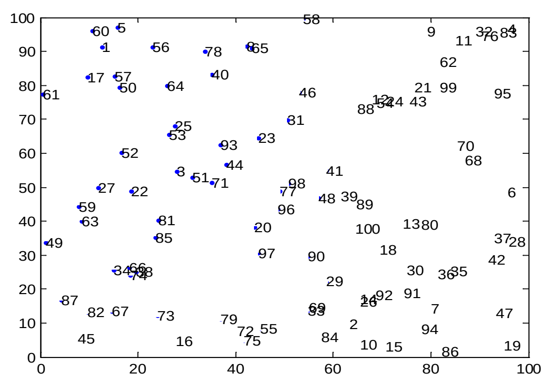
$$d_o = (E_{fs}/E_{mp})$$

And to receive this message, the radio expends energy equivalent to

$$E_{rx}(L) = L \text{ X } E_{elec}$$

III. Network Model

Our sensor network consists of 100 nodes in a 100 x 100 sensor field as shown in Figure 2



For Simplicity, we have taken following Assumptions [2, 8]:

- All nodes are static.
- All nodes have power control capabilities, and each node can change the power level and communicate with BS directly.
- BS is located far away from the sensor field and at a fixed location.
- For a given signal to noise ratio, symmetric radio channel, making the energy required to transmit from one point to another and in reverse direction identical.
- Nodes always have data to send.
- Every sensor node generates a fixed size packet and forwards it to next node in the chain.
- BS schedules transmission based on TDMA to avoid collision.

IV. PEGASIS-E

PEGASIS-E is a improved chain based routing algorithm which operates in rounds. It consists of 3 stages: (1) Chain construction phase, (2) leader selection phase, (3) data transmission phase.

a) Chain Construction Phase

The algorithm uses the following steps to form a chain:

a) Initialize the network parameters. Determine the number of nodes, initial energy, BS location information et al. Then, the chain construction starts.
b) BS broadcasts the whole network a *hello* message to obtain basic network information such as ID of nodes alive, distance of each node to BS, and distance among the nodes.
c) Set the node farthest from BS as *end node*, it joins the chain first and is labeled as node 1.
d) Calculate average distance between the alive nodes, D_{avg} and set it as the radio range for *end node.*
e) Join all the nodes to the chain which have not joined the network and lies in the radio range.
f) Compare distance of all nodes joined in the chain to calculate the minimum distance node.
g) Set the selected node as new *end node*.
h) Repeat steps e), f), g) till all the nodes have joined the chain.

The chain building scenario in PEGASIS-E for a network of 100 nodes randomly arranged is shown in figure 3.

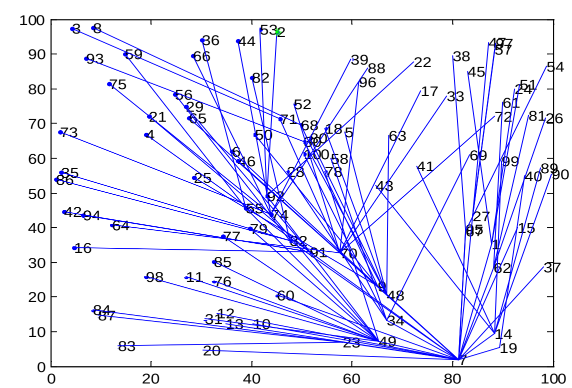


Figure 3 : The chain formed in PEGASIS-E

b) Leader Selection Phase

Leader selection in PEGASIS-E is same as that of PEGASIS [5]. Node which transmits the data from the chain is called a leader. Leader will be in some random position *j* on the chain. Nodes take turns transmitting to the BS, and will use node number *i* mod N (N represents the number of nodes) to transmit to the BS in round *i*. Therefore, the leader in each round of communication will be at a random position on the chain, for node deaths at random locations. This concept of random node deaths on the chain ensures robustness of the network towards failures.

c) Data Transmission Phase

Data transmission starts on successful construction of chain and leader node selection. Leader node initiates a token passing approach to start data transmission from nodes which have just one link. Each node delivers its own sensed data to its neighbor node in the chain during their time slots assigned by TDMA mechanism. Then, the neighbor nodes fuse the received data with their own data & forwards further towards the leader. One round will end until BS receives data from the leader. In addition, it is assumed that chain is rebuilt when a node of the chain dies during simulation of experiment.

V. Performance Metrics

The number of Nodes Alive, number of Packets received at BS, Energy consumed per round & Total Residual Energy of the sensor network are the performance parameters that have been used to study and evaluate the performance of the proposed protocol.

- *Number of alive nodes :* This instantaneous measure reflects the total number of nodes and that of each type that has not yet expended all of their energy.
- *Data Packets received at base station :* It is total number of data packets or messages that are received by the base station. This is also a measure of amount of information sent to BS from the sensor field. This measure varies linearly for all protocols.
- *Energy consumed :* It measures the instantaneous amount of energy being consumed in the network per round. This is simply the energy difference from the beginning till the end of a round.
- *Network residual energy :* It measures the total remaining energy of the network. It is calculated at each transmission round of the protocol.

The metrics used allow us to conclude about the stability of the network which is the time interval from the start of network operation until the death of the last sensor node. The lifetime of the network defined as the number of rounds until the last node die is simply the operational period of the network that is the period for which the network continues to provide information to the BS.

VI. Results and Discussions

Table 1 : System parameters value

Parameter	Value
Network Size	100 X 100 meter^2
Sink	(50,300)
Number of Nodes	100
Initial Energy of Node	0.50 J
E_{elect}	50 nJ/bit
E_{fs}	10 pJ/bit/m^2
E_{mp}	0.0013 pJ/bit/m^4
E_{fusion}	5 nJ/bit/message
Data Packet	2000 bits

This paper uses MATLAB as simulator to evaluate the performance of PEGASIS-E. The system parameters used in the simulation are shown in the table 1 [1,5,9, 10].

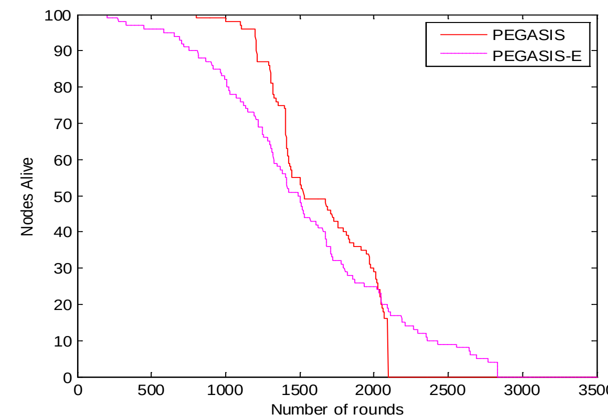


Figure 4 : Number of nodes a live

Figure 4 depicts the number of alive nodes in the network. It is observed that PEGASIS-E has a stable lifetime as compared to PEGASIS. The lifetime period of PEGASIS-E before the death of first node is less, but it continues to provide information about the sensor field for a longer period of time. PEGASIS shows abrupt death of nodes due to almost same energy dissipation in all nodes, as they consume same amount of energy in each round. While in PEGASIS-E, energy dissipation is different in every round. It is higher for end node.

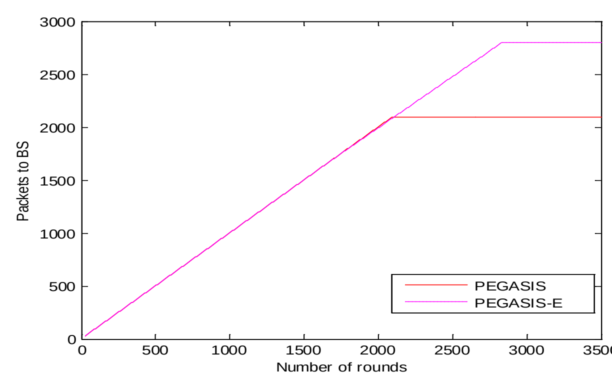


Figure 5 : Number of Packets to BS

Figure 5. indicates a clear gain of 34% in number of Packets sent to BS for PEGASIS-E as compared to PEGASIS. This is because death pattern of nodes in PEGASIS-E is such that a sub section of sensor field is not clearly cut-off after the death of certain nodes, leading to the availability of sensed data for a longer period of time.

Figure 6. shows energy consumption of PEGASIS-E. It is concluded that PEGASIS-E consumes less energy compared to PEGASIS because the number of nodes to be covered becomes less due to death of nodes with simulation time.

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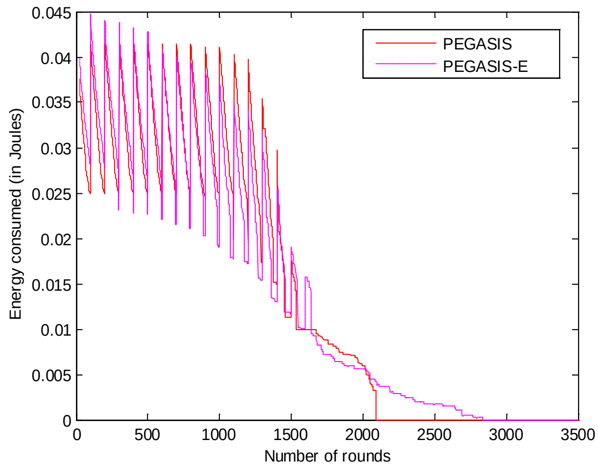

Figure 6 : Energy consumed over time.

Figure 7 depicts that PEGASIS-E has a balanced energy dissipation and more stable lifetime.

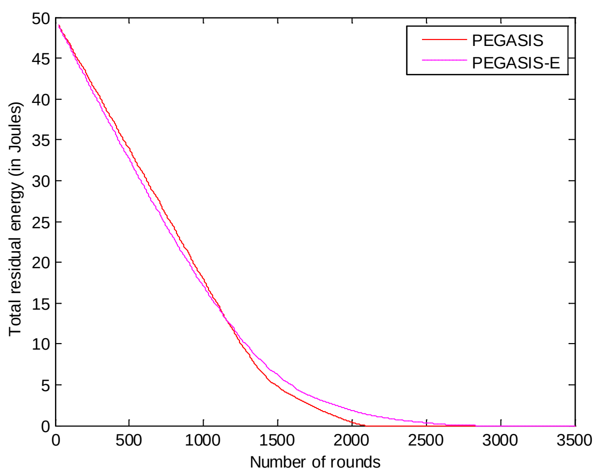

Figure 7 : Total residual energy

VII. Conclusion

This paper proposes an improved energy-efficient PEGASIS based protocol PEGASIS-E, which not only provides a set threshold, D_{avg} for chaining but also simplifies the complexity of chain construction. Moreover, the chaining speed of PEGASIS-E is faster than PEGASIS. The novel algorithm avoids the formation of LL and provides a stable and balanced lifetime to the network. The simulation results prove that PEGASIS-E outperforms PEGASIS by achieving higher energy-efficiency extending lifetime of network.

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