M-PEGASIS: Energy Efficient Pegasis for Mobile Wireless Sensor Networks

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Abstract

Recent advances in wireless networks have led to many new protocols specifically designed for wireless sensor networks (WSNs) where energy awareness is an essential consideration. In this paper, we have presented an energy efficient PEGASIS protocol for mobile WSN (M-PEGASIS). The key idea of M-PEGASIS is to form a chain among the sensor nodes so that each node will receive from and transmit to a close neighbor, nodes move according to random way point mobility model, after moving of the nodes, if a node doesn't find a close neighbor it goes into sleep mode for random period of time and then wakes up, this method is repeated until it finds one in its transmission range. This method conserves energy of the mobile nodes. Gathered data moves from node to node, get fused, and eventually a designated node transmit the aggregated data to the base station (BS). Selecting head node is based on both the residual energy of sensor nodes and the distance of each node from the BS. Nodes take turns transmitting to the BS so that the average energy spent by each node per round is reduced. Simulation results show that M-PEGASIS outperforms existing protocols such as LEACH, PEGASIS and LEACH-M in terms of average energy consumed and number of alive nodes.

Keywords: *Mobile Wireless Sensor Networks, Routing protocol, PEGASIS, LEACH.*

1. Introduction

With rapid advancement in electronics industry, small inexpensive battery-powered wireless sensors have already started to make an impact on the communication with the physical world. WSN consists of large number of low cost devices to gather information from the diverse kinds of physical phenomenon. The sensors can monitor various entities such as: temperature, pressure ,humidity, salinity, metallic objects, and mobility; this monitoring capability can be effectively used in commercial, military, and environmental applications [11, 12]. For these sensor network applications, most research has discussed problems by the deployment of large number of low-cost homogeneous devices. But in practical applications, in order to meet the demands of various applications for the technologies of sensor networks, increasing attentions have been attracted to the researches on heterogeneous WSNs [13]. Heterogeneous WSN is composed of different types of sensor nodes, which are in a wide range of applications. In fact, the heterogeneity is common in the WSNs. For heterogeneous

WSN, it should be given priority to reduce energy dissipation in network operation, improve network load and stability and prolong network lifetime. WSN can be classified into static sensor network (SSN) and mobile sensor network (MSN). In SSN, the sensor nodes are localized only first time during deployment. In case of MSN, sensor nodes collect the data by moving from one place to another place. MSNs are more energy efficient, better targeting and provide more data fidelity than SSN. MSNs have gained great attention in recent years due to their ability to offer economical and effective solutions in a variety of fields.

As sensor has limited battery and this battery cannot be replaced due to area of deployment, so the network lifetime depends upon sensors battery capacity. A careful management of resources is needed to increase the lifetime of the WSN. The conventional routing schemes are inefficient when applied to WSNs as the performance of the existing routing schemes varies from application to application. Thus, there is a strong need for development of new efficient routing schemes/protocols, which can work considerably across the wide range of applications, number of routing protocols have been proposed for WSN. Major chain based routing protocol; Power-Efficient Gathering in Sensor Information Systems (PEGASIS) [1] presents the notion of chain formation among sensors and then conveys the data to base station. The leader node collects data of all other chain nodes and sends it to the sink. The proposed protocol is a modified version of PEGASIS protocol to support mobile WSNs. Most of routing protocols assume WSNs to be stationary, however, but this is not the general case as we discussed above. For instance, in wildlife applications, sensors are casted in the field as well as equipped on animals to be monitored. The self-organized WSN is mobile as animals are moving around. In telemedicine applications, sensors attached to patients also constitute a mobile WSN. As expected, the mobile WSN is more difficult to deal with than stationary counterpart. The mobility in sensor nodes possesses challenges like available battery power, minimal lifetime, packet loss and energy consumption. Kim et al. [2] projected a new cluster based routing protocol applicable to mobile WSNs called LEACH Mobile. The vital concept in LEACH-Mobile is to confirm whether a mobile node is capable of communicating with specific cluster head within the time slot allotted in TDMA schedule. The proposed protocol is a chain based routing protocol to overcome this problem.

In this paper, we propose an energy efficient chain based routing protocol for mobile WSNs based on PEGASIS protocol. The proposed protocol adds feature to PEGASIS to support mobile nodes and also reduces the consumption of the network resource in each round. Our simulation results show that our proposed protocol can effectively prolong the network lifetime compared with LEACH, PEGASIS and LEACH-M protocols.

The rest of the paper is organized as follows: Section 2 covers the related work of our problem. In section 3, we introduce our proposed protocol. In Section 4 we show the simulation results of our proposed protocol compared with LEACH-M, LEACH and PEGASIS protocols. We conclude our work in Section 5.

2. Related Work

Routing in WSNs is challenging due to the specific characteristics that distinguish WSNs from other wireless networks such as wireless ad hoc networks or cellular networks. Many new algorithms have been proposed, taking into consideration the inherent features of WSNs along with the application and architecture requirements. Based on the network structure adopted, routing protocols for WSNs can be classified into flat network routing, hierarchical network routing, location-based network routing. In flat network routing, all nodes have the same functionality and they work together to perform sensing and routing tasks. The Sensor Protocols for Information via Negotiation (SPIN) and Directed Diffusion fall into this category. Hierarchical network routing divides the network into clusters to achieve energy-efficient, scalability and one of the famous hierarchical network routing protocol is low-energy adaptive clustering hierarchy (LEACH) protocol [3].

In location-based network routing, location information of nodes is used to compute the routing path. This information can be obtained from global positioning system (GPS) devices attached to each sensor node. Examples of location-based network routing protocols include geography adaptive routing (GAF) and

Geographic and Energy-Aware Routing (GEAR). Chain based protocols, eliminate the overhead of dynamic cluster formation. Examples of chain based protocols include Power-Efficient Gathering in Sensor Information Systems (PEGASIS) Protocol, [1] which is a near optimal chain-based protocol that is an improvement over LEACH. In PEGASIS, each node communicates only with a close neighbor and takes turns transmitting to the base station, thus reducing the amount of energy spent per round. In [4] Energy-Efficient Chain-Based routing protocol (EECB) is proposed which is an improvement over PEGASIS. EECB uses distances between nodes and the BS and the remaining energy levels of nodes to decide which node will be the leader that takes charge of transmitting data to the BS. Also, EECB adopts distance threshold to avoid formation of Long Link on the chain. In [5] the authors proposed an energy-efficient PEGASIS-Based protocol (EEPB) which is also a chain-based protocol that has certain deficiencies including the uncertainty of threshold adopted when building a chain, the inevitability of long link when valuing threshold inappropriately and the non-optimal election of leader node.

An improved energy-efficient PEGASIS-based protocol (IEEPB) was proposed in [5]. IEEPB adopts new method to build chain, and uses weighting method when selecting the leader node, that is assigning each node a weight so as to represent its appropriate level of being a leader which considers residual energy of nodes and distance between a node and BS as key parameters. The proposed protocol is a chain based protocol to support mobile nodes.

Designing routing protocols for mobile WSNs is a great challenge due to the following reasons: (1) it is not easy to grasp the whole network topology, so it is hard to find a routing path. (2) Sensor nodes are tightly constrained in terms of energy, processing, and storage capacities. Thus, they require effective resource management policies, especially efficient energy management, to increase the overall lifetime of a WSN.

In [2] the author proposed LEACH Mobile it is based on LEACH protocol, however the authors added features to LEACH protocol to support mobile nodes and also reduced the energy consumption in each round. In [6], the authors proposed a tree based routing protocol (TBRP) which builds an optimum mobility pattern for maximum energy efficiency. TBRP is better targeting because sensor nodes are deployed randomly, therefore there is often a requirement to move the sensor nodes for better sight or for close proximity to the physical activity. Mobility in TBRP helps in better quality of communication between sensors.

TBRP improves nodes and network life time by moving the node to the next higher level.

In [7] the author proposed cluster based routing protocol for mobile nodes in WSN (CBR-Mobile) which uses across layer design between medium access control (MAC) and network layer to overcome packet loss that occurs due to the mobility of sensor nodes. The CBR-Mobile is mobility and traffic adaptive protocol. The time slots assigned to the mobile sensor nodes that had moved out of the cluster have no data to send will be reassigned to incoming sensor nodes within the cluster region. CBR-Mobile sends data to cluster heads in an efficient manner based on received signal strength .In CBR-Mobile protocol, cluster based routing collaborates with hybrid MAC protocol to support mobility of sensor nodes. Schedule time slots are used to send the data message while the contention times lots are used to send join registration messages.

In [8] the author proposed Energy Efficient Routing Protocol for Mobile Wireless Sensor Network in which the sink node (base station) is in static state and all other neighbor nodes are in mobile state. Here gateway node acts as a relay for transmitting data from one group of node to another group. Our proposed protocol adds feature to PEGASIS to support mobile nodes and also reduces the consumption of the network resource in each round through the elimination of the overhead caused by dynamic cluster formation and reduction of number of transmissions through data aggregation.

3. Energy Efficient Mobile PEGASIS (M-PEGASIS)

M-PEGASIS is a chain based routing protocol for mobile WSN based on PEGASIS protocol to support mobile nodes. In M-PEGASIS nodes move according to random way point mobility model, after moving of the nodes, if node doesn't find close neighbor it goes into sleep mode for random period of time and then wake up. This method is repeated until it finds one in transmission range. This method conserves energy of the mobile nodes. In our proposed protocol, we make the following assumptions.

1. BS is fixed at a distance from the sensor nodes.
2. Sensor nodes are mobile and every sensor knows its velocity and location.
3. BS has a communication range R, which is long enough to cover all sensor nodes.
4. Mobile nodes randomly move according to Random way point mobility model.
5. Energy consumption model in [9] and mobility model in [10] is used for M-PEGASIS protocol implementation.

3.1. Mobility Model

In this protocol we assume that the mobile nodes move according to Random way point mobility model which is a variation of random walk model with spatial dependence. It includes pause times between changes in direction and/or speed. A mobile node stays in one location for a certain period of time (a pause time), then it chooses a random destination (x, y) in the simulation area with parameters such as speed between $[0,V_{max}]$, pause time between $[P_{min},P_{max}]$ that are uniformly distributed. The mobile node then travels toward the newly chosen destination at the selected speed. Upon arrival, the mobile node pauses for a specified time period before starting the process again. The value of pauses and speeds are relevant. Fast nodes and long pauses produce a more stable network than slow nodes and short pauses. The most argued issue is that nodes are more likely to be in the central part of the topology rather than close to the bounds [10].

3.2. Energy Consumption Model

The energy consumption in the mobile WSN is categorized as four operating modes: sleep, listening, reception, and transmission. Each node goes to sleep for some time and then wakes up and listens to see if any other node wants to talk to it. The energy consumed by the sleep and listening mode is E_{sleep} *(Jules per unit time)* and E_{listen} *(Jules per bit interval)*, respectively. When the node detects a transmission from other nodes, it consumes receiving energy E_{rx} *(Joules/bit)*. The energy consumed by the transmission that covers the neighborhood of a given radius r is E_{tx} *(r) (Joules/bit)*. The energy expended in transmitting an L-bit message over a distance d is given by:

$$E_{Tx}(l,d) = \begin{cases} l.E_{elec} + E_{tx}\,(r) + Esleep\ +\ Elisten, & \textit{The energy expended by non leader node} \\ l.E_{elec} + E_{tx}\,(r), & \textit{The energy expended by leader node} \end{cases}$$

Table 1: Energy consumed by reception and transmission. (CC2420, 250 kbps).1

Energy	*Signal strength (dBm)*	*Jules per bit (uJ/bit)*
E_{tx}	**0**	0.122
	-1	0.113
	-3	0.105
	-5	0.088
	-10	0.078
	-15	0.069
	-25	0.060
E_{tx}	-	0.140

Where E_{elec} the energy is dissipated per bit to run the transmitter or the receiver circuit and d is the distance between the sender and the receiver.

Table 1 shows the energy consumed by the reception and transmission in the case of a CC2420 radio transceiver [9].

3.3. Working Principle

M-PEGASIS is a chain based routing protocol for mobile WSNs based on PEGASIS protocol. The proposed protocol put some features that PEGASIS does not support to support Mobility of the nodes.

The proposed protocol consists of three phases. Chain construction phase where all nodes have global knowledge of the network and employ the greedy algorithm. We could have constructed a loop; however, to ensure that all nodes have close neighbors is difficult as this problem is similar to the traveling salesman problem. The greedy approach to constructing the chain works well and this is done before the first round of communication. Data gathering phase for gathering data in each round, each node receives data from one neighbor, fuses with its own data, and transmits to the other neighbor on the chain. Nodes take turns transmitting to the BS based on the residual energy and the distance of each node from the BS. In mobility phase, all nodes are mobile except BS after moving of the nodes, if node doesn't find close neighbor it goesinto sleep mode for random period of time and then wakes up. This method is repeated until it finds one in its transmission range. We will discuss each phase in detailed in the following subsections

3.4. Chain Construction Phase

The algorithm uses the following steps to form a chain:

1. Initialize the network parameters (the number of neighbors, initial energy, BS location information etc.).
2. BS broadcasts the whole network a hello message to obtain basic network information such as ID of nodes alive and distance from each node to BS.
3. Set the node which is farthest from BS as end node, it joins the chain first and it is labeled as node 1.
4. End node of the chain obtains the information of distance between itself and other nodes which have not joined the chain yet, finds the nearest node and sets it as node i waiting to join the chain, I represents the i^{th}node joined

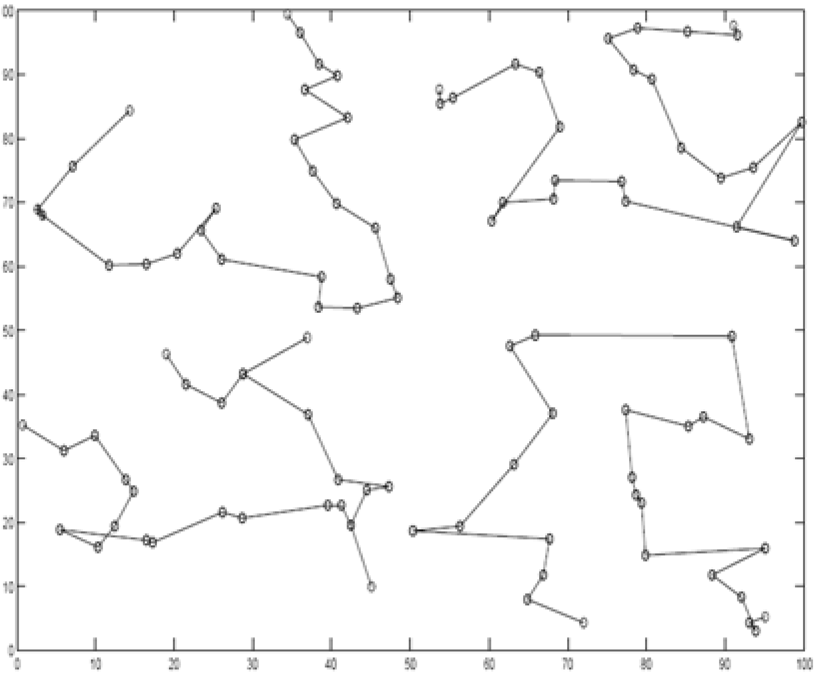

Figure 1: snapshot of the Chain construction

3.5. Data gathering phase

During each round, a leader node is selected based on residual energy and distance from BS, the nodes with more energy and less distance from BS are probable to be selected as leader node. The leader node is responsible for forwarding the aggregated data to BS. Once the leader node is selected and notified by the BS, each node in both sides of the chain (with respect to the leader node), receives and transmits the aggregated data to its close neighbor in the chain, until the data reaches the leader node.

3.6. Mobility Phase

We assume that all nodes are mobile except BS and nodes move according to Random way point mobility model. When a node moves from one location to another location, it changes its position. There are two possibilities regarding to the movement of the node:

1. If a node finds a close neighbor in its transmission range it send its data to it.
2. If a node doesn't find a close neighbor in its transmission range it goes into sleep mode for some time and then wakes up and listens to see if any other node wants to talk to it. This approach will conserve energy and maximize the network life time

Algorithm1 M-PEGASIS

Input Parameters: Table 2 listing the input parameters of this algorithm for each round
For i =1 to N do
node[i].$\boldsymbol{E_0} = \boldsymbol{E_0}$
  If node[i]>0
    If (energy(node[i]) >energy(node[i-1]))
    If (distance between node[i] and BS <=mindistance) then
        node[i] is selected to be leader node
        node[i] send the data to BS
        Transmission cost $\boldsymbol{E_{Tx}(l,d)} = \boldsymbol{l.E_{elec} + E_{tx}\ (r)}$
        Subtract the transmission cost from the leader node
    End if
    End if
Else if (distance between node[i] and BS > mindistance)then
    node[i] is not leader node
        If (distance between node[i] and node[i-1] >TR)
        node[i] doesn't have a close neighbor and goes into sleep mode for Random period of time and then wakes up and listens to see if any other node in its transmission rang wants to talk to it
        End if
        If (distance between node[i] and node[i-1] <TR)
            node[i] is in transmission rang of node[i-1]
            node[i] send data to node[i-1]
            Transmission cost is $\boldsymbol{l.E_{elec} + E_{tx}\ (r) + Esleep + Elisten}$
            Subtract the transmission cost from the sending node
        End if
  End if
energy consumption(node[i])=$\boldsymbol{connectdistance(node[i])^2 * E_{Tx}(l,d)}$
    If (remaining energy <= 0)
        Display node has died
  End if
End for

4. Simulation Results

In this section, using Matlab and Random Way point mobility model [14] we evaluate the performances of M-PEGASIS discussed in the previous section, we compared the performance of the proposed protocol with LEACH, PEGASIS and LEACH-M protocols. For performance comparison, we mainly take into account the following performance parameters: Average energy consumed and Number of alive nodes, for our experiments, we consider that the energy consumption of reception and transmission for the sensor nodes is equal to the case of a CC2420 radio transceiver, nodes which move according to Random Way point mobility model.

Description	Parameter	Value
Number of nodes	N	100
Location of the BS	BS	(50,50)
Initial energy	E_0	1 J
NodeTranR	TR	10
Data packet size	L	5000 bits
energy consumed by the sleep mode	E_{sleep}	0.123(Jules/time)
energy consumed by the listening mode	E_{listen}	0.155(Jules/interval)
receiving energy	E_{rx}	0.113(Joules/bit)
transmission energy	$E_{tx}(r)$	0.078(Joules/bit)
Network dimensions	Rx R	100 x100 m2

M- PEGASIS, LEACH-M, LEACH and PEGASIS protocols are simulated for 100 nodes with random topology and 100mX100m network region, the initial energy of every node is considered to be 1J and BS has no energy constrain problems. BS is located at x = 50, y = 50. When a node uses energy down to its energy threshold, it can no longer send data and it is considered as a dead node. In both LEACH-M and M-PEGASIS, except base station all other nodes are mobile

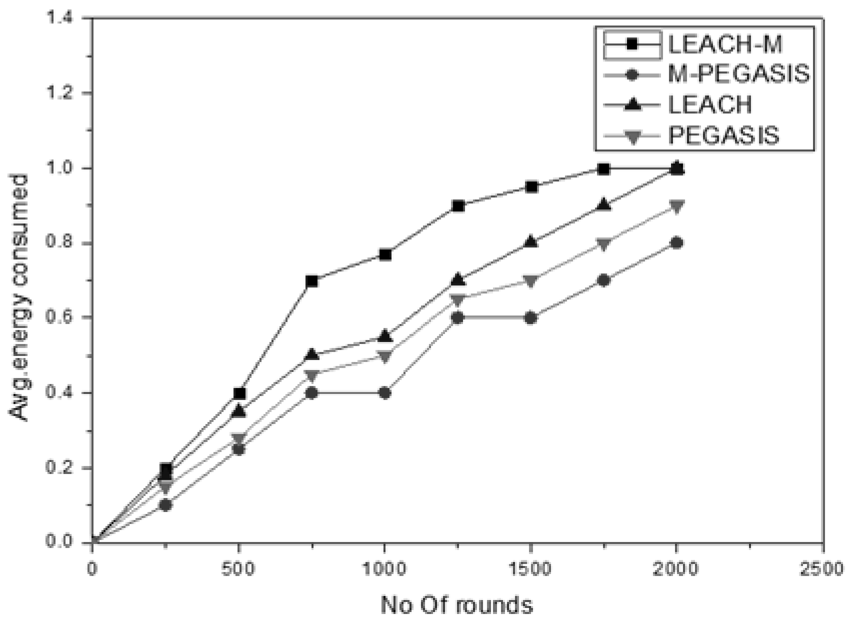

Figure 2: Average energy consumed with LEACH-M, M-PEGASIS, LEACH and PEGASIS.

Figure 2 shows the average energy consumed by sensor nodes in each round. For M-PEGASIS, energy consumed is less when compared to LEACH-M protocol for each round. Such performance gain is achieved through the elimination of the overhead caused by dynamic cluster formation and reduction of number of transmissions through data aggregation and also due to the fact that more control request packets are usedin the LEACH-M to maintain the network communication. For transmitting these packets extra energy is consumed in the LEACH-M than M-PEGASIS protocol.

Comparing with static routing protocols to show the effect of mobility on the performance of the network we notice that the energy consumed of the proposed protocol is less than that consumed in static routing protocols such as LEACH and PEGASIS this is because that all the nodes in static routing protocols remain active all the time this reduce the energy of the nodes but in M-PEGASIS the nodes go into sleep mode if it doesn't find a close neighbor in its transmission range and become active only when it finds neighbor, this method conserve energy of mobile nodes and increase the life time of whole network.

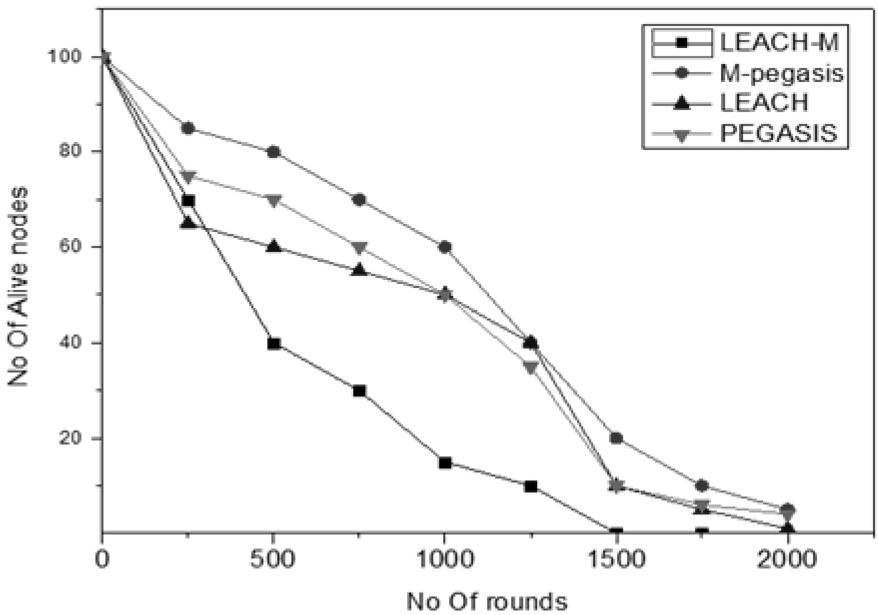

Figure 3: Number of alive nodes with LEACH-M, M-PEGASIS, LEACH and PEGASIS.

Figure 3 shows the number of alive nodes at each round of the network. Since energy consumed by the LEACH-M, static LEACH and PEGASIS is high compared to M-PEGASIS, the life of nodes reduces quickly in the former for each round in LEACH-M, LEACH and PEGASIS than M-PEGASIS this means that our proposed protocol increases the network life time and reduces the energy consumption of whole network.

5. Conclusion

Mobile WSNs have enhanced performance over static wireless sensor networks because of the mobility of the nodes. In static WSNs, the nodes closer to the sink always lose their energy first, thus causing the overall network to “die". This paper presents an energy efficient Mobile PEGASIS for mobile WSN which adds feature to PEGASIS protocol to support for mobile nodes and also reduces the consumption of the network resource in each round. Simulation results show that M-PEGASIS outperforms LEACH, PEGASIS and LEACH-M in terms of average energy consumed and number of alive nodes.

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