JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

POWER-AWARE SLEEP-SCHEDULED TREE-BASED ROUTING PROTOCOL

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Abstract : *In wireless sensor networks, to reduce the energy utilization of sensor nodes, this paper presents a Power-Aware Sleep-Scheduled Tree-Based Routing Protocol EEPEG-PA that modifies the chain formation in PEGASIS. Using a distance and sensing range threshold, form a set of paired and unpaired nodes in the network. The paired nodes switch between active and sleep modes to eliminate redundant data and preserve the battery power. To minimize energy utilization as nodes switching between the modes, this scheme considers transitioning to be done based on the node's residual energy approaching near depleted. To further reduce the energy utilization during transmission, this protocol uses prim's minimum spanning tree mechanism to transfer the data from the active nodes to the Base Station (BS). Simulation results shows that this proposed mechanism can considerably improve network lifetime in comparison to PEGASIS.*

Index terms*: Network lifetime, sleep scheduling, residual energy, sensing range*.

1 INTRODUCTION

Wireless Sensor Networks (WSNs) consist of several small, cheap, under power wireless sensors[1]. WSNs are employed in various applications such as area monitoring, landslide detection, industrial detection, health care monitoring etc. [2]. WSNs are of significance to the evolution of the Internet of Things (IoT). By 2020, it is expected that the Internet of Things (IoT) will have more than fifty billion new connections.[3]. The key challenge in WSNs is designing power-aware routing mechanisms to minimize energy utilization in the network. One of the emerging trends of minimizing energy utilization during routing in sensor networks is the use of the sleep scheduling concept[4]–[6]. This concept involves switching off some unnecessary nodes sensing the same data so as to remove redundant data and save battery power. However, a significant amount of energy is consumed if nodes frequently switch between sleep and active modes [7]. This issue is considered in the design of EEPEG-PA (Energy efficient PEGASIS- Prims Algorithm).

Researchers have insinuated several energy-efficient routing protocols for WSNs. Power-Efficient GAthering in Sensor Information Systems (PEGASIS)[8] is a chain-based protocol, in which a chain is constructed to connect all of the nodes in the network by using the greedy algorithm. Data is transmitted along the chain to a chain leader, totalling the data and sending it to the BS. However, there is a bottleneck problem due to single-chain leader. Also, during the selection of the chain leader, no attention is given to node remaining energy and distance from the BS[9][10].

Moreover, long links inevitably exist in the chain[5]. Geography-Informed Sleep Scheduled and Chaining Based Routing (GSSC)[4][11] selects one node in the network with maximum residual energy in each round as the active node among nodes in a small area while the other nodes take up a sleep mode. The active nodes forward their data along a chain to the BS. However, nodes consume a large amount of power by using Geographic Positioning System (GPS).

Moreover, energy is consumed during frequent switching between active and sleep modes. This happens due to the criteria of selecting the node with the highest residual energy as the active node in each round. In Ref.[5][12][13], the Sleep Scheduled and Tree-Based Clustering (SSTBC) routing protocol uses a centralized algorithm to select one node with maximum remaining energy in each round as the active node in a grid while the other nodes in that same grid take up a sleep mode so as to save battery power. The active nodes forward their data along a tree to the BS. However, there is significant energy utilization due to frequent switching between active and sleep modes.

The organization of the paper is divided into four sections as follows:

In the Section 1 the network and radio model which is considered. Section 2 describes the proposed EEPEG-PA scheme. Section 3 presents simulation and analysis of results. Finally, Section 4 concludes this paper.

2 PRELIMINARIES (NETWORK AND RADIO MODEL)

The proposed scheme considers the following network model assumptions:

- Within the target field, sensor nodes are placed at random, and there is only one base station in the network's centre.
- Sensor nodes are fixed and have limited power.
- The base station is fixed but not constrained by power.
- All sensor nodes are monolithic, with the same target area sensing, data processing, and the capacity to modify the power level to communicate directly with the BS.
- All communication links are uniform [8].
- Each node possesses its own unique identifier (node ID) [11].

For analysis of the radio model in EEPEG-PA, we assume a first-order radio energy dissipation model as in[8], [15][9]. The amount of energy utilization for transmitting a *k*-bit data packet over a distance, *d* is given as follows:

$$E_{TX}(k,d)=E_{elec}*k+E_{fs}*k*d^2, \quad \text{if } d<d_0 \qquad (2.1)$$

$$E_{TX}(k,d)=E_{elec}*k+E_{amp}*k*d^4, \quad \text{if } d\geq d_0 \qquad (2.2)$$

For receiving *k*-bit data, the amount of energy utilization is

$$E_{RX}(k)=E_{elec}*k \qquad (2.3)$$

In this versionof model, a radio dissipates E_{elec} to run the transmitter or receiver circuitry. E_{fs} (free space) and E_{amp} (multi-path fading) refer to the amplifier energy utilization coefficient when the communication distance is less than and greater than or equal to the threshold distance, d_0 respectively, which is determined as:

$$\sqrt{\frac{E_{fs}}{E_{amp}}} = d_0 \qquad (2.4)$$

3 PROPOSED EEPEG-PA ALGORITHM

The proposed algorithm is separated into five phases: the setup phase, which consists of region splitting and one-hop adjacent node pairing, the sleep scheduling phase, cluster head selection phase, the minimum spanning tree formation phase and the data transmission phase.

3.1 Set-up phase

3.1.1 Area dividing

Initially, all the nodes in the network send a HELLO message containing their node ID and remaining energy to the BS. From this information, using positioning techniques such the Received Signal Strength Indicator (RSSI) [15], the BS can determine the location of the nodes. The BS then divides the network area into four consecutive regions, each having an equal number of nodes.

3.1.2 One-hop neighbour node pairing

According to[7][15], if a node s_i is positioned at a known place (xs_i , ys_i), and has a sensing range, Rs_i , the Euclidean distance between node s_i and its neighbour node, s_j , is computed as follows:

$$d(s_i, s_j) = \sqrt{(xs_i - xs_j)^2 + (ys_i - ys_j)^2} \tag{3.1}$$

If a node s_j, is close to node s_i then it is considered an internal sensor of node s_i as in Eq.(6). Therefore, both nodes will sense the same target point.

$$d(s_i, s_j) < Rs_i \tag{3.2}$$

In the analysis of the PEGASIS chain as shown in Fig 1, nodes s_2 and s_3 are covering the same target point, X. Considering the Eq.(6), node s_2 is an internal sensor to node s_3. If both of these two sensors, s_2 and s_3 sense and transmit data about point X, this introduces redundancy and a waste of battery power.

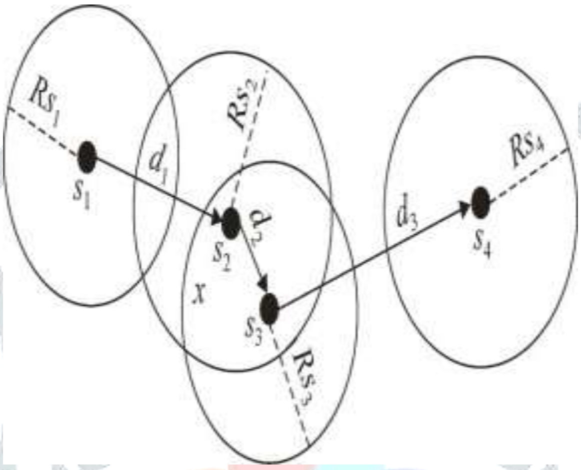

Fig. 1 Redundancy in PEGASIS chain

In the proposed scheme, the BS uses the greedy algorithm to find each node's close neighbour and follows a distance and sensing range threshold to establish a set of paired and unpaired nodes in each region as shown in Fig 2 and detailed in Fig 3. The paired nodes are assigned a paired status while the unpaired nodes maintain an unpaired status, such as in Ref.[6]

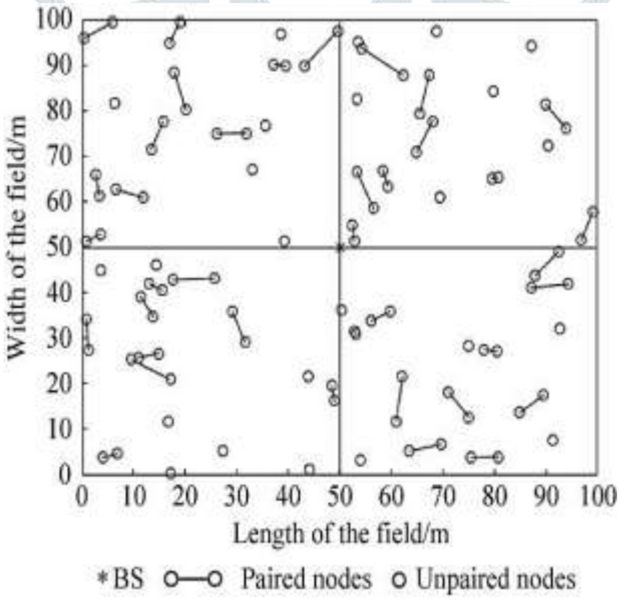

Fig. 2 One-hop neighbour node pairing in EEPEG-PA

One-hop neighbor node pairing Algorithm

for each alive node in each region **do**
node.status = Unpaired // Initially BS assigns all nodes as Unpaired
end for
Starting from the farthest node from the BS in each region
for a node s_i find its close neighbor s_j using greedy algorithm
  if ($s_i.status$ = Unpaired) **then**
    if $d(s_i, s_j) \leq Rs_i$ **then**
      $s_i.status$ = Paired // update *node* s_i *status*
      $s_j.status$ = Paired // update *node* s_j *status*
      Assign same *Pair_ID* to s_i and s_j
      // proceed to find current node s_j's close neighbor
    end if
    // otherwise s_i remains permanently unpaired
    // proceed to find current node s_j's close neighbor
  end if
  //s_i is already paired. find current node s_j's close neighbor
end for

Fig. 3 Pseudocode of one-hop neighbour node pairing in EEPEG-PA

3.2 Sleep scheduling phase

In this phase, all the unpaired nodes are assigned an active status by the BS and remain in active mode throughout the rounds until they are dead. The paired nodes are considered to be sensing the same data. Therefore, to remove redundant data and save battery power, they switch between active and sleep modes during the rounds until they are dead, as in Fig 4.

Paired nodes sleep scheduling Algorithm

Get *P* node pairs in each region of the network
for each pair **do**
  if ($s_i.E_{res} \geq 0.1*En$) **then**
    $s_i.mode$ = Active
    $s_j.mode$ = Sleep
  else if ($s_j.E_{res} \geq 0.1*En$)
    $s_i.mode$ = Sleep
    $s_j.mode$ = Active
  else // both nodes energy below 0.1**En*
    if ($s_i.E_{res} > s_j.E_{res}$) **then**
      $s_i.mode$ = Active
      $s_j.mode$ = Sleep
    else
      $s_i.mode$ = Sleep
      $s_j.mode$ = Active
    end if
  end if
end for

Fig. 4 Pseudocode of sleep scheduling in EEPEG-PA

Using the *Pair_ID*, the BS identifies each node pair. The nodes in each pair are denoted as s_i and s_j, where s_j is the close neighbour to s_i as discovered during the one-hop neighbour node pairing. Initially, node s_i is assigned an active mode while node s_j switches to sleep mode. Node s_i remains active for several rounds until its residual energy, E_{res} is below 10% of its initial energy, *En*. At this point, node s_j switches to active mode and node s_i switch to sleep mode. Node s_j remains active for the next rounds until its residual energy is below 10% of its initial energy. At this point, for each of the remaining rounds, a node in the pair with the greatest amount of remaining energy with the greatest amount of remaining energy is chosen as the active node while the other node switches to sleep mode.

3.3 Chain leader selection phase

Based on a weight value Q of residual energy of the active nodes and distance from the BS, the BS selects a chain leader (CL) in each region from the active nodes in each round. The active node, s_i, with the greatest weight ratio is chosen.

$$Q_{res}(s_i) \tag{3.3}$$

$$d(s_i, BS) = \sqrt{(xs_i - x_{BS})^2 + (ys_i - y_{BS})^2} \quad (3.4)$$

3.4 Minimum spanning tree formation phase

In this phase, considering each region as a connected undirected graph, *G (V, E)*, here V is the set of all vertices, which represents the active nodes in each region and *E* is the set of the edges representing the links between the active nodes. In process to connect all the active nodes in *V* together with the minimal total weighting for their edges, the BS builds a minimum spanning (MSP) tree in each region with the CL as the root using prim's algorithm as follows: Initially, for each region, the CL node is put in the tree.

Next, in each iteration, a minimum weighted edge is selected from an active node in the tree to an active node, not in the tree, and that edge is added to the tree. The active node that has just been incorporated in the tree will transmit its data through that edge, which represents a link of distance, *d*. This process is repeated till all active nodes are added to the tree, as shown in Fig 5.

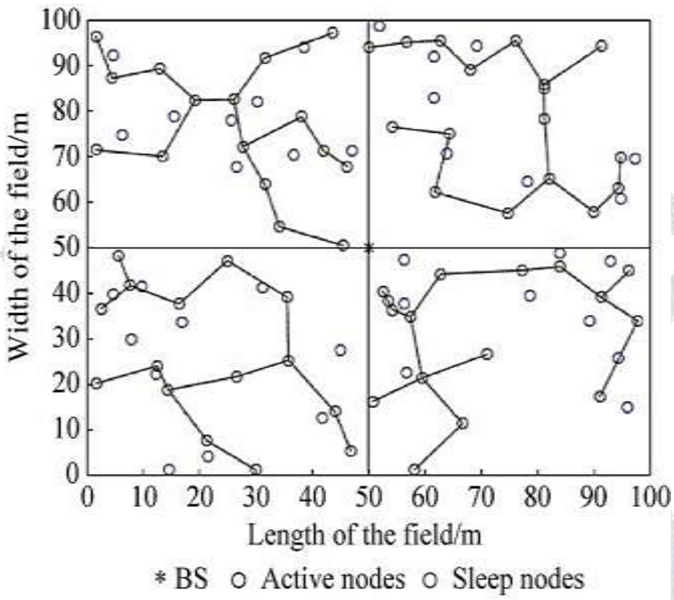

Fig. 5 Minimum spanning tree in EEPEG-PA

3.5 Data transmission phase

The BS computes the routing information for each active node in each region. This information includes the parent node ID and a TDMA schedule for when each child node will transmit the data to its parent node in its time slot. After receiving this information, each child node transmits its sensed data and residual energy data to its parent node. The data is received by the parent nodes, that combine it with their own sensed data and residual energy data.. This is done along the tree in each region until data is received by the CL nodes. The CL nodes then combine this data together with their own sensed data and residual energy data and then finally transmit it to the BS.

After this phase, the sleep scheduling phase and the phases that follow are repeated until all the nodes in the network are dead.

4 SIMULATION AND ANALYSIS OF RESULTS

A MATLAB simulation of EEPEG-PA is carried out to evaluate its performance using simulation parameters in Tab. 1. For a fair comparison with PEGASIS, we deploy the BS at the centre of the PEGASIS network and utilize the BS to construct the chain.

No.	Simulation Parameter	Values
1.	Simulation Area	100 m x100 m
2.	Network size	100 nodes
3.	*Eelec(ETx & ERx)*	50 nJ/bit
4.	E_{fs} (free space)	10 pJ /bit/m^2
5.	E_{mp} (Multipath fading)	0.0013 pJ/bit/m^4
6.	Initial Energy of nodes (*En*)	0.5J
7.	HELLO-bit packet size	30
8.	*K*- bit data packet size	4 000
9.	Simulation rounds	5 000
10.	Sensing range (*Rs*)	10 m

Tab 1. Simulation parameters used

4.1 Network lifetime

The findings of the simulation are as shown in Fig 6. In PEGASIS, the first node and last node die after 1135 and 2270 rounds, respectively. In EEPEG-PA, the first node and last node die after 2122 and 4516 rounds, respectively. Therefore, EEPEG-PA performs 1.87 times and 1.98 times better than PEGASIS in analyzing when the first and last node die.

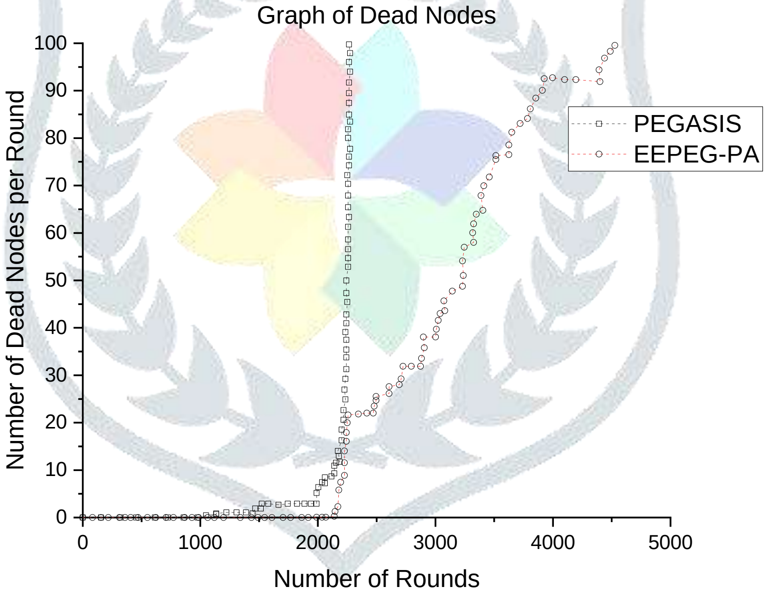

Fig. 6 Growth curve of dead nodes

4.2 Residual energy

Fig. 7 exhibits the energy utilization of the two protocols. The results show that the energy utilization in the EEPEG-PA network is less than that of the PEGASIS network and therefore has more residual energy per number of rounds in comparison to the PEGASIS network.

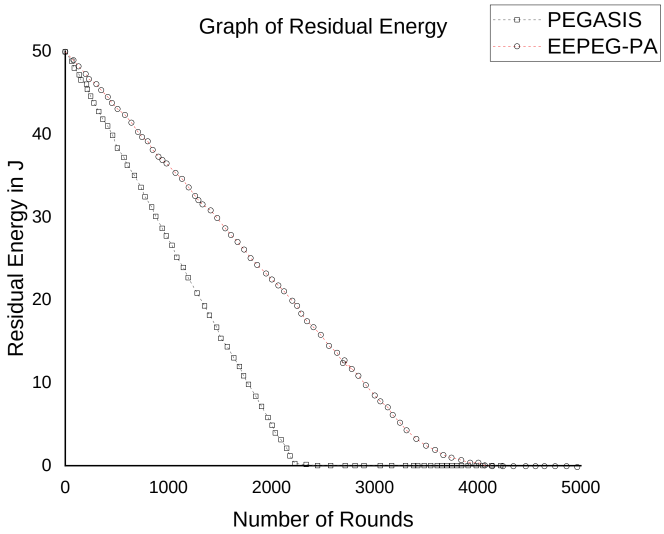

Fig. 7 Energy utilization

5 CONCLUSION

In this paper, we come up with a new power-aware sleep-scheduled tree-based routing protocol to extend the lifetime of the sensor nodes in the wireless sensor network. In the proposed routing scheme, battery power can be saved by switching off some nodes that sense the same data. Energy utilization due to nodes switching from one mode to another is minimized by ensuring that the paired nodes do not switch between the active and sleep modes in each round of communication, thus maximizing Sensor Network Life. Selection of the CL role in each round is made based on remaining power and distance from the base station, thus improving energy efficiency and lifetime in the network.

Further, routing using the minimum spanning tree minimizes the energy utilization of nodes since the nodes communicate the data to their nearest parent node. The MATLAB simulation demonstrated that the proposed EEPEG-PA approach attains a more extended network lifetime in comparison to PEGASIS.

REFERENCES

[1] G. V. Selvi and R. Manoharan, “A Survey of Energy Efficient Unequal Clustering Algorithms for Wireless Sensor Networks,” *International Journal of Computer Applications*, vol. 79, no. 1, pp. 975–8887, 2013.

[2] S. Babaie and S. S. Pirahesh, “Hole Detection for Increasing Coverage in Wireless Sensor Network Using Triangular Structure,” Mar. 2012, Accessed: Aug. 15, 2021. [Online]. Available: https://arxiv.org/abs/1203.3772v1

[3] S. E. Collier, “The Emerging Enernet: Convergence of the Smart Grid with the Internet of Things,” *IEEE Industry Applications Magazine*, vol. 23, no. 2, pp. 12–18, Mar. 2017, doi: 10.1109/MIAS.2016.2600737.

[4] P. Lohan and R. Chauhan, “Geography-informed sleep scheduled and chaining based energy efficient data routing in WSN,” *2012 IEEE Students’ Conference on Electrical, Electronics and Computer Science: Innovation for Humanity, SCEECS 2012*, 2012, doi: 10.1109/SCEECS.2012.6184802.

[5] N. D. Tan and N. D. Viet, “SSTBC: Sleep scheduled and tree-based clustering routing protocol for energy-efficient in wireless sensor networks,” *Proceedings - 2015 IEEE RIVF International Conference on Computing and Communication Technologies: Research, Innovation, and Vision for Future, IEEE RIVF 2015*, pp. 180–185, Feb. 2015, doi: 10.1109/RIVF.2015.7049896.

[6] M. Pramanick, C. Chowdhury, P. Basak, Md. A. Al-Mamun, and S. Neogy, “An energy-efficient routing protocol for wireless sensor networks,” *Proceedings - International Conference on 2015 Applications and Innovations in Mobile Computing, AIMoC 2015*, pp. 124–131, Apr. 2015, doi: 10.1109/AIMOC.2015.7083840.

[7] M. Chenait, B. Zebbane, C. Benzaid, and N. Badache, “Sleep scheduling with predictive coverage redundancy check in wireless sensor networks,” *Proceedings of the International Symposium on Wireless Communication Systems*, vol. 2016-April, pp. 366–370, Apr. 2015, doi: 10.1109/ISWCS.2015.7454365.

[8] S. Lindsey and C. S. Raghavendra, “PEGASIS: Power-efficient gathering in sensor information systems,” *IEEE Aerospace Conference Proceedings*, vol. 3, pp. 1125–1130, 2002, doi: 10.1109/AERO.2002.1035242.

[9] A. Arman and D. S. Saini, “WSN node lifetime enhancement based on hybrid protocol,” *International Conference on Computing, Communication and Automation, ICCCA 2015*, pp. 518–522, Jul. 2015, doi: 10.1109/CCAA.2015.7148432.

[10] A. Arman and D. S. Saini, “WSN node lifetime enhancement based on hybrid protocol,” 2015, Accessed:Aug.15,2021.[Online].Available: http://172.16.73.104:8080/jspui/handle/123456789/6604

[11] S. Vahabi, S. P. Mojab, M. Eslaminejad, and S. E. Dashti, “EAM: energy aware method for chain-based routing in wireless sensor network,” *Journal of Ambient Intelligence and Humanized Computing 2021*, pp. 1–13, Apr. 2021, doi: 10.1007/S12652-021-03278-7.

[12] L. Chan, K. Gomez Chavez, H. Rudolph, and A. Hourani, “Hierarchical routing protocols for wireless sensor network: a compressive survey,” *Wireless Networks 2020 26:5*, vol. 26, no. 5, pp. 3291–3314, Jan. 2020, doi: 10.1007/S11276-020-02260-Z.

[13] N. D. Tan and N. D. Viet, “SSTBC: Sleep scheduled and tree-based clustering routing protocol for energy-efficient in wireless sensor networks,” *Proceedings - 2015 IEEE RIVF International Conference on Computing and Communication Technologies: Research, Innovation, and Vision for Future, IEEE RIVF 2015*, pp. 180–185, Feb. 2015, doi: 10.1109/RIVF.2015.7049896.

[14] M. Shokouhifar and A. Jalali, “A new evolutionary based application specific routing protocol for clustered wireless sensor networks,” *AEU - International Journal of Electronics and Communications*, vol. 69, no. 1, pp. 432–441, Jan. 2015, doi: 10.1016/J.AEUE.2014.10.023.

[15] M. Chenait, B. Zebbane, C. Benzaid, and N. Badache, “Energy-efficient coverage protocol based on stable and predictive scheduling in wireless sensor networks,” *Computer Networks*, vol. 127, pp. 1–12, Nov. 2017, doi: 10.1016/J.COMNET.2017.07.015.