# PEER: Proximity-Based Energy-Efficient Routing Algorithm for Wireless Sensor Networks

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**Abstract**

With efficient routing, Wireless Sensor Networks (WSNs) can provide the continuous transmission with improved lifetime. Different routing protocols account for the different results over the WSNs. WSNs acquire special place in modern day network applications such as body area networks, home animations, cellular enhancement, etc. Especially, focusing on the home automation, a lot of routing algorithms and protocols have been proposed over the years that aim at enhancing the lifetime of such networks. Some of the popular algorithms include Relative Direction Based Sensor Routing (RDSR), Convention Routing (CR), Relative Identification and Direction-Based Sensor Routing (RIDSR), etc. These protocols focus over solving the routing loop problem along with improvement in lifetime of the overall network. However, the gains attained by these networks show a relatively less improvement. Thus, considering the similar problem of routing loop and a lifetime, an energy efficient routing algorithm developed on the backbone of the RIDSR is proposed. The proposed routing algorithm uses the proximity approach to find the appropriate set of nodes for transmission, thus, improving lifetime and resolving routing loop issues. The effectiveness of the proposed Proximity Based Energy Efficient Routing (PEER) is demonstrated in as gains attained in terms of improved lifetime, and energy consumption.

**Keywords**: WSNs, Routing algorithm, PEER, RIDSR.

## 1 Introduction

In the recent years, the development of networks with low-cost, low-power, and multifunctional sensors has received focus from both industry and academia. Such sensors are deployed as a unique topology forming a new set of wireless sensor networks (WSNs). WSNs are the special type of ad hoc networks with provisioning of intermittent routing providing a vast range of applications in areas of civilian activities and military expeditions. Development and deployment of sensor is a primary task in utilization of WSNs. These networks, if successfully deployed, can provide vast range of applications such as environment monitoring, telemetry, battlefield surveillance, homeland security, and home automation, etc [2].

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WSNs included set of hybrid nodes deployed as sensors that communicate with each other as well as with the base stations. The base stations are the accounting heads of WSNs [1]. Further, the nodes include manager sensors and normal sensors. All the se sensors are deployed for a particular task of data collection which is transmitted towards the base stations using the routing procedures without forming any loop. A loop in the routing can waste the resources, especially energy. Being dependent on the energy for operations, these networks require efficient management of the energy to form a reliable and a continuous network. Routing is one area, if applied correctly, can save a lot of resources and can prevent wastage of a certain amount of energy. An efficient routing algorithm aims at providing a loop free path between the nodes of the networks to relay data without any wastage of network resources. There are a lot of routing algorithms and protocols developed over the years, particularly focusing on the loop free and energy consumption of the sensors. Some of the popular algorithms include Relative Direction Based Sensor Routing (RDSR), Convention Routing (CR), Relative Identification and Direction-Based Sensor Routing (RIDSR), etc. The routing mechanisms have considered the characteristics of sensor nodes along with the architecture and application requirements [9].

In this paper, the gains attained by the existing routing protocols and algorithms have been further improved by developing a new routing algorithm for energy efficient transmission. The proposed routing algorithm provides a stable and loop free path selection between the network nodes. The proposed routing algorithms use the proximity approach [11] initially proposed for flying networks. The proximity approach allows selection of nodes with improved connectivity, thus, providing a continuous connectivity with enhanced lifetime.

The rest of this paper is organized as follows. A background and motivation are depicted in Section 2. The proposed algorithm is depicted in the Section 3. The performance analysis and simulation results are shown in Section 4. Finally, Section 5 concludes the paper.

## 2 Background and Motivation

Wireless sensor networks (WSNs) are the special family of ad hoc networks with nodes capable of forming an intermittent connection. These networks allow formation of static topology that can be used for a particular task of data gathering and analyses [4] [14]. These networks, however, suffer major energy loss during their operations. Thus, energy is one of the constraint for efficient transmission in these networks. Over the years, a lot of energy efficient routing approaches have been developed that aims at enhancing the lifetime of WSNs. Heo and Varshney [6] proposed an intelligent algorithm for cluster based WSNs. The algorithm developed by authors primary focuses on the energy issues of the WSNs. Coverage, uniformity, and time are the parameters considered in their approach. The authors further developed an energy aware approach for mobile wireless sensor networks [5]. Their algorithm provides an energy efficient solution for routing over mobile sensors. Kulik *et al.* [7] presented a negotiation based sensor protocols that allows efficient dissemination of information in energy constrained networks. The authors also discussed the adaptive protocols for wireless sensor networks. One of the other approaches is Relative Direction-based Sensor Routing (RDSR) [10] scheme. In this approach, the monitor area is divided into sectors and setup a manager node in each sector. The sensors transmit the data to the manager node in its corresponding sector, which further transmits it to the base station. Another approach to its extension is the RIDSR [13] which includes identification apart from the direction based routing only. RIDSR is capable of providing a loop free and energy efficient provisioning of data between the sensor nodes and the base station. Some of the other approaches include, minimum cost forwarding in sensor networks by Ye *et al.* [15], application specifying routing by Heinzelman *et al.* [3], annealing algorithm for WSNs by Lin *et al.* [8], and power efficient routing in WSNs by Slijepcevic and Potkonjak [12].

All these approaches focus on lowering the chance of loop for energy efficient routing in wireless sensor networks. However, the gains attained in these approaches are quite low, and requires further improvement. Thus, focusing on the routing loop and energy efficiency, a new proximity based energy efficient routing (PEER) algorithm is proposed that requires less iterations and consumes less energy in comparison with the existing approaches.

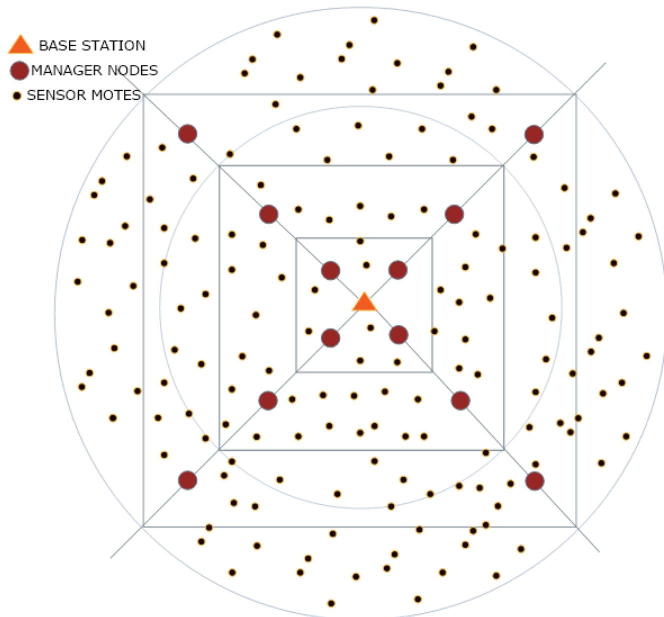


Figure 1: Sensor Deployment

## 3 Proposed Routing Approach: PEER

The proposed Proximity based Energy Efficient Routing (PEER) aims at the utilization of proximity calculation approach [11] for finding the appropriate set of nodes that can relay without any loop and improved connectivity. The system model comprises of a network area divided into a set of clusters with nodes classified as base node, manager nodes, and regular sensor nodes, as shown in Figure 1. The deployment and arrangement of nodes are performed using the similar one defined in RDSR and RIDSR approaches. Although, the network logical proximity is defined over the geographical constraints of the network, however, the proximity used in this paper is derived using Ref. [11], which is defined over the network sensitivity $N_s$. Network sensitivity defines the optimized connectivity between the network nodes for efficient routing. Sensitivity allows selection of appropriate links within the network that can sustain for maximum lifetime. Thus, for a network operating with varied classification of nodes, $N_s$ will be computed using Ref. [11] as:

$$N_s = \frac{R}{E}\left[\eta_1 \frac{L_s}{L_a} + \eta_2 \frac{1}{D}\right], \tag{1}$$

where $E$ is the energy available with the node, R is the geographical distance between the nodes, $L_s$ is the link speed, $L_a$ is the link availability, $D$ is the distance of the node from the base station, $\eta_1$ and $\eta_2$ are the energy constants defined for energy proximity between the two linked nodes such that $0 \leq (\eta_1, \eta_2)$ $\leq 1$. Now, the proximity $P_s$, for a node to be selected as a next hop, will be computed as:

$$P_r = N_s \times W, \tag{2}$$

where $W$ is the weight defined for the link between the node and the base station controller. This value is selected based on the hop distance between the node and the base station controller. Nodes, with more close range towards the base station posses higher weight than the those with distance larger from the base station. $P_r$ forms the basis of the selection algorithm for routing in the proposed sensor network setup.

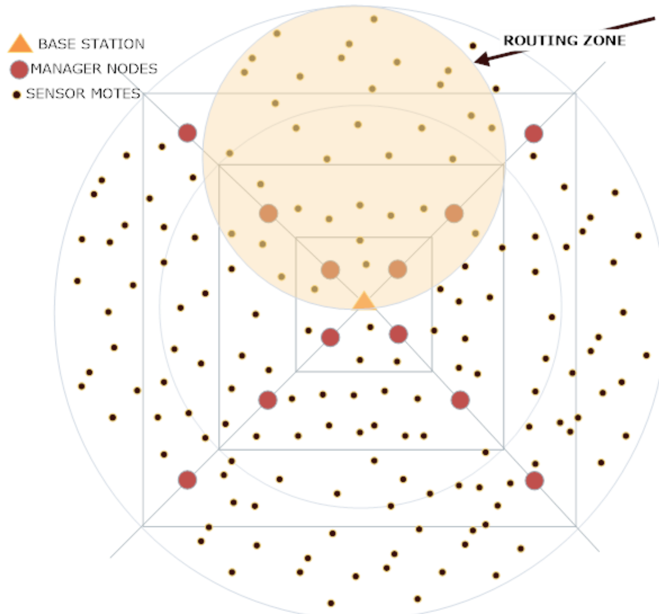


Figure 2: Initial Routing Zone

**Algorithm 1** Route Selection and Rehabilitation

**Require:** $source, destination$
**Ensure:** $network\_deployment = true$

```
j=1
while (j ≤ V) do
    Compute Weight W[j]
    Compute N_s
    Compute P_r
    if (W[j] ≥ W_TH) & (P_r ≥ P_r^TH) then
        Save path[j] ⟵ j
    else
        rehabilitate and adjust W
    end if
    j=j+1
end while
transmit ⟵ shortest_route[path]
```

## 3.1 Route Selection

The proposed PEER algorithm aims at selection of nodes that can form a loop free path as well as provide prolonged connectivity with enhanced lifetime. The selection of routes is based on the proximity, network sensitivity and the distance of the node from the base station. The steps involved in the selection of an appropriate set of nodes that may account for loop free paths are as follows:

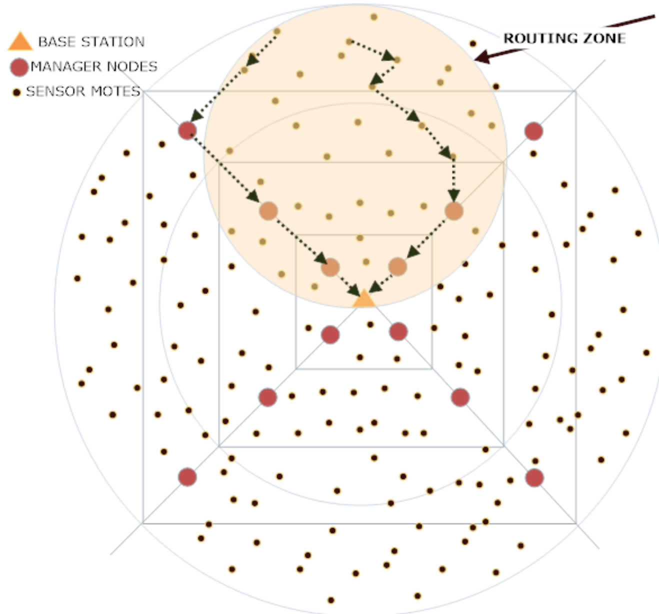


Figure 3: Final Route Selection Using Algorithm 1

i. The whole network is initialized, during which, each of the nodes computes their weight based on the geographical deployment from the base station.

ii. Based on the initial values attained, the network proximity is computed for each node.

iii. Nodes with proximity above the certain threshold value, advertises themselves for possible selection of the route towards the base station.

iv. During routing, next hop will be selected from the other cluster via the nearest manager node. It is to be noted that, during this procedure, a node might select the node from its own cluster after 1+ step. However, with this simple mechanism, a loop in the network can easily be avoided.

v. This loop free path selection will follow a zig-zag pattern towards the base node. Now, a similar procedure is repeated with other nodes that has data ready to be transmitted towards the base node.

vi. The whole procedure is repeated till all the cycles or the potential loops are removed in the network topology.

### 3.2 Route Rehabilitation

The possibility of link breakage in the sensor network is based on the energy consumption of the network nodes, and the rate of depletion of network resources. With almost, negligible routing loop issues in path selection, depletion of network nodes also reduces, thus, limited amount of route rehabilitation is required. However, the case may prevail, where the network energy goes extremely low, and route rehabilitation is required. Thus, in those scenarios, a proximity is computed over the initially analyzed sensitivity, but the weight is added with a value of +1 towards the manager node providing an altogether new set of nodes for route selection. Further, after the procedural rehabilitation, similar procedure as that of route selection is used to setup the new route. Both route selection and rehabilitation explained in this paper allows selection of energy efficient routes with prolonged connectivity. Algorithm 1 presents the steps for the selection of an appropriate set of nodes for energy efficient routing in WSNs. The diagrammatic view of the proposed PEER algorithm is presented in Figure 2 and Figure 3.

| PARAMETER | VALUE |
|---|---|
| Area | $35 \times 35\ m^2$ |
| Radio Range | 5 m |
| Total Sensor Nodes | 250 |
| Initial Energy (Joule) | 100 |
| Transmission Energy Consumption (Joule) | 0.5 |
| Receival Processing Energy (Joule) | 0.25 |
| Maximum Iterations | 100 |
| Simulation Runs | 100 |

Table 1: Network Configurations for Performance Analysis

## 4 Performance Evaluation

The proposed proximity based energy efficient routing algorithm was evaluated for improvement with the existing RDSR [10], and RIDSR [13] routing algorithms. The simulations were configured to operate with sensor nodes ranging between 50 to 250 arranged in an area of $35 \times 35\ m^2$. Each node was allowed an initial energy of 100 Joules with transmission consumption of 0.5 Joule per transmission, and 0.25 Joule per receival of data. The network was evaluated for energy consumption against the increase in the number of nodes, number of iterations required to route in contrast with energy consumption, and the number of iterations required to acquire mean hops for stabilized routing. Analyses show that the

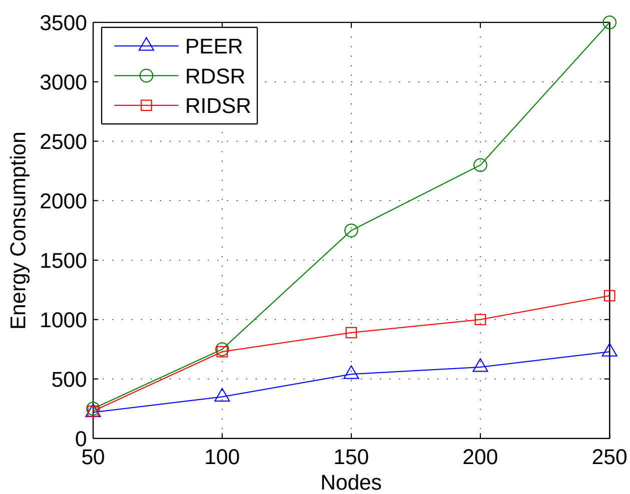


Figure 4: Energy consumption vs. nodes

proposed routing algorithm PEER consumed 71% less energy than the RDSR, and 43.3% less energy than the RISDR algorithms as shown in Figure 4. The selection of proximity based nodes provides a relatively no loop path for data transmission, thus, lowering the amount of consumed energy. Also, the number of retransmission required for rehabilitation is relatively less in the proposed PEER algorithm.

Further, with lesser loops, and non-complex selection of paths for a route between the sensors and the base station, the proposed PEER algorithm requires 33.3% less iterations than the RDSR, and 20% less iterations than the RIDSR algorithm, as shown in Figure 5. Further, the mean hops acquired by RIDSR and PEER remain constant during the initial 5 iterations, whereas for RDSR it varies from 32 to 5, as shown in Figure 6. Finally, a comparative chart between RDSR, RIDSR, and PEER is presented in Table 2.

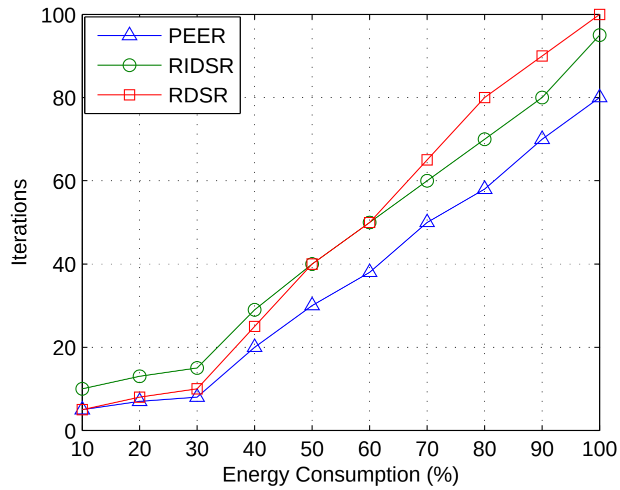


Figure 5: Number of iterations vs. energy consumption using Algorithm 1

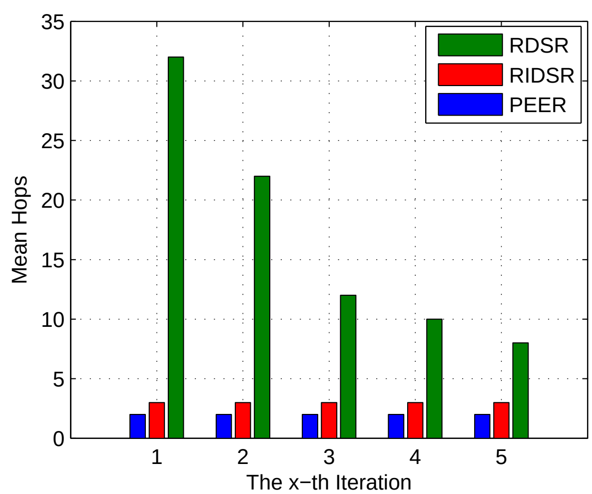


Figure 6: Mean hops vs. x-th iteration for zone presented in Figure 2

| PARAMETER | RDSR | RIDSR | PEER |
|---|---|---|---|
| Routing Loop Problem | Yes | No | Yes |
| System Lifetime | Least | Less | More |
| Energy Consumption | More | Less | Least |
| Mean Hop | More | Less | Least |

Table 2: Comparison Between RDSR, RIDSR, and PEER

# 5 Conclusion

Routing in Wireless Sensor Networks (WSNs) is one of the challenging tasks. Further, depleting energy of the sensor nodes makes it tedious to efficiently route data between the network nodes. Also, routing loops are the other issues to be resolved during the network transmission. In this paper, a new energy efficient routing algorithm based on the network proximity is proposed. The proposed proximity based energy efficient routing algorithm (PEER) provides loop free routing with prolonged connectivity and enhanced lifetime. Analyses proved the effectiveness of the proposed PEER algorithm in comparison with RDSR and RIDSR algorithm in terms of significant gains attained for energy consumption and number of iterations.

# References

[1] K. Akkaya and M. Younis. A survey on routing protocols for wireless sensor networks. *Ad hoc networks*, 3(3):325–349, 2005.

[2] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci. Wireless sensor networks: a survey. *Computer networks*, 38(4):393–422, 2002.

[3] W. B. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan. An application-specific protocol architecture for wireless microsensor networks. *IEEE Transactions on Wireless Communications*, 1(4):660–670, 2002.

[4] W. R. Heinzelman, J. Kulik, and H. Balakrishnan. Adaptive protocols for information dissemination in wireless sensor networks. In *Proc. of the 5th Annual ACM/IEEE International Conference on Mobile Computing and Networking (MobiCom'99), Seattle, WA, USA*, pages 174–185. ACM, August 1999.

[5] N. Heo and P. K. Varshney. A distributed self spreading algorithm for mobile wireless sensor networks. In *Proc. of the 2003 IEEE Wireless Communications and Networking (WCNC'03), New Orleans, LA, USA*, volume 3, pages 1597–1602. IEEE, March 2003.

[6] N. Heo and P. K. Varshney. An intelligent deployment and clustering algorithm for a distributed mobile sensor network. In *Proc. of the 2003 IEEE International Conference on Systems, Man and Cybernetics (SMC'03), Washington, D.C., USA*, volume 5, pages 4576–4581. IEEE, October 2003.

[7] J. Kulik, W. Heinzelman, and H. Balakrishnan. Negotiation-based protocols for disseminating information in wireless sensor networks. *Wireless networks*, 8(2/3):169–185, 2002.

[8] F. Lin and P.-L. Chiu. A simulated annealing algorithm for energy-efficient sensor network design. In *Proc.of the 3rd International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WIOPT'05), Trentino, Italy*, pages 183–189. IEEE, April 2005.

[9] D. Niculescu and B. Nath. Ad hoc positioning system (APS). In *Proc. of the 2001 Global Telecommunications Conference (GLOBECOM'01), San Antonio, TX, USA*, volume 5, pages 2926–2931. IEEE, November 2001.

[10] H. Oh, H. Bahn, and K.-J. Chae. An energy-efficient sensor routing scheme for home automation networks. *IEEE Transactions on Consumer Electronics*, 51(3):836–839, 2005.

[11] V. Sharma, R. Kumar, and N. Rathore. Topological broadcasting using parameter sensitivity-based logical proximity graphs in coordinated ground-flying ad hoc networks. *Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications (JoWUA)*, 6(3):54–72, 2015.

[12] S. Slijepcevic and M. Potkonjak. Power efficient organization of wireless sensor networks. In *Proc. of the 2001 IEEE International Conference on Communications (ICC'01), Helsinki, Finland*, volume 2, pages 472–476. IEEE, June 2001.

[13] C.-E. Weng and T.-W. Lai. An energy-efficient routing algorithm based on relative identification and direction for wireless sensor networks. *Wireless personal communications*, 69(1):253–268, 2013.

[14] Y. Xu, J. Heidemann, and D. Estrin. Geography-informed energy conservation for ad hoc routing. In *Proc. of the 7th Annual International Conference on Mobile Computing and Networking (MobiCom'01), Rome, Italy*, pages 70–84. ACM, July 2001.

[15] F. Ye, A. Chen, S. Lu, and L. Zhang. A scalable solution to minimum cost forwarding in large sensor networks. In *Proc. of the 10th International Conference on Computer Communications and Networks, Scottsdale, AZ, USA*, pages 304–309. IEEE, October 2001.

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