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A Novel Routing Algorithm for Energy Optimization in Wireless Sensor Networks

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ABSTRACT

Wireless sensor networks (WSNs) have become an interesting area to researchers in recent times due to the low cost of sensor nodes, wide application areas and with low or no cost of maintenance after deployment in a target area. Sensor nodes are expected to remain in operation for a longer time without human intervention. However, due to the small size and cost of these nodes, they have been equipped with small batteries with limited energy source. This has been a major constraint to WSNs, since in most cases sensor nodes are deployed in large number where it may be difficult or impossible to replace the batteries of each node when they run out of supplying power. In this study, a novel Routing Algorithm for Energy Optimization in WSNs (RAEO) has been proposed to reduce communication distance among the nodes by transmitting sensed data through the shortest path from source node to the base station along the neighbouring nodes. The simulation results show that our approach reduces energy consumption during data transmission and increases networks lifetime compared with MECN and SPIN protocols. Finally, the proposed algorithm reduces protocol propagation delay and packets loss during data transmission.

Key words: Sensor node, wireless sensor networks, routing algorithm, energy, optimization

INTRODUCTION

Wireless sensor networks (WSNs) are new field that have attracted attention of researcher in recent times. With recent development in wireless communications, analog devices and digital electronics have lead to the development of sensor nodes that are relatively cheap, small in size with low power (Akyildiz *et al.*, 2002). These nodes can communicate untethered in short distances with one another. A sensor node consists of four main component units: sensing unit, processing unit, communication unit and power unit (Gerla *et al.*, 2001). WSNs are collection of sensor nodes ranging from tens to thousands of nodes depending on the area in which they are being deployed. These nodes have ability to organize and communicate among themselves through radio signals (Rabaey *et al.*, 2002; Xin *et al.*, 2008). WSNs consist of distributing sensor nodes, they sense changes in environmental and send the changes to other nodes within the network for further processing. One of the reasons researchers found interest in WSNs is that they can be applied in many areas (Akyildiz *et al.*, 2002; Conner *et al.*, 2004).

Traditionally, WSNs have been used in the context of high-end applications such as battle field surveillance, home security, habitat sensing and seismic monitoring (Clouqueur *et al.*, 2002). Currently, its applications have been extended to healthcare, monitoring movement of vehicles on highways, equipment management services and preventive maintenance, weather sensing, industrial and manufacturing automation and so on (Ma and Yoon, 2005; Chong and Kumar, 2003). Furthermore, WSNs can operate in harsh environments where it may be infeasible or dangerous for human being to reach (Abidoye *et al.*, 2011a). For instance, they can be deployed randomly inside the forest to monitor the movement and interactions of wild animals.

However, in spite of the innumerable applications of wireless sensor networks, they have some constraints: they have limited energy capacity, limited hardware resources (i.e., limited memory and processing capability), scalability and fault tolerance (Guo *et al.*, 2010; Al-Karaki and Kamal, 2004). Among all these, energy has been a major constraint to sensor nodes. Due to their small size and low cost, they have been equipped with small batteries with limited energy source (Gao *et al.*, 2010). The small batteries supply power to the whole sensor node and hence play important role in determining sensor node lifetime (Heinzelman *et al.*, 2002).

It is expected that these batteries remain in operation for years before they can be replaced. Sensor networks in most cases are deployed in remote areas, hostile environment or unreachable areas where it may be difficult or even impossible to change the batteries when they run out of energy (Fu *et al.*, 2012). During sensor networks operation, data communication (i.e., data transmission and reception) is a major energy consumption. It consumes more energy than the rest of all other components that make up a node (Pottie and Kaiser, 2000). Failure of a node due to limited energy, sensor nodes within the network may not be able to communicate with each other. Hence, the optimal operation of a WSN is prolonging the life of energy source in order to extend network lifetime utilization. One of the ways of achieving this is through the development of an energy efficient routing protocol (Shanoon-Aiyal *et al.*, 2011). Data routing occurs at networking layer and is the process of selecting different paths in a network between the source and the destination upon request of data transmission (Chu *et al.*, 2002). Routing in sensor networks is different from wireless ad hoc networks like cellular networks and mobile ad hoc networks because of some specific characteristics that distinguish them which pose a great challenge to wireless sensor nodes (Shan *et al.*, 2011).

Firstly, significant redundant data is generated by the WSNs during transmission because multiple sensors may sense the same data within a particular sensing field. This redundancy needs to be eliminated to reduce energy consumption and to increase bandwidth utilization in the network (Gao *et al.*, 2010).

Secondly, sensor nodes have limited transmission power, processing capability and memory. These require cautious resource management.

Lastly, due to large number of sensor nodes, it is not possible for each node to have global addressing like Internet Protocol (IP) address used in mobile ad hoc network (Akkaya and Younis, 2005; Guo *et al.*, 2010).

The main aim of this research is to develop a new routing protocol that is energy efficient to increase WSNs lifetime.

There are several routing protocols for WSNs that have been developed for the efficient transmission of data from the source node to the sink (base station).

Depending on the network structure, routing protocols in WSNs can be classified into three: Location-based protocol, Data centric protocol and hierarchical protocol.

Location-based protocol: Most routing protocols for WSNs depend on sensor node's location information to determine energy consumption.

Energy consumed during data transmission depends on the distance over which data is transmitted. Location based protocol uses the position information to transmit data to the target area rather than broadcasting the data to the whole network (flooding) (Dai *et al.*, 2009). For instance, to sense a particular target area using this technique, sink sends a query to specific sensor nodes in the target area and not to the whole network. Tremendous amount of energy can be saved through this method. Overhearing which is one of the wasteful energy consumption is avoided through this method.

Minimum Energy Communication Network (MECN) (Rodoplu and Meng, 1999) is one of the protocols that used this technique. MECN is a self-configuring protocol that keeps network connectivity is spite of sensor mobility. It calculates optimal path from each node to the sink. Energy consumed by MECN is minimized and increases network lifetime.

However, MECN does not consider energy available to each node before sending data to the next node. Also, MECN uses the same nodes to transmit its data to the sink. These nodes will run out of energy quickly and will not be able to receive and/or forward data to the neighbour node or to the sink thus leads to loss of data within the network.

Data centric protocol: Data centric protocol involves the transmission of data from source node to the sink through the intermediate nodes. The intermediate nodes perform data aggregation on the received data and forward it to the next neighbouring nodes. The process continues until the data gets to the sink. The process saves energy because less data is transmitted from source node to the sink.

A good example of data centric protocol for WSNs is Sensor Protocols for Information via Negotiation (SPIN) was proposed by (Kulik *et al.*, 2002). The main objective of this protocol is to efficiently transmit sensed data by individual sensor nodes to all neighbouring nodes in the network with the assumption that all sensor nodes are potential base stations. With this assumption in mind, it assists a user to query a node and receive the needed information instantly. SPIN operations are based on two main mechanisms: data negotiation and resource adaptation algorithms.

Data negotiation allows the sensor nodes to negotiate with each other before data transmission in order to eliminate redundant and non-useful data throughout the network. Resource adaptation enables sensor nodes running SPIN to monitor their activities based on the current state of their energy sources. Each node with the help of its resource manager can keep track of its current energy level before data transmission. A node may reduce or totally back off from participating from some activities if it's current energy level is low. SPIN protocols save more energy than existing traditional data-centric and MECN protocols by prolonging sensor nodes longevity and hence extends network lifetime.

However, data advertisement method of SPIN cannot guarantee data delivery. The relaying node (intermediate node) may not have interest in the data it receives and stops forwarding it to the next neighbouring node or to the base station.

Hierarchical routing protocol: Hierarchical routing protocol was originally proposed for wired networks (Al-Karaki and Kamal, 2004). Its concept is used to perform energy efficient in WSNs. Its architecture involves using higher energy nodes to process and transmit received data. While sensor nodes with low-energy can be used to perform sensing within the neighbourhood of target area. Hierarchical routing in WSNs involve partitioning of sensor nodes into different clusters and nodes are assign different roles to play i.e cluster heads, gate way nodes and ordinary nodes in each cluster (Xin *et al*., 2008). This protocol is energy efficient, improves network scalability and increases network lifetime.

Moreover, LEACH protocol (Heinzelman *et al*., 2002) and PEGASIS protocol (Lindsey and Raghavendra, 2002) are examples of hierarchical routing protocol.

However, LEACH Protocol is the first energy efficient hierarchical routing protocol developed for WSNs other protocols developed thereafter were based on it (Abidoye *et al*., 2011b).

LEACH operation is divided into rounds. Each round consists of setup phase and steady state phase. During the set-up phase, the network is organized into a set of clusters and a node is randomly selected based on probability as Cluster Head (CH). Elected CHs manage the clusters and are given the responsibility to carry out multiple tasks. They act as data collector, aggregate and transmit it to the base station. LEACH allows rotation of CHs in each cluster for even distribution of energy to avoid sudden death of a node when it runs out of energy. LEACH achieves reduction in energy consumption compared with existing traditional protocols. Hence, prolongs network lifetime.

However, it has several shortcomings. Firstly, CHs are not evenly distributed in LEACH, CHs may be selected from one side of the network and if this happens more energy will be consumed during data transmission.

Secondly, CHs selection method is based on probability which will lead to increase in overhead and results to increase in energy consumption.

Based on the above review, there is need to develop a new routing protocol that will take care of all the shortcomings mentioned above, more energy efficient, reduce data propagation delay and loss of packets during transmission.

PROPOSED ALGORITHM FOR ROUTING PROTOCOL

This algorithm is developed for optimal data transmission between the source nodes and the base station by intelligently select a reliable and efficient path to the base station.

In our algorithm, the following assumptions were made:

- The sensor network is composed of N stationary nodes and they are all identical
- Sensor nodes are densely and uniformly distributed in sensor field
- Each node has the ability to forward data to the next node or to the base station
- All nodes have the same initial energy in the sensor network
- All nodes have the same maximum radio (transmission) range R

Algorithm:

Step 1:	N sensor nodes are uniformly distributed in a target area
Step 2:	Let n_1, n_2, n_3, n_4, ... n_N be the number of sensor nodes
Step 3:	Initially all nodes N are inactive mode to conserve energy
Step 4:	Nodes wake-up from inactive mode to active mode upon sensing changes in their environment
Step 5:	Each data sensed by a node is assigned a unique number id and broadcast it to all nodes in the network
Step 6:	Each node that receives the id checks if it is already store in its memory
	If yes, the data will be discarded. It shows the data has been sensed and forwarded by other nodes
Else:	
Step 7:	A node n_i selects M nodes where M is set of all nodes within its transmission range R
	End if

Algorithm: Continue

Step 8: Select node n_k with shortest distance to the Base station such that $n_k \in M$

Step 9: Check whether the current energy of
n_k>Ave. energy of M
if yes, n_i sends data to n_k
Else $n_k \leftarrow d(n_i, n_k) - 1$ and go to step 7
End if

Step 10: Check whether the data has reached the Base station
if yes, broadcast the data id to all nodes (to prevent other nodes send similar data through other paths)
Else go to step 4

End if
End

During initialization phase, sensor nodes are distributed uniformly in a target area and remain inactive prior they detect any event in order to conserve energy. When nodes detect any event, they change from inactive to active mode and select all nodes within their transmission range R as shown in Fig. 1 below. For simplicity, a node is picked as source node to transmit the event to the next node and finally to the base station. The above algorithm transmits the event detected from source node to the base station through the shortest path. However, Fig. 2 shows flowchart of the proposed routing protocol.

Simulation and analysis: The main aim of this research work is to reduce sensor nodes' energy consumption during data transmission which has been a major energy consumption and loss of packets. In order to evaluate the performances of our proposed algorithm, RAEO is simulated with MECN and SPIN protocols using OPNET modeler 16.1 simulator. We randomly distributed 100 sensor nodes into the sensing field. Other parameters used for the simulation are shown in the Table 1.

In order to know how efficient our proposed algorithm (RAEO) is, it was simulated with MECN and SPIN protocols. The simulation results as shown in Fig. 3 below show that first node dies in

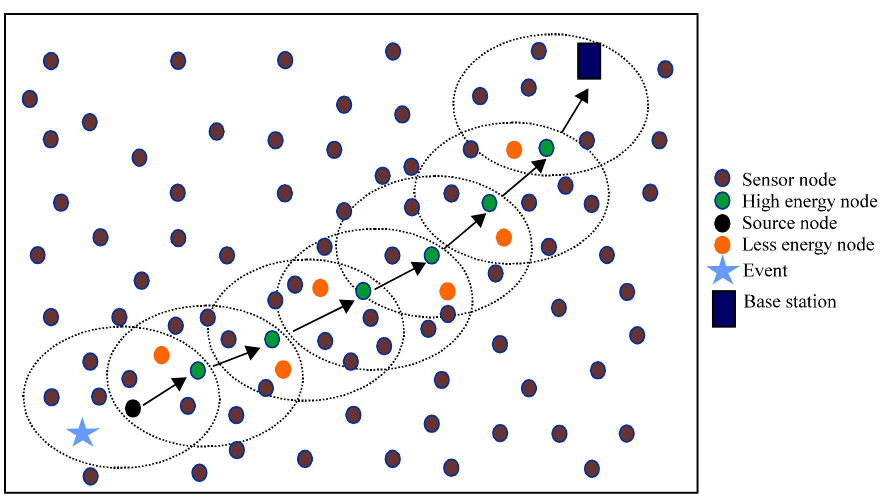

Fig. 1: Data routing

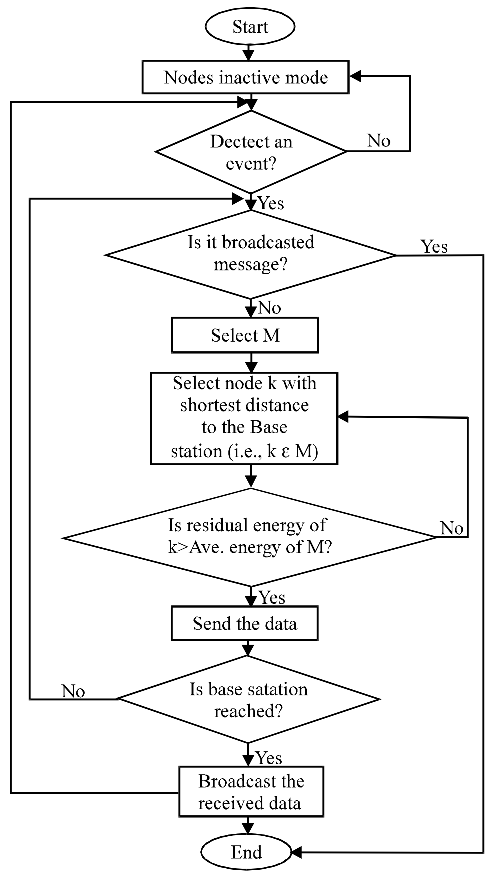

Fig. 2: Flowchart of the proposed routing protocol

Table 1: Simulation parameters

Parameters	Values
No. of sensor nodes	100
Network dimension	100 m × 100 m
MAC layer protocol	IEEE 802.11
Nodes initial energy	0.5 J
Transmission range R	50 m
Simulation time	60 sec
Transmit power	0.660 W
Receiving power	0.395 W
Idle power	0.335 W
Base station location	50, 185 m

MECN and SPIN after about 130 and 180 iterations respectively while in RAEO first node dies after about 220 iterations. Moreover, last node dies in MECN and SPIN after about 600 and 710 iterations, respectively while in RAEO last node dies after 800 iterations. This is as a result the relay nodes are selected intelligently by the algorithm.

Thus, RAEO saves energy and hence extending sensor network lifetime.

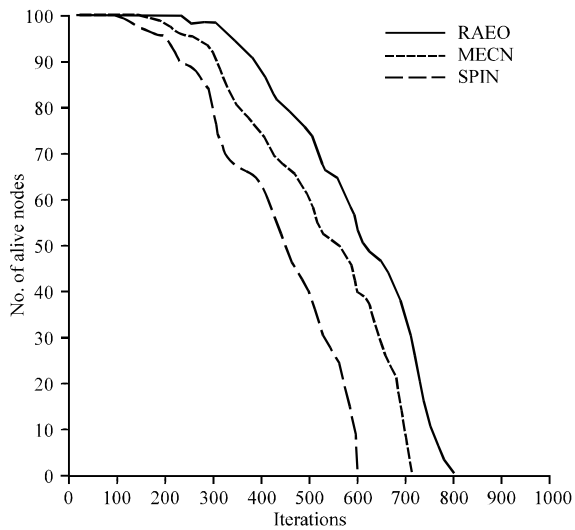

Fig. 3: Number of alive nodes over number of iterations

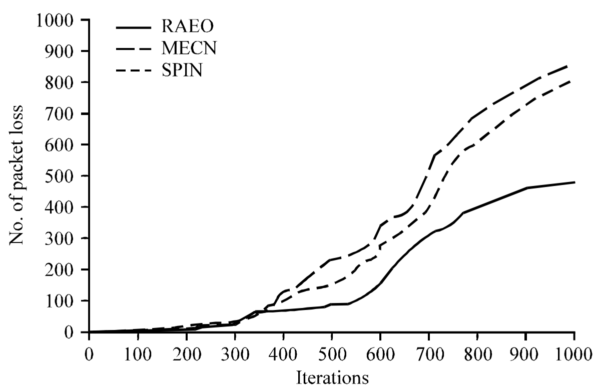

Fig 4: Number of packet loss over number of iterations

Packet loss: Simulation result shows that packet loss in RAEO is minimum compared with MECN and SPIN in Fig. 4. This is so because node that has enough energy to transmit data is selected as relay node. However, after about 550th iteration, packets loss increases because energy in each node has been reduced, most of the nodes do not have enough energy to transmit data as it were initially.

CONCLUSION

In this study, we have proposed a novel routing algorithm for energy optimization in wireless sensor networks. The proposed protocol has carefully selected a node within its transmission range as a relay node to transmit data to the base station through shortest path. The algorithm ensures that only node that has shortest distance to the base station and has more energy than average energy of all nodes within the transmission range of source node is elected as relay node to avoid packet loss during data transmission.

Simulation results showed that RAEO saved more energy than MECN and SPIN protocols and hence extends network lifetime.

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