Enhancing Nodes Lifetime Optimum Protocol for Dissemination of Information in WSN

M. Gholami, A. Panahi

Mohammadreza Gholami
Department of Electrical Engineering,
Saveh Branch, Islamic Azad University,
Saveh, Iran
E-mail: Reza5762@ yahoo.com

Abdorreza Panahi*
Department of Mathematics,
Saveh Branch, Islamic Azad University,
Saveh, Iran
*Corresponding author: panahi53@ gmail.com

Abstract: Challenging issue in Wireless Sensor Networks (WSNs) is assessment of energy and lifetime at different nodes within the networks. Various methods may be employed to improve lifetime (reduce energy consumption). One such method involves balancing loads on nodes when data is being transmitted from source to destination nodes. Multi-path routing techniques can be used for this purpose. In these techniques no global information is available regard the path, making it difficult to create multi-path routes from sources nodes to destination nodes. Another problem with these networks is a routing applied to source nodes independently from that applied used for destination nodes. This creates energy loss and reduces lifetime. To overcome this problem, the present paper makes use of clustering by selecting virtual nodes to gather information from sources and sending it to destination nodes. The New Protocol for Enhancing Nods Lifetime (PENL) is implemented through NS-2.
Keywords: Wireless Sensor Networks (WSN), optimum routing, dissemination of information, enhancing nodes lifetime.

1 Introduction

Sensor networks have experienced a considerable growth over the recent years [4]. These networks are composed of a large number of nodes of very small sensors used to collect and process environmental information [5]. Nodes in sensor networks usually do not have unique addresses, and the information collected through nodes is of greater importance [6]. In addition, the nodes become inaccessible once they are distributed in the environment. They become useless (reach the end of their lifetime) once they consume the available energy [8]. Therefore, energy and its optimization is a major challenge is sensor network and received attention from a large body of research over the past years [1, 3]. To this date, sensor networks have found increasing applications in different areas including military, environmental monitoring, medicine, agriculture, and so on. One data-centric method proposed for routing data in sensor networks is directed diffusion [7], in which nodes use only local data in routing packets. In this method, interest packets are disseminated over the network and to all nodes by basic nodes. Then the nodes containing information of interest (information sources) receive these packets and direct collected information to the destination node. The present paper attempts to overcome problems (e.g. late aggregation, extra explanatory data, and high levels of power consumption) experienced in previous protocols. Figure 1 illustrates the process.
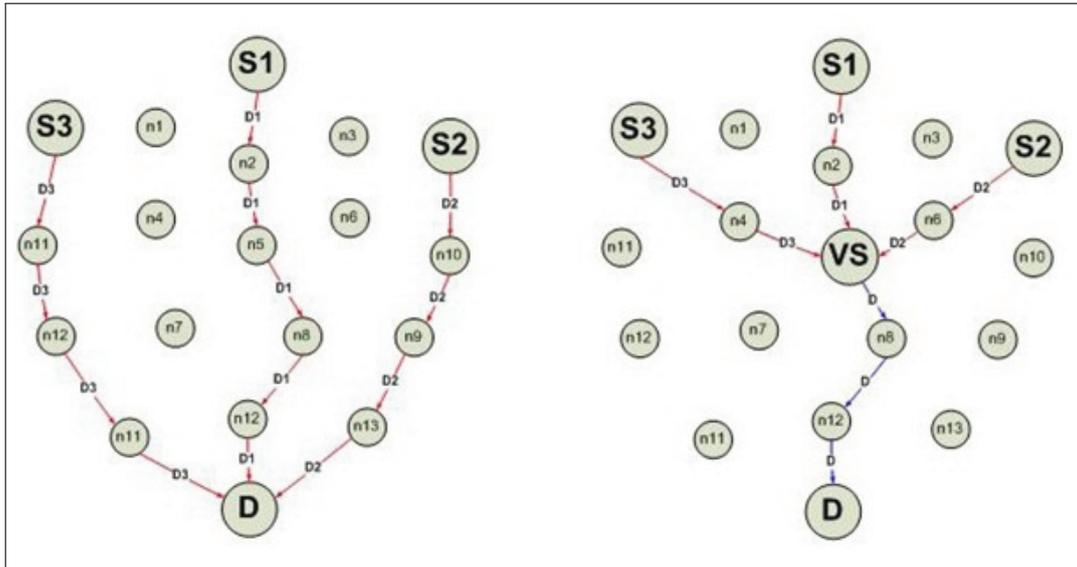
Figure 1: Comparison between routing in MECH (left one) and PENL (right one)

The method uses a virtual node in vicinity of source nodes to collect information and send it to destination nodes. This paper presents PENL and uses the routing method described above to improve lifetime and reduce overload compared to MECH [2], as we shall see in simulation results presented in the final section of this paper.

2 Maximum energy cluster head

In MECH [2], source and destination nodes use characteristics of the graph to determine information that needed to be disseminated and to find a multi-direction efficient path connecting source and destination nodes. To send data, an interest message is disseminated over an area of interest in the network. Each node remembers the node through which it has received information and assigns a gradient to that node. The gradient represents both the direction of information flow and the status of query (which can be active or inactive). If the node is able to predict the next path using the gradient, then it delivers the query to an adjacent node related to that query; otherwise, the query will be sent to all adjacent nodes. The sending node will be recognized as a source. When being send to destination, data is stored in intermediate nodes in order to prevent repeated sending. If one node stops working, other nodes will try to locally recover the path. Once initial exploratory data are sent, the next data will be sent only through reinforced paths. Source nodes alternatively send exploratory data from time to time to update gradients based on dynamic changes in network.

Properties of MECH:

- MECH uses neighbor-to-neighbor or step-by-step in which each node can interpret data.

- Information diffusion is a data-centric method and all connections in a WSN use interests to determine named data for dissemination.

- Nodes are not assigned globally unique addresses and since each node can individually interpret data, it is possible to reduce data load and send data in concise form.
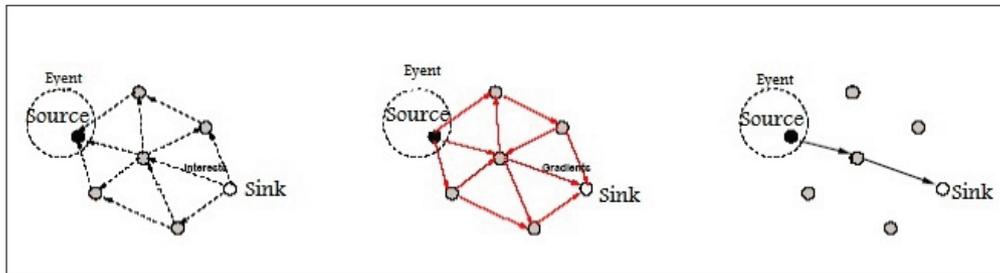
Figure 2: MECH protocol

A drawback of MECH is the increased number of data steps which, in turn, shortens lifetime of nodes and the overall network. NPDI, described below, overcomes these issues.

3 The proposed protocol (PENL)

As seen in C, an appropriate node close to source nodes is selected as virtual node. In D, the virtual node creates a path to destination node. In E, another node adjacent to the first virtual node is selected as the second virtual node. And finally in F, in cases where source nodes do not receive local interest packets for a while, they overlook the virtual node and send collected data directly to the destination node.

3.1 Selecting virtual node

A major and one of the most difficult steps in PENL is selecting virtual node which has to:

- Be spatially close to sources and have the largest number of nodes adjacent to it in order to be able to collect data as quickly as possible.

- Maintain a minimum level of energy above some threshold (e) in order to be able to handle a large amount of data.

Since each node reports its location, it is easy to select a virtual node with the largest number of adjacent nodes close to sources (the goal is to prevent reduction in lifetime as a result of information dissemination). Selection of virtual node in this manner meets the above mentioned properties to a large extent. The minimum distance for the virtual node (denoted by D) can be determined based on node density in the network. In simulations through NS-2, D is equal to 3 steps. As seen in Fig. 3, VS1 meets the above mentioned conditions and therefore is selected as virtual node.
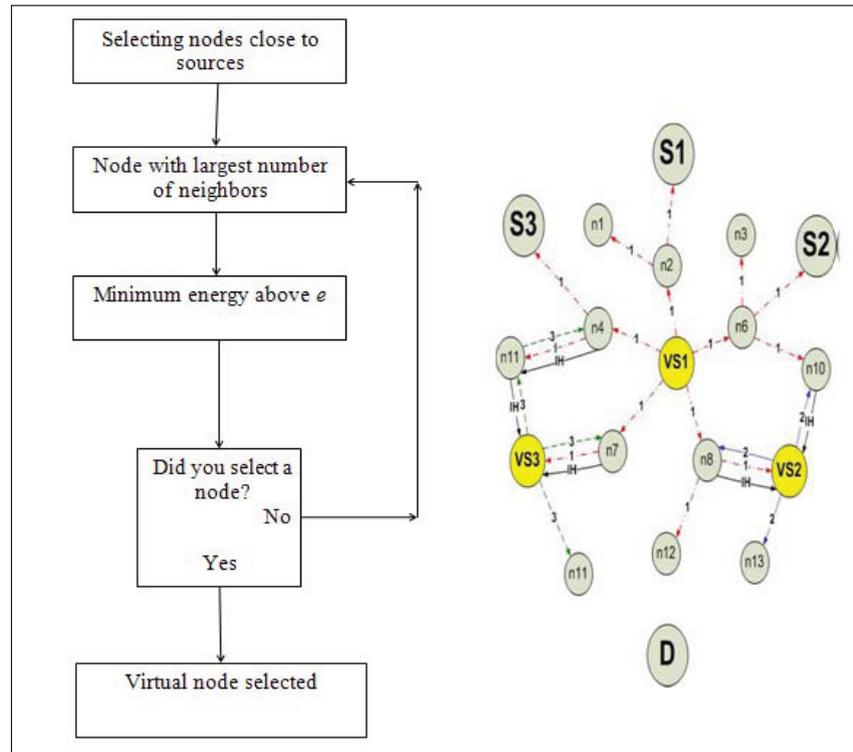
Figure 3: Flowchart for selecting virtual node

3.2 The shortest path

The shortest path problem can be formulated into a linear programming model:

$$
\begin{aligned}
Min \ z &= \sum_{i} \sum_{i \neq j} c_{ij} x_{ij} \\
st: \ \sum_{k \neq j} x_{jk} - \sum_{k \neq j} x_{kj} &= 1 \qquad if \ j \ is \ source \\
\sum_{k \neq j} x_{jk} - \sum_{k \neq j} x_{kj} &= 0 \qquad if \ j \ is \ neither \ source \ nor \ destination \\
\sum_{k \neq j} x_{jk} - \sum_{k \neq j} x_{kj} &= -1 \qquad if \ j \ is \ destination
\end{aligned}
\tag{1}
$$

The model does not account for the direction of edges (links). Each link may transmit data from j to k or in opposite direction. The following graph shows a part of a network where this technique is applied to find the shortest path. Here, the goal is to find the shortest path between Vs and S. Fig. 4 presents a typical graph of a WSN.

$$x_{01} + x_{02} + x_{03} - (x_{10} + x_{20} + x_{30}) = 1$$
$$x_{10} + x_{13} + x_{14} - (x_{01} + x_{31} + x_{41}) = 0$$
$$x_{20} + x_{23} + x_{25} - (x_{02} + x_{32} + x_{52}) = 0$$
$$x_{30} + x_{31} + x_{32} + x_{34} + x_{35} + x_{36} - (x_{03} + x_{13} + x_{23} + x_{43} + x_{53} + x_{63}) = 0$$
$$x_{41} + x_{43} + x_{46} + x_{48} - (x_{14} + x_{34} + x_{64} + x_{84}) = 0$$
$$x_{52} + x_{53} + x_{56} + x_{57} - (x_{25} + x_{35} + x_{65} + x_{75}) = 0 \tag{2}$$
$$x_{63} + x_{64} + x_{65} + x_{67} + x_{68} + x_{69} - (x_{36} + x_{46} + x_{56} + x_{76} + x_{86} + x_{96}) = 0$$
$$x_{75} + x_{76} + x_{79} - (x_{57} + x_{67} + x_{97}) = 0$$
$$x_{84} + x_{86} + x_{89} - (x_{48} + x_{68} + x_{98}) = 0$$
$$x_{96} + x_{97} + x_{98} - (x_{69} + x_{79} + x_{89}) = -1$$
$$a \le x_{ij} \le a + \epsilon \qquad (i, j = 1, 2, \ldots, 9)$$
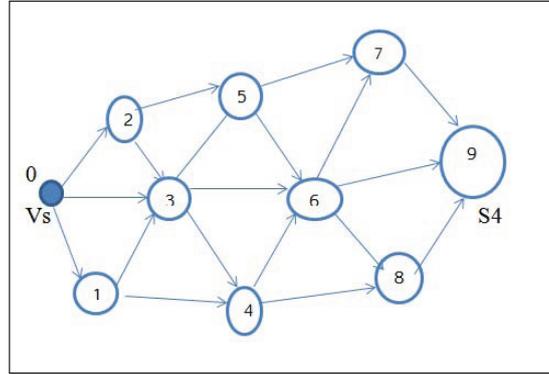$$Min\ z = a_{01}x_{01} + a_{02}x_{02} + \ldots + a_{89}x_{89}$$

Figure 4: Connecting paths in a typical graph

3.3   Selecting a new virtual node

Since virtual node is required to handle a large amount of data, it will be eliminated once its energy is used up. To prevent this, a new virtual node will be selected after a certain period of time is passed. In PENL, this time interval is denoted by Pe. When Pe is reached, the virtual node sends an NR message to its neighbors requesting them for sending an Na message in response indicating the remaining amount of energy for the virtual node. The virtual node allows for a delay in responses and then selects an adjacent node with the highest level of energy as the new virtual node. An SN message is sent to this node. The new node will disseminate an interest message to update paths to the new node. After a certain period, the new virtual node floods exploratory data globally over the network to find a path to the destination node. The process is illustrated in Fig. 5.

3.4   Virtual node expiration

In some cases virtual node may become inoperative. This can be caused by different factors such as hardware problems, expiry of working period, used up energy, failure in finding a node with required level of energy, etc. In this case, if virtual node is still working, a message will

be sent over the network to request source nodes for overlooking the virtual node and sending individual packets of exploratory data over the network to find a path to the destination node. The process is illustrated in Fig. 5.
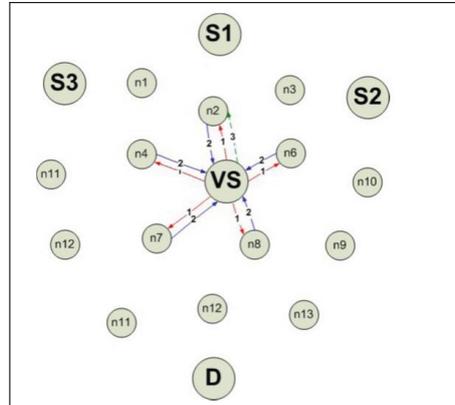

Figure 5: Selecting a new virtual node using the original virtual node

4 Analysis of simulation results

This section presents simulation results obtained through NS-2.

4.1 Routing overload

Overloads contain additional bits used to identify and correct errors. This increases the level of disseminated unwanted information and redundant processing at intermediate nodes as well as end stations. Fig. 6 shows routing overload. As seen in this figure, routing overhead of PENL when the number of sources is greater than 2, is smaller compared to that of MECH.
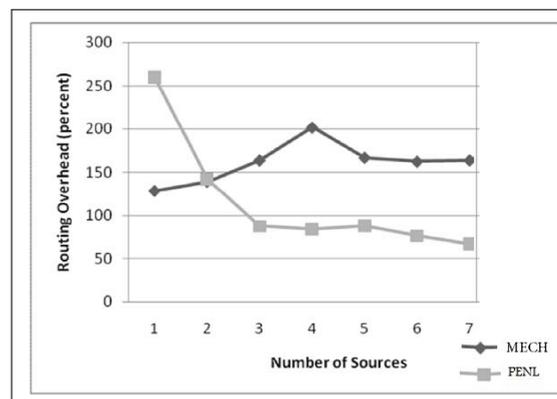

Figure 6: Comparison of routing overload in PENL and MECH

4.2 Packet loss rate

Fig. 7 compares number of lost data packets for different number of sources when connection is established between source and destination nodes. As seen in this figure, packet loss rate does not change considerably with the increase in the number of sources for PENL while increase in

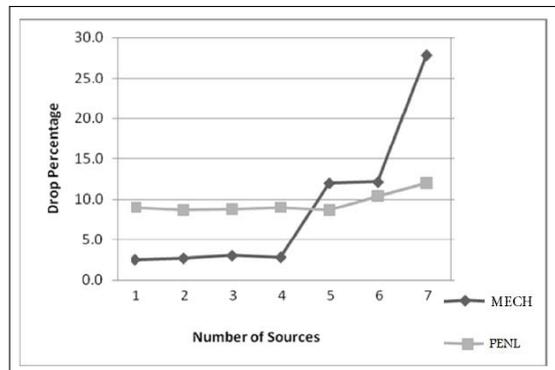the number of sources for MECH, particularly from 6 to 7 sources, significantly raises packet loss rate.

Figure 7: A comparison of packet loss rate of nodes in PENL and MECH

4.3 Energy consumption in networks

Fig. 8 shows overall energy used by all nodes of the network. As seen in this figure, PENL is much more energy-efficient compared to MECH mainly because of reduction in the number of transmission paths. In this simulation 7 sources were used over a 25×15 grid containing 320 nodes.
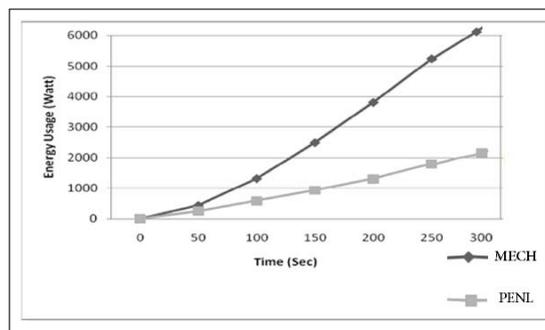

Figure 8: A comparison of energy consumption of nodes in PENL and MECH

5 Conclusions

In this paper, PENL was proposed as a protocol to improve routing in WSNs. The protocol is often used to increase efficiency of the previously used protocols in terms of energy consumption by reducing routing overload and balancing loads on nodes. PENL outperforms previous protocols such as MECH in many aspects including packet loss rate, energy consumption, and routing overload.

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