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# A Novel Energy Efficient Routing Protocol in Wireless Sensor Networks

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## Abstract

Wireless sensor networks are employed in several applications, including military, medical, environmental and household. In all these applications, energy usage is the determining factor in the performance of wireless sensor networks. Consequently, methods of data routing and transferring to the base station are very important because the sensor nodes run on battery power and the energy available for sensors is limited. In this paper we intend to propose a new protocol called Fair Efficient Location-based Gossiping (FELGossiping) to address the problems of Gossiping and its extensions. We show how our approach increases the network energy and as a result maximizes the network life time in comparison with its counterparts. In addition, we show that the energy is balanced (fairly) between nodes. Saving the nodes energy leads to an increase in the node life in the network, in comparison with the other protocols. Furthermore, the protocol reduces propagation delay and loss of packets.

**Keywords:** Wireless Sensor Network, Gossiping, Routing Algorithm, Fair Energy Consumption

## 1. Introduction

Wireless Sensor Networks consist of tiny sensor nodes that, in turn, consist of sensors (temperature, light, humidity, radiation, etc.), microprocessor, memory, transceivers, and power supply. In order to realize the existing and potential application for WSNs, advanced and extremely efficient communication protocols are required [1]. WSNs are application-specific, where the design requirements of WSNs change according to the application. Hence, routing protocol requirements are changed from one application to another. For instance, the requirements of routing protocols designed for environmental applications are different in many aspects from those designed for military or health applications [2-4]. However, routing protocols for all Wireless Sensor networks, regardless of the application, must try to maximize the network life time and minimize the overall energy consumption in the network. Network lifetime is a critical concern in the design of WSNs. In many applications, replacing or recharging sensors is sometimes impossible [5]. Therefore, many protocols have been proposed to increase network lifetime. It is difficult to analyze network lifetime because it depends on many factors, like network architecture and protocols, data collection initiation, lifetime definition, channel characteristics, and the energy consumption model [6]. For all routing protocols, energy consumption during communication is a major energy depletion parameter; the number of transmissions must be reduced as much as possible to achieve extended battery life. For these reasons, the energy consumption parameter is a top priority [7].

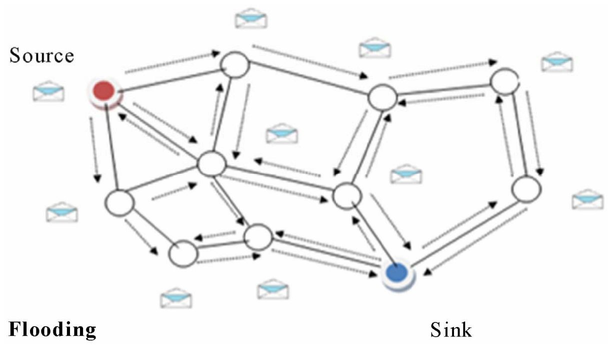
In this article, we propose a new routing protocol based on Gossiping called Fair Efficient Location-based Gossiping (FELGossiping) to improve the problems of Gossiping and its extensions. FELGossiping consists of three phases: Initialization, Information Gathering and Routing. In the first phase, each node generates the gradient to the sink. In the second phase, the FEL Gossiping sends a request message to the other nodes to receive the information of other members or neighboring nodes. Once the hop count and the remainder energy of the member nodes are known, FELGossiping chooses two nodes in the third phase. The nodes are chosen near to the base station, according to the hop count of the selected nodes with the sink node, in order to deliver the packet to the sink. After selecting two nodes, the protocol only chooses one of the two nodes to send the packet. The node with more residual energy is selected, and the message is sent to the selected node to broadcast the packet to the base station. Finally, we present some optimal strategies and through simulation results show that the optimal routing strategies provide a significant benefit.

This paper is organized as follows. In Section 2 we give a brief description of the energy efficient routing protocols, especially GOSSIPING. Section 3 presents our proposed algorithm and its details. Section 4 shows the methodology we followed to perform the simulations and the results are also provided in this Section. Finally, Section 5 presents our conclusions and suggestions for future projects.

## 2. Literature

During previous research, many differences have been observed, generally, between flat and hierarchical routing protocols and, exactly, between these researched routing protocols [8,9]. In this paper, we choose Gossiping as a target protocol to conduct our research and some extensions. Firstly a technical glimpse on Gossiping: Gossiping is a data-relay protocol, based on a Flooding protocol, and does not need routing tables or topology maintenance [10]. It was produced as an enhancement for Flooding and to overcome the drawbacks of Flooding, *i.e.*, implosion [11]. In Flooding, a node broadcasts the data to all of its neighbors even if the receiving node has just received the same data from another node. The broadcasting will continue until the data is received by the destination [1,12]. However, in Gossiping, a node randomly chooses one of its neighbors to forward the packet to, once the selected neighbor node receives the packet it, in turn, chooses another random neighbor and forwards the packet to it. This process will continue until the destination or number of hops has been exceeded. As a result, only the selected nodes/neighbors will forward the received packet to the sink [13]. Unlike Flooding, Gossiping operates well in a one-to-one communication scenario but it does not in a one-to-many. Packet forwarding mechanisms for both Flooding and Gossiping are shown in **Figure 1** [4,14].

Gossiping consumes less energy than Flooding. However, it suffers from latency; information propagates slowly, one node at each step. Despite the simplicity and inefficiency of Flooding and Gossiping, they could be used for specific functions, for example, during deployment phases and network initialization [11,12]. The power consumed by Gossiping, is approximately equal to $O(K^L)$.



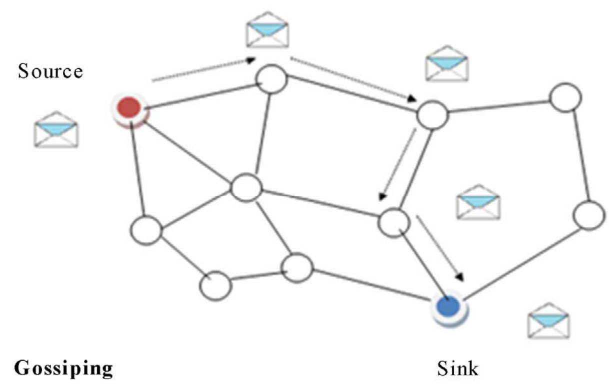




**Figure 1. Forwarding mechanisms of Flooding and Gossiping.**

*K*: *number of nodes that forward the packet.*

*L*: *number of hops before the forwarding stops.*

The most remarkable feature of Gossiping is the ability to control the power consumption by appropriately selecting *K* and *L* [15].

After a technical review of Gossiping protocols we can determine these disadvantages:

- The next hop neighbor is randomly chosen, this means it may include the source itself.
- The packet will travel through these selected neighbors until it reaches the sink or exceeds the number of hops.
- It suffers from packet loss.

The most significant disadvantage of Gossiping is that it suffers from latency caused by data propagation.

Finally, in order to enhance the Gossiping protocol, many protocols have been produced as an expending to it. For example FLossiping [16], SGDF [17], LGossiping [18] and ELossiping [19].

***FLossiping Protocol*****:** combines the approaches of both the Flooding and Gossiping routing protocols. When a node has a packet to send, it chooses a threshold and saves it in the packet header, it then randomly selects a neighbor to send the packet in Gossiping mode, while the other neighbor nodes listen to this packet and generate a random number. The neighbors whose randomly generated numbers are smaller than the threshold will broadcast the packet in Flooding mode. As a result, FLOSSIPING improves the packet overhead in Flooding and the delay issue in Gossiping [16].

***SGDF Protocol*:** **S**ingle **G**ossiping with **D**irectional **F**looding routing protocol is divided into two phases; Network Topology Initialization and Routing Scheme. In the first phase, each node generates a *gradient* (showing the number of hops to the sink). In the second phase, in order to deliver the packet, SGDF uses single gossiping and directional flooding routing schemes. As a result (see **Figure 2**), SGDF achieves a high packet delivery ratio, low message complexity, and short packet delay [17]. However, the disagreeable side effect of this protocol is that the amount of packets becomes larger during packet delivery due to directional flooding.

***LGossiping Protocol*:** in Location based Gossiping protocol, when a node has an event to send it randomly chooses a neighboring node within its transmission radius. Once the neighbor node receives this event, it in turn randomly chooses another node within its transmission radius and sends it. This process will continue until the sink is reached. As a result, the delay problem has been solved to some extent. **Figure 3** shows the main objective of LGossiping [18].

Although in this protocol the delay problem has been solved to some extent, there is still the problem of many events not reaching the main station. Moreover, this protocol uses GPS to determine the location of each node. Hence, additional hardware is required, which means extra money.

***ELGossiping Protocol*:** in the Energy location base Gossiping protocol, when a node detects an event and wants to send information, it selects a neighboring node within its transmission radius and the lowest distance to the base station/sink. Once the neighboring node receives the event, it will in turn select another neighboring node within its transmission radius and the lowest distance to the sink. The event will travel in the same manner to the sink. As a result, the problem of latency and the situation of non-reaching packets have to some extent been solved [19]. In **Figure 4** you can see details of this protocol.

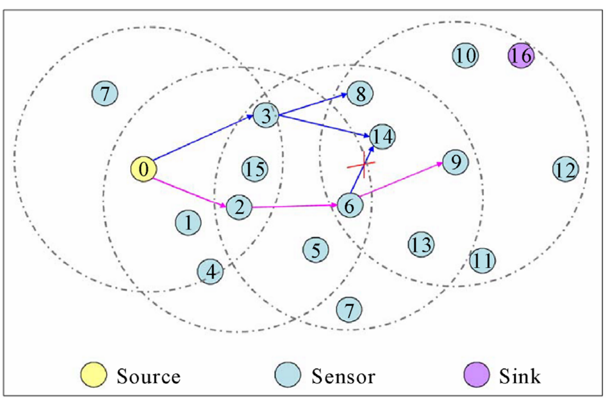



**Figure 2. Routing scenario in SGDF.**

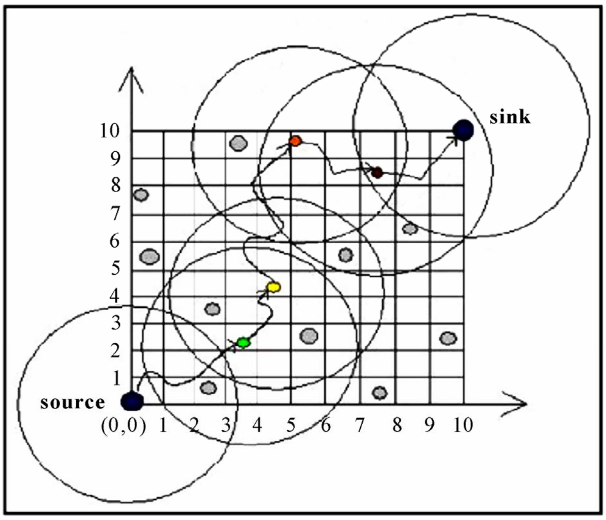



**Figure 3. Schematic of data routing in LGossiping.**

Two important metrics have been exploited in this protocol; Energy and distance to the base station, and in this way when a node detects an event within its transmission range it sends the data to a neighboring node that has a shorter distance to the sink.

Although in this protocol and its extensions some of the problems have been solved, there is still a problem of many packets not reaching the main station.

## 3. New Algorithm

With some changes to the Gossiping protocol we can decrease the energy consumption and also increase the network lifetime. Therefore, in order to resolve the drawbacks of the Gossiping protocol, we have proposed a new protocol as an extension for Gossiping. In this protocol we have increased the network lifetime by selecting a node with a maximum residual energy and lower distance to the sink. We have also achieved a high packet delivery ratio and reduced the delay in delivering the packet.

The new algorithm consists of three phases: Network Initialization Phase, Information Gathering Phase and Routing Phase. In this section we explain three parts of the algorithm as follows.

- *Network Initialization Phase*

The network initialization phase starts after the sensor nodes are randomly distributed in the application area. In the beginning, the base station broadcasts a “HELLO” message to its neighbors. The HELLO message contains: the Base Station Address (fixed) and Hop Count (variable). The hop count is used to setup the gradient to the base station, which means it shows the node distance to

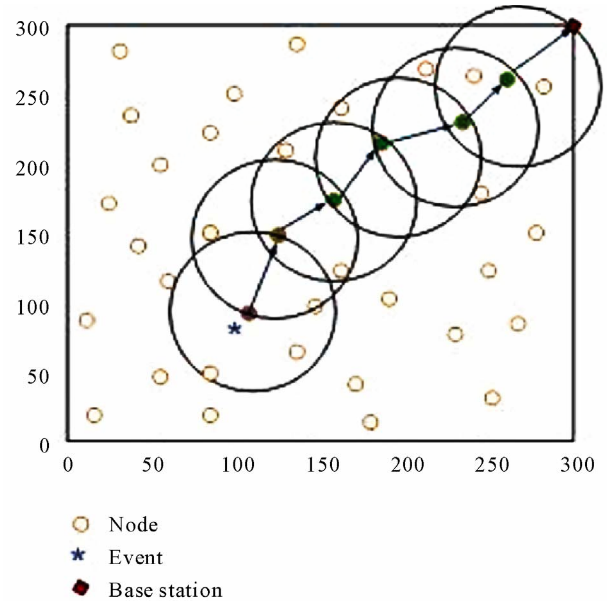



**Figure 4. Routing in ELGossiping.**

the base station. After broadcasting the HELLO massage, all 1-hop neighbors will receive this message and get the base station address and the hop count. Each node saves the hop count in its memory and increases the hop count by 1. The new hop count is then replaced with the old one. After each node has received the HELLO message it will continue to broadcast this message to farther nodes. As shown in **Figure 5**, at each stage the hop count will be incremented by 1.

When a node receives a HELLO message it will check whether it already has a gradient. If it has a gradient, it will compare it to the hop count of its own message and will replace its hop count with the message's hop count if the latter is smaller, and will add 1 to the hop count prior to broadcasting it. However, if its hop count is smaller than or equal to the hop count of the message, it will discard the message. This case occurs due the message has broadcasted previously through different routes. As a result, the gradient will keep the best route. Finally, the process will continue until all the sensors receive the HELLO message, at that time the network initialization phase will be completed. Now each node through the gradient knows its distance to the base station. **Figure 6** summarizes the setup phase in a simple flowchart. **Figure 5** shows how the HELLO message is broadcast through the network. In **Figure 5(a)** 1-hop neighbor to the Base Station will store the hop count in its memory and start constructing the gradient. Each node increments the message hop count by 1 and broadcasts the message with the new hop count (at this time is has become 2). In **Figure 5(b)** we can see that the HELLO message has reached 1-hop neighbors; two of them become broadcasting nodes which in turn continue broadcasting the message. Then the neighbors of the broadcasting node receive the message and compare the hop count of the message with their own. If it is smaller than its hop count, they will discard the message as shown in the **Figure 5**. The process will continue until completing the initialize-tion phase as shown in **Figure 5(c)**. The network initialization phase is as shown in the following flow chat in **Figure 6**.

- *Information Gathering Phase*

After detecting the event the source node will draw a transmission radius of 40 m to deal with the nearby nodes.

All sensors have GPS and can move to any position within their mobility range. The source node then generates the request message to acquire the information from the neighboring nodes in its transmission radius. The request message is contained in the hop count of the neighboring node to the sink, or the distance of nodes from the sink and the residual energy of all nodes. After that, the nodes that received the request message send

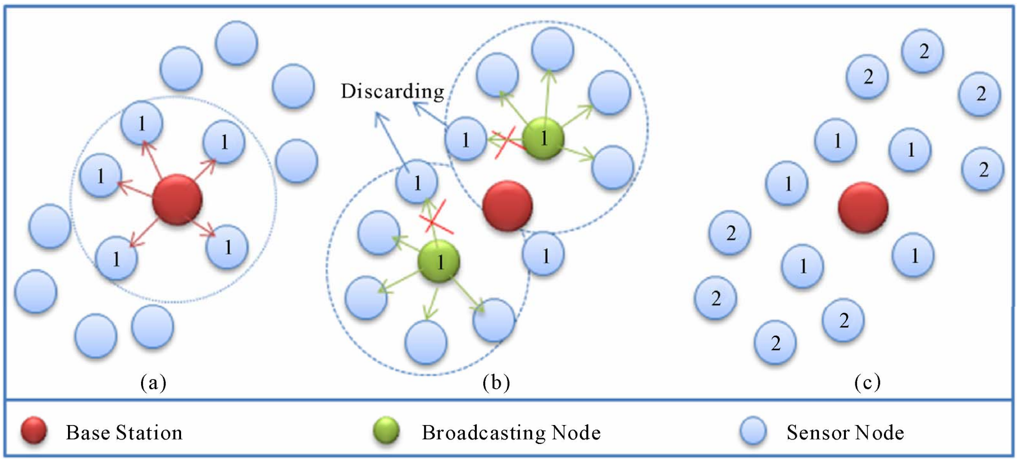



**Figure 5. Network initialization phase.**

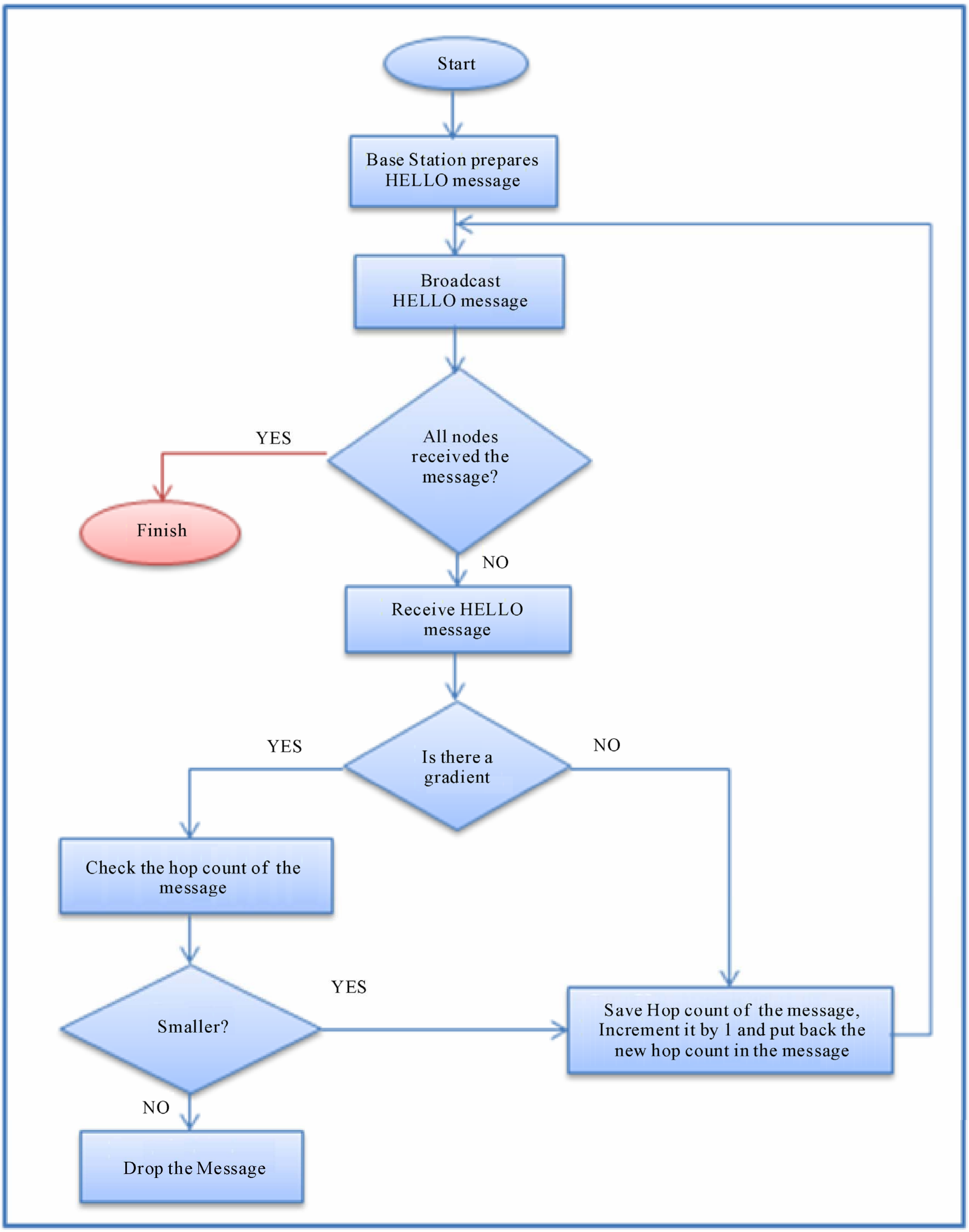



**Figure 6. Flowchart of the network initialization phase.**

their information to the source node or to the node that detected the event. The information gathering phase is as shown in the following flow chat in **Figure 7**.

- *Routing Phase*

After the network request phase finishes, the routing phase will start. Following we state some assumptions:

- At the start all nodes are full of energy and have the same amount of energy.
- Each node knows its remaining energy at any stage of its life.
- Each node has a transmission radius of 40 m.

After this, the receiving neighbor replies to this re-

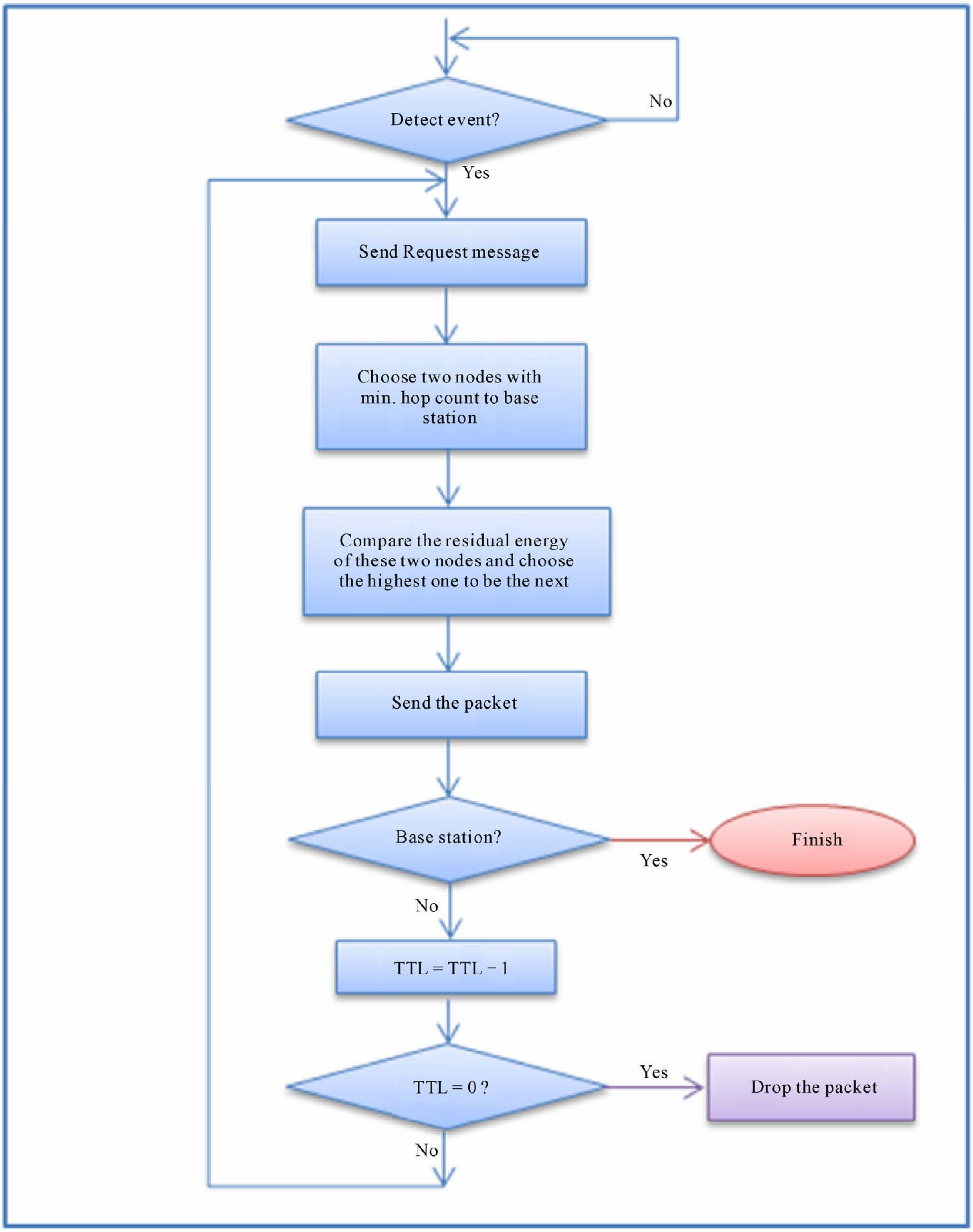



**Figure 7. Flowchart of information gathering phase and routing phase.**

quest by using its residual energy and hop count. Next, the source chooses within its transmission radius two neighboring nodes that have the minimum hop count towards the sink. **Figure 9** shows the selection of valid nodes in a defined radius. The hop count of one node will be a unit lower than the other node, or equivalent. After choosing two nodes near the sink, we compare between these two nodes according to the residual energy of the two nodes. **Figure 10** shows this operation clearly among two selected nodes, we select the nodes that had the most residual energy and we ignore the maximum hop count of the two nodes. If two nodes have the same residual energy we take the nodes that have a lower hop count to the sink. After that the source node sends the packet to the selected node. Upon receiving the message the node repeats the information gathering phase and routing phase processing to transmit the message to another node. **Figure 11** shows the routing operation. The process continues until the message reaches the sink or the TTL is finished. The sent packet is including message and packet header. The header packet is shown in **Figure 8**. The header consists of six fields as shown below:

| | | | | | |
|---|---|---|---|---|---|
| *Source* | *Destination* | *Present* | *Next* | *Hop* | *TTL* |

**Figure 8. Header packet data.**

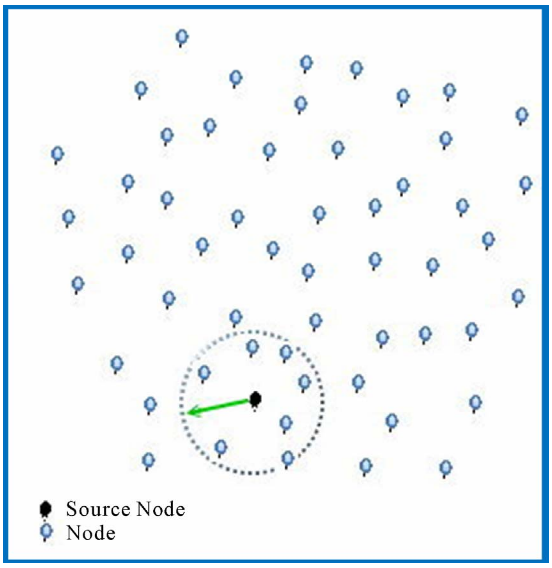



**Figure 9. Source node outlining its transmission radius.**

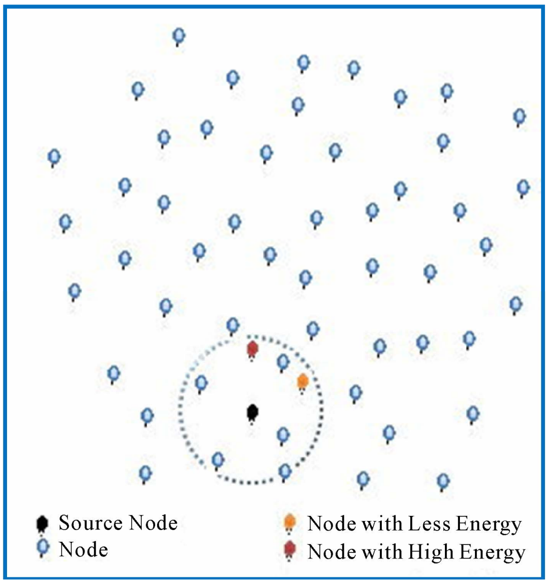



**Figure 10. Source node within its transmission radius selecting two nodes.**

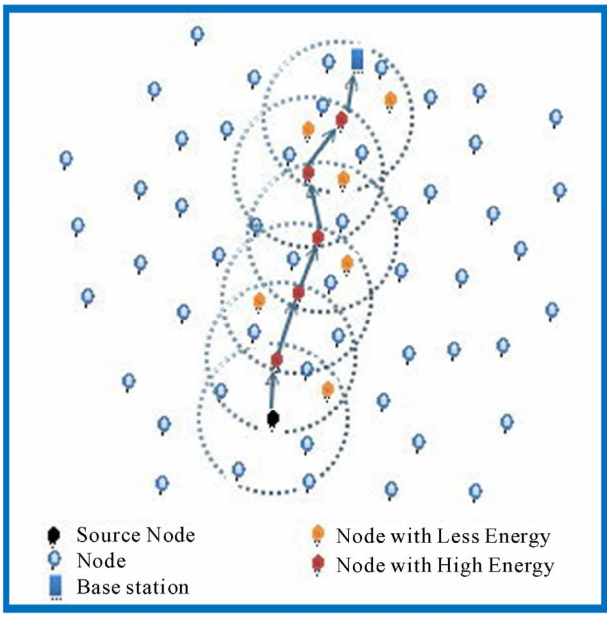



**Figure 11. Routing phase.**

Source: Source address of the source node (event node).

Destination: Address of the sink.

Present: Address of the current node.

Next: Address of the next hop.

Hop: Hop count from the current node to the base station (number).

TTL: Time to live of the packet. The packet will be dropped if this field becomes 0.

As soon as the next hop is selected its address will be written in the next field of the header. The source will write its address in the source field and the present field, just as information for the node that detected the event. After which the source field (address of the event detected node) will be fixed, but the present field will change according to the present node. The hop count of the next node will be written in the hop field of the header. Finally, will be put a value in the TTL[1] field, taking into account that the source will not find a neighbor with hop count lower than its hop count, in this case it selects a neighbor with a hop count equal to its own. Each node receiving the packet will subtract 1 from the TTL field and will progress the packet towards the base station. The packet relaying will continue until the Base Station receives the packet, or the TTL field becomes 0.

When the base station receives the packet, it will broadcast a declaration message of successful reception to inform other nodes trying to send the same packet through another route to drop the packet. This declaration message prevents the same message reaching the

[1]Time to Live of the packets.

base station twice, reduces the message overhead and the energy consumed by the other nodes during packet transmission through other route.

## 4. Simulation and Evaluation

We assume some the parameters to implement the simulation results:

**Radius**: the radius of coverage of the sensors is 40 m. Any sensor that detects the event draws the transmission radius to limit the number of nodes in its transmission range.

**Residual Energy**: shows the amount of energy remaining. We assume that in the beginning the energy of all nodes is same.

**Location of sensor**: all sensors have GPS or other location devices and can move to any position (with known coordinates) within their mobility range. It can be shown that the proposed FELGossiping routing protocol performs better when compared to the other routing protocols. We investigated the performance of the proposed protocol by comparing packet loss, delay, live node and total energy saving per round.

**Packet loss:** as seen in **Figure 12**, packet loss is at a minimum in FELGossiping when compared with Gossiping, LGossiping and ELGossiping. However, the packet loss increased after the 500th iteration.

**Live nodes:** after the 100th iteration in Gossiping almost all nodes die. However, as shown in **Figure 13**, in our proposed protocol the nodes die after approximately 750 iterations by balancing and using the energy in a fair manner.

**Delay:** in contrast to other protocols that randomly select the next hop for the packet, in our protocol the nearest node to the base station is selected as the next hop. Moreover, we have used GPS to find the base sta-

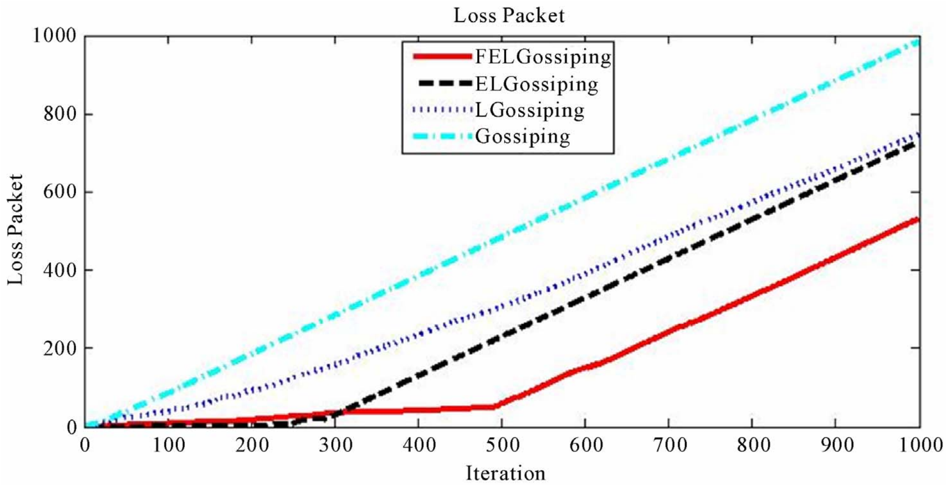



**Figure 12. Packet loss.**

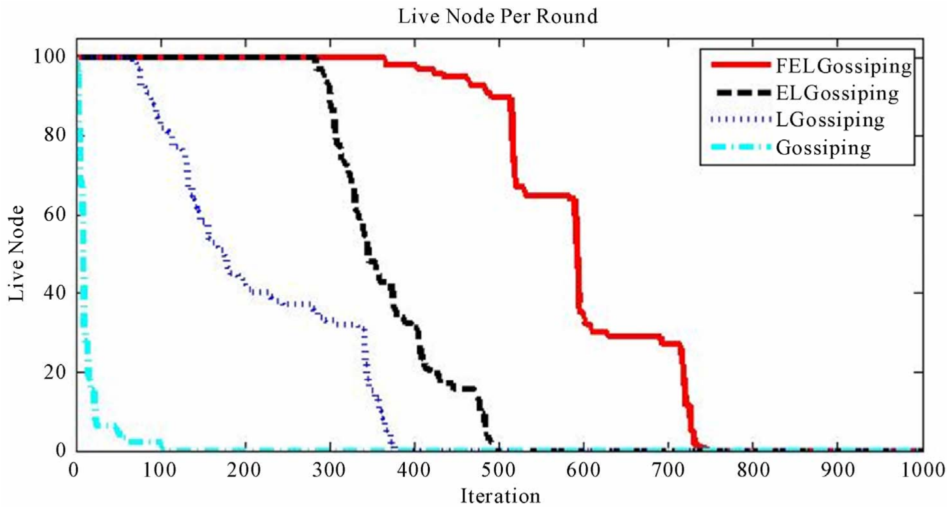



**Figure 13. Amount of live nodes.**

tion address in an efficient manner. Therefore the delay in our protocol is the smallest among the protocols compared. We can see this clearly from the simulation results in **Figure 14**. Until the 450th iteration the delay is fixed approximately at 2msec.

**Energy Consumption:** in our proposed protocol the relay nodes are not selected blindly (without knowing their residual energy) as is done in the other routing protocols in this comparison. Moreover, energy reduction for each node occurs for every transmission or reception made. Hence, the probability of choosing the same node as the next hop is reduced. Thereby, the energy has been balanced and fairly used. All this leads to saving energy and hence prolonging the overall network lifetime compared to the other protocols, as seen in **Figure 15**.

## 5. Conclusions and Proposals for Future Work

Wireless Sensor Networks are powered by the limited capacity of batteries. Due to the power management activities of these sensor nodes, the network topology changes dynamically. These essential properties pose additional challenges to communication protocols. In this article we studied the operation of a Gossiping routing protocol with safe energy consumption, and discussed the factors of energy optimization. By carefully attending to the Gossiping protocol we find that by altering the ways in which we choose the next hop, the network lifetime can be extended.

As a result, in our proposed protocol; we firstly have

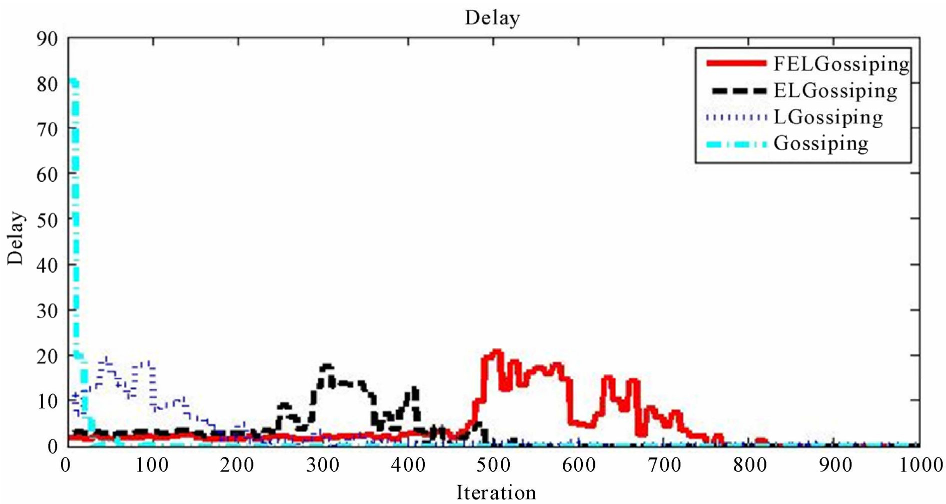



**Figure 14. Packet delay.**

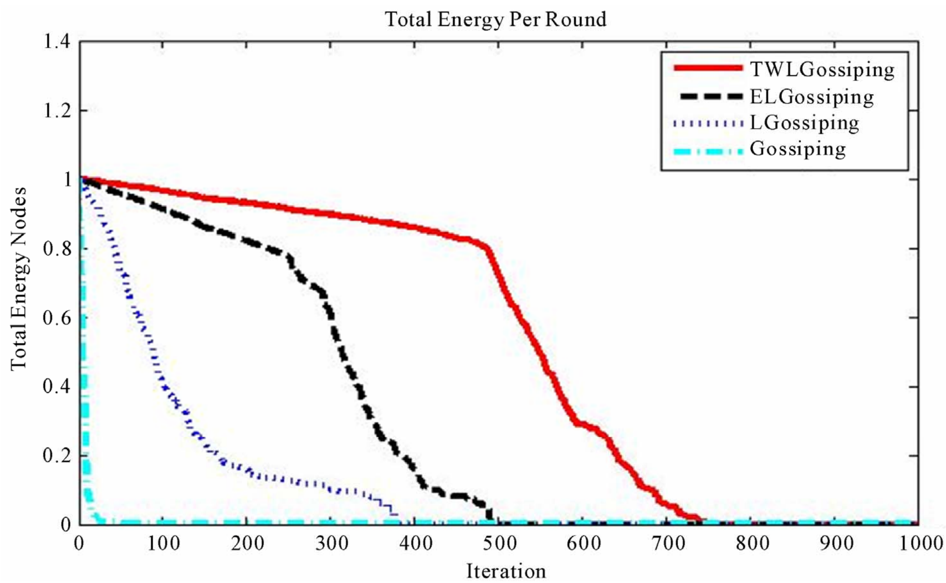



**Figure 15. Energy consumption.**

extended the network lifetime through fair use of the energy by selecting nodes with the maximum residual energy and lowest distance to the sink. Secondly, we have achieved a high packet delivery ratio (number of non-reaching nodes has been reduced) and reduced the delay in delivering the packet. Thirdly, we have reduced the message overheads and the energy consumed by the nodes that have already tried to send the data to the base station by sending an acknowledgement message of the successful reception of the packet. At this time we would like to introduce the Green Network Project as a future project. In Green Wireless Networks" we propose a new routing protocol that optimizes energy consumption and bandwidth. Using less energy in routing protocols reduce nature pests.

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