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Journal of Behavioral Informatics
Digital Humanities & Development Research
Vol 6, No 2, June, 2020

Optimization of Wireless Sensor Performance for Real-Time Detection of Intrusion in a Remote Environment

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ABSTRACT

Routing problems in Wireless Sensor Networks (WSNs) have been receiving increasing attention in the last few years. Most of the proposed routing protocols concentrate on finding and maintaining routes in the face of changing topology caused by mobility or other environmental changes (Carle & Simplot, 2004). More recently, power-aware routing protocols and topology control algorithms have been developed to address the issue of limited energy reserve of the nodes in WSNs (Cardei & Wu, 2006). In this paper we present a method that improves the performance of the sensor by extending the life of the network through making an efficient packet-routing decision. The idea is that any node may be connected to more than one downstream node, and it may be more desirable to use one than the other. For instance, if several nodes are connected to downstream bottleneck node that is rapidly exhausted, the lifetime can be extended by reducing the traffic going through it (i.e., upstream nodes preferentially use alternative downstream nodes.). This paper is divided into five chapters. Chapter one introduces the background, motivation and aim for the research. Chapter two gives a detailed review of the literature used for this paper. Chapter three proposes and describes the methodology/algorithm used in this research. Chapter four gives a detailed explanation of the result obtained during the experiment and the implementation procedure and finally Chapter five draws conclusions from the research undertaken.

Keywords: Optimization, Wireless Sensor, Performance, Real-Time Detection, Intrusion, Remote Environment

Journal Reference Format:
Ezea, I.L. (2020): Optimization of Wireless Sensor Performance for Real-Time Detection of Intrusion in a Remote Environment. Behavioural Informatics, Digital Humanities & Development Journal Vol 6. No. 1.Pp 136-144. SMART Research Group, International Centre for IT & Development (ICITD), Southern University Baton Rouge, LA, USA. © Creative Research Publishers.
DOI: http://dx.doi.org/10.22624/AIMS/BHI/V6N2P12. Available online at https://www.isteams.net/behavioralinformaticsjournal

1. INTRODUCTION

Wireless sensor network (WSN) is a wireless network consisting of small nodes with sensing, computation and wireless communication capabilities (Jamal, Ahmed, & kamal, 2004). Each sensor collects data from the monitor area (such as temperature, sound, vibration, pressure, motion, or pollutants) then it routes data back to the base station (BS) (Akyildiz, Su, Y, & Cayirci, 2002). Data transmission is usually a multi-hop; from node to node toward the base station. Wireless sensor networks (WSNs) are a rapidly emerging technology which will have a strong impact on research and will become an integral part of human lives in the near future. The huge application space of WSNs covers national security, surveillance, military, health care, environment monitoring and many more (Chong & Kumar, 2003). Due to their wide-range of potential applications, WSNs have attracted considerable research interest in the recent years. A wireless sensor network is composed of a large number of low-power, low-cost sensor nodes which are deployed close to an area of interest and are connected by a wireless interface (Cardei, Thai, Li, & Wu, 2005). Sensor nodes are tiny devices equipped with sensing hardware, transceivers, processing and storage resources and batteries.

Wireless Sensor Network can be deployed simply by scattering sensor units across the area, e.g. by dropping them out of an airplane; the sensors should automatically activate, self-configure as a wireless network with a mesh topology, and determine how to send communications packets toward a data collector (e.g., a satellite uplink.) Thus, one important feature of such a network is that collected data packets are always travelling toward the data collector and the network can therefore be modelled as a directed graph (and every two connected nodes can be identified as "upstream" and "downstream.").

1.2. Statement of Problem

A number of sensors are randomly distributed in a region. Targets move in the region and if one or more targets are in the sensor range of a sensor, the sensor is said to be in the detection period. Each sensor generates a packet periodically during its detection period and doesn't generate any packet at other times. The generated packets are to be delivered to one of the gateway nodes. Our goal is to maximize the time until the first failure of the packet delivery due to battery outage and that is to make a packet-routing decision that will extend the life of the network.

1.3 Motivation and Aim

A. Controlled vs. Random Node Placement

There are two main reasons why a deterministic placement of sensor nodes is impractical:
Sensor networks are often deployed in remote or inhospitable areas, which prevent individual sensor node deployment. Also, the current state-of-the-art sensor nodes are not capable of dynamic adjustment of their positions (Brinza, Calinescu, Tongngam, & Zelikovsky, 2005). The number of sensor nodes in a network is large, so the deterministic placement is associated with increased cost and latency in the deployment of the network.

Therefore, the preferred method of sensor placement is bulk dispersion of sensor nodes from an aircraft (Cardei, Wu, Lu, & Pervaiz, 2005). Still, it is instructive to consider the deterministic case when we can control placement of nodes since it provides the lowest bound on the required number of nodes needed to cover the area. Figure 1. shows the optimal regular placement of nodes, so that the whole area is covered with the minimal number of nodes. The minimal number of sensor nodes is given by the equation (Cardei & Wu, 2006):

$$\frac{(N*R^2)}{P_{ARFA}} = \frac{2\pi}{\sqrt{27}} \qquad 1$$

where P_{ARFA} is the size of the monitored area, *N* is the minimal number of nodes needed to cover the area, and *r* is the sensing range of a sensor in a sensor node. It is assumed that the sensing range of the nodes is significantly smaller than the dimensions of the monitored area.

B. Motivational Example

Here, we further clarify the problem discussed in this project using the following example. Let us assume that the monitored area is divided into five fields. (A detailed description of a field is given in the following section.) Let F be a set of those parts: {F_1, F_2, F_3, F_4, F_5}. In a general case, each sensor covers one or more of these fields and each field is observed by at least one sensor node. In our example, we have six nodes, denoted by S_i, 1i <=6. The sensors cover the following fields: S_1={F_1, F_2, F_3, F_4}, S_2={F_1, F_2, F_5}, S_3={F_2, F_3, F_4, F_5}, S_4={F_2, F_3, F_5}, S_5={F_1, F_3, F_5}, and S_6={F_3, F_4, F_5}.

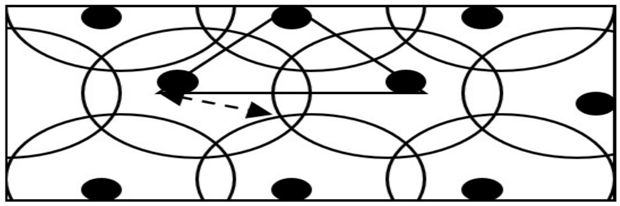

Figure.1. Sensor nodes with a sensing range ***r*** placed in a regular structure that ensures the coverage of the whole area with a minimal number of nodes (Cardei & Du, 2005).
The lines connecting three nodes whose sensing ran is r √3

2. METHOD OF DATA COLLECTION

We used a formal and informal method of data collection. Some of our data were collected through; Literature study: this is to have in-depth information regarding wireless intrusion detection. The literature studies were also helpful in obtaining ideas on useful experiment and related works that have been conducted in this area. The major source of our literature is the University of Lagos Library, internet, IEEE and Citeseer, telephone and email contact with the wireless sensor network community, etc. Experiments were also conducted on network to know the environmental adaptability, accuracy, and error, etc.

3. IMPLEMENTATION AND RESULTS

This simulation consists of two major implementation procedures: deploying the network and running simulations. Before the simulation could take place there are other settings and controls (e.g. Network Size, Sensor Radius, Period and Cost, Transmission Radius, Transmitters Period, Transmit Cost and receive Cost, etc) that need to be adjusted for optimum performance. See figures bellow for detailed explanations. Figure 2 shows the state of the system before the settings are being adjusted.

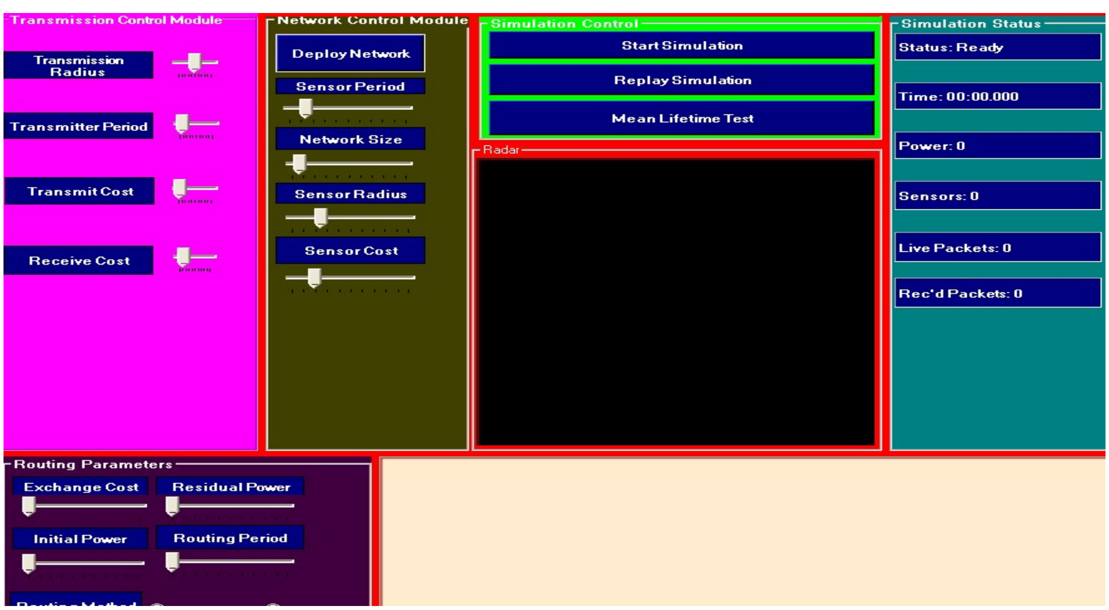

Figure 2: Example of the system before setting of the controls

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Before deploying the network, the properties of the network should be set using the configuration sliders. (Note: The properties of the network are set at the time the network is created, so changes to the network configuration and routing parameters will not be effective until a new network is deployed.) The network configuration properties are grouped into two categories:

3.1. Network Control Module

These factors determine the hardware properties of the network. The following variables can be configured:

- **Network Size:** The number of nodes in the network. If set to a high value, the network will have several hundred nodes; and since this will hugely increase the density of the network and the number of network connections, this may bog down the simulation. If a large network is desired, it is recommended to reduce the Transmission Radius.). See Figure 3 for a typical example.

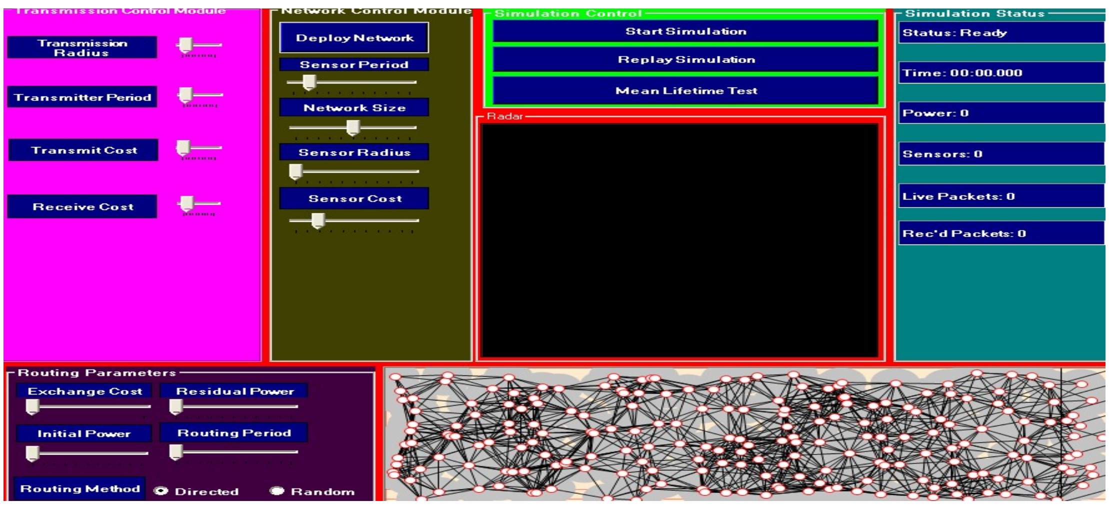

Figure 3: Setting the network size and deploying sensor

Sensor Radius: The proximity range of the sensors in the network (Figure 4).

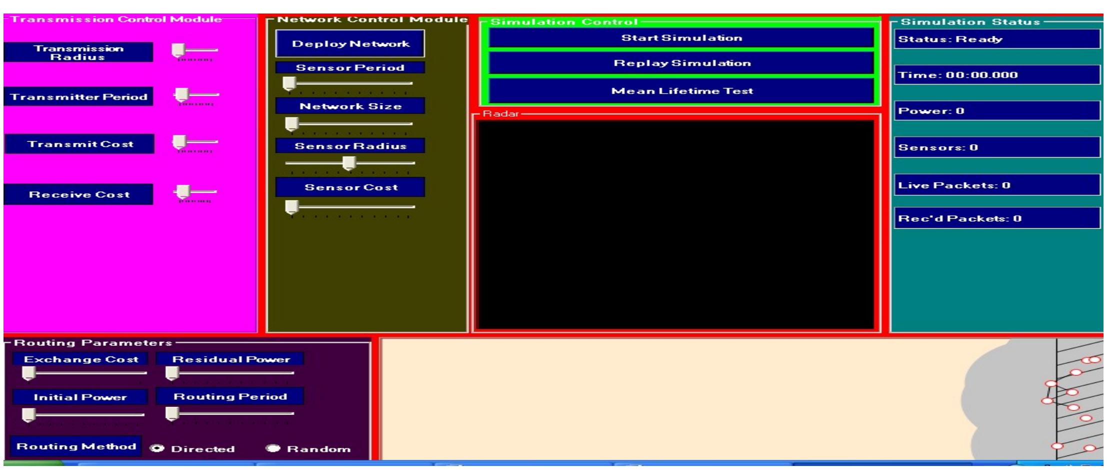

Figure 4 Setting the sensor radius and deploying network

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Sensor Period: The delay period between sensor detection events. If set to a low value, a network sensor will fire rapidly as a vector enters its sensor radius (thereby consuming a lot of energy.) If set to a high value, the network sensor will wait a long time between firing a second packet.

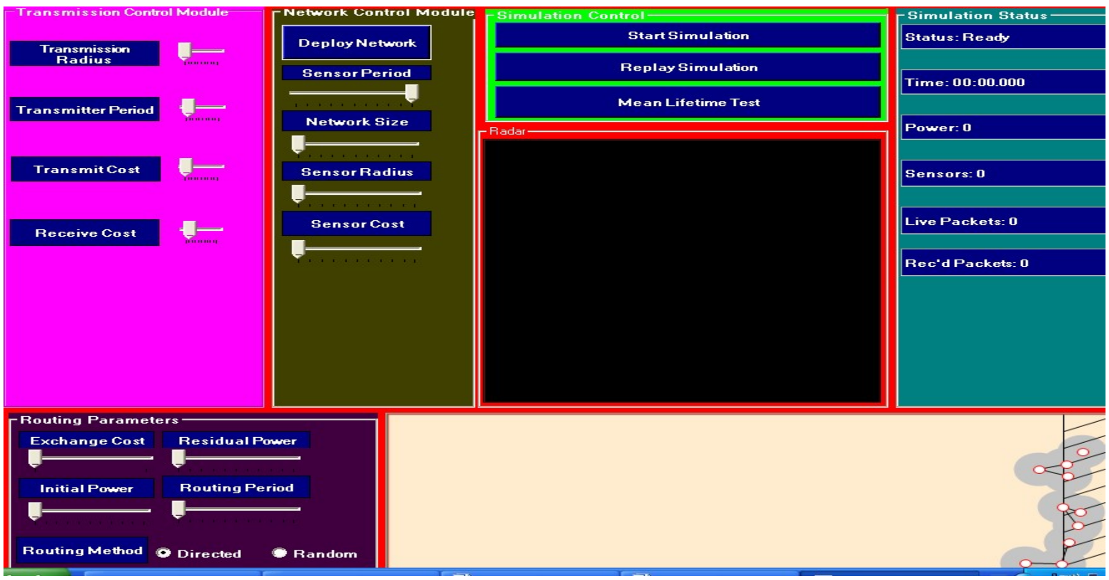

Figure 5: Adjusting the sensor period to a very high value and starting network simulation

Sensor Cost: The energy cost in detecting a vector and generating a packet (see Figure 6).

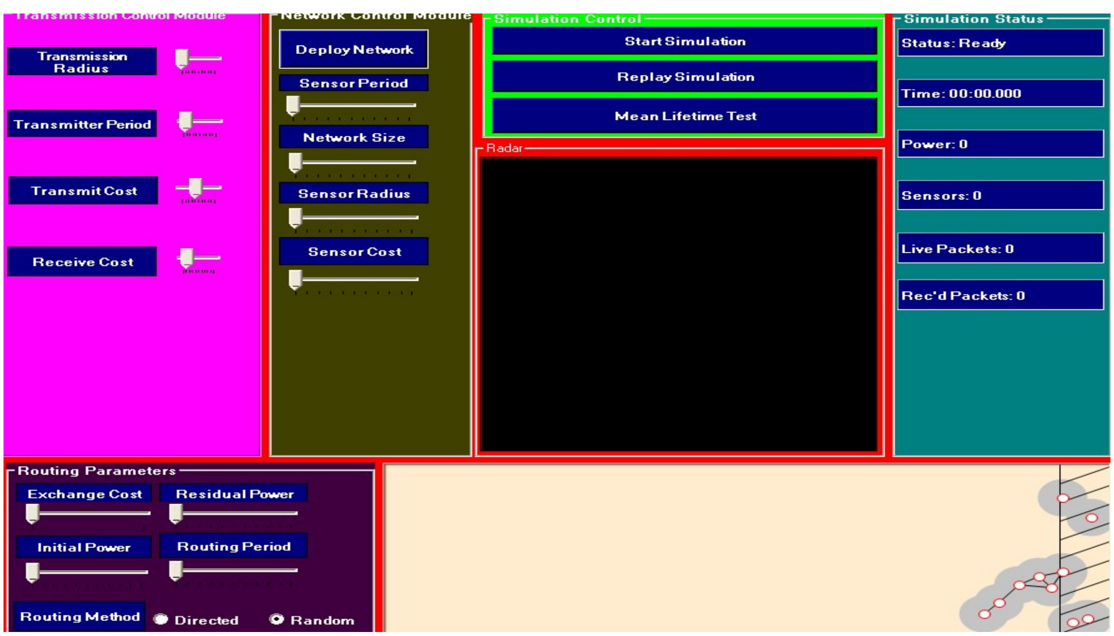

Figure 6: Adjusting sensor cost to an intermediate range and starting simulation

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3.2. Transmission Control Module

Transmission Radius: The maximum distance within which two network nodes can communicate. If set to a high value, nodes on opposite sides of the map may be able to reach each other; if set to a low value, nodes must be very close to communicate. This is displayed on Figure 7.

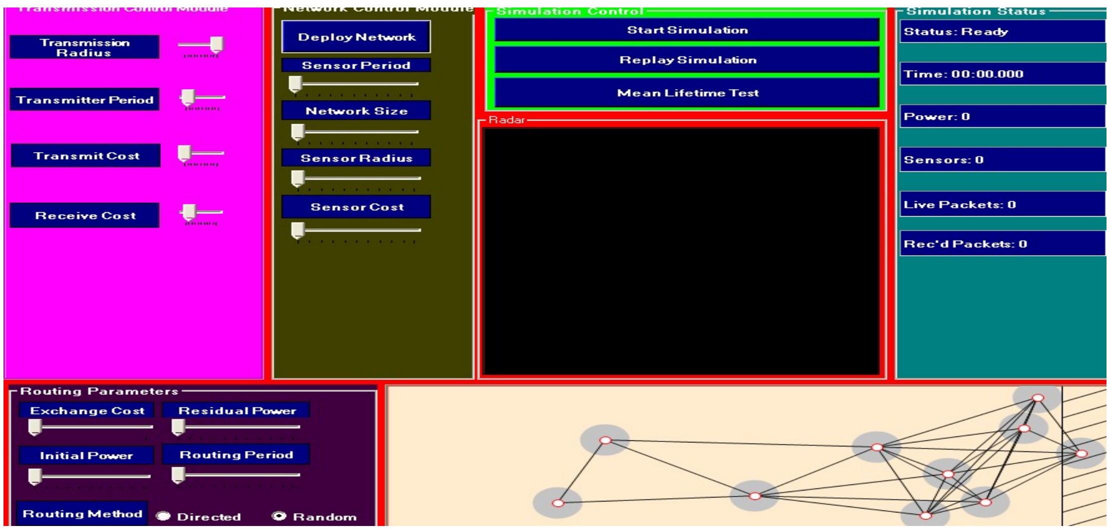

Figure 7: Setting transmission radius and deploying network

Transmitter Period: The amount of time required to send a packet. Setting this to a high value will cause each packet transmission to take several seconds. Thus, the data received at the radar will be quite stale, since many seconds will have elapsed since the triggering event. However, the high period allows the user to monitor the packet-exchange process on the network map (see Figure 8).

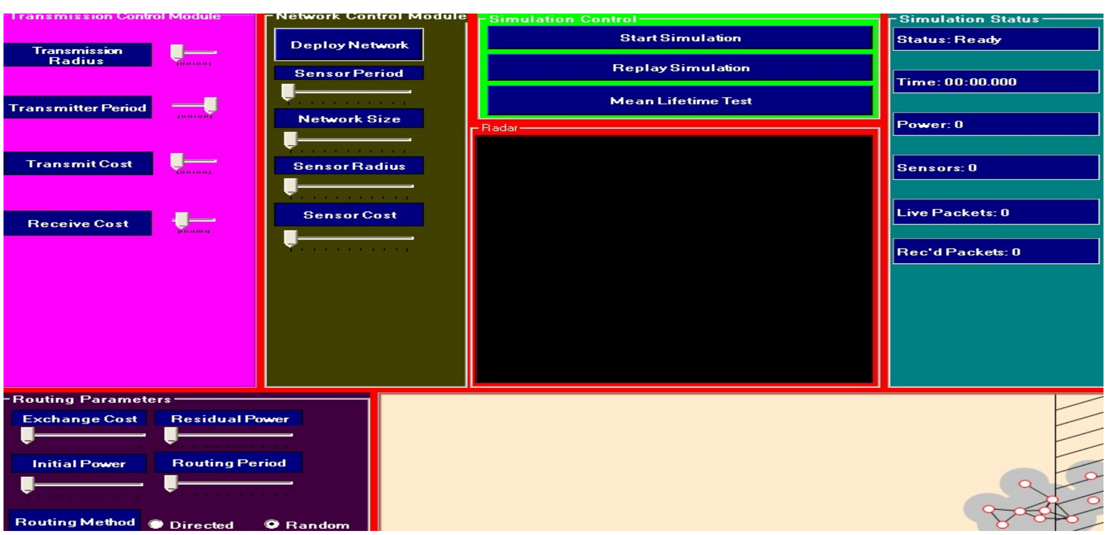

Figure 8: Setting up transmission period to a very high level and deploying network

Transmit Cost: The energy cost in sending a packet. Setting this value very high will cause nodes to be depleted after sending only a few packets; setting this value very low allows the nodes to send many hundred packets. (Note that this is always scaled based on the distance between the nodes; thus, since more distant nodes can only be reached by a more powerful broadcast, such transmissions more quickly deplete the energy store of the transmitting node.). Figure 9 shows in much detail the above explanations.

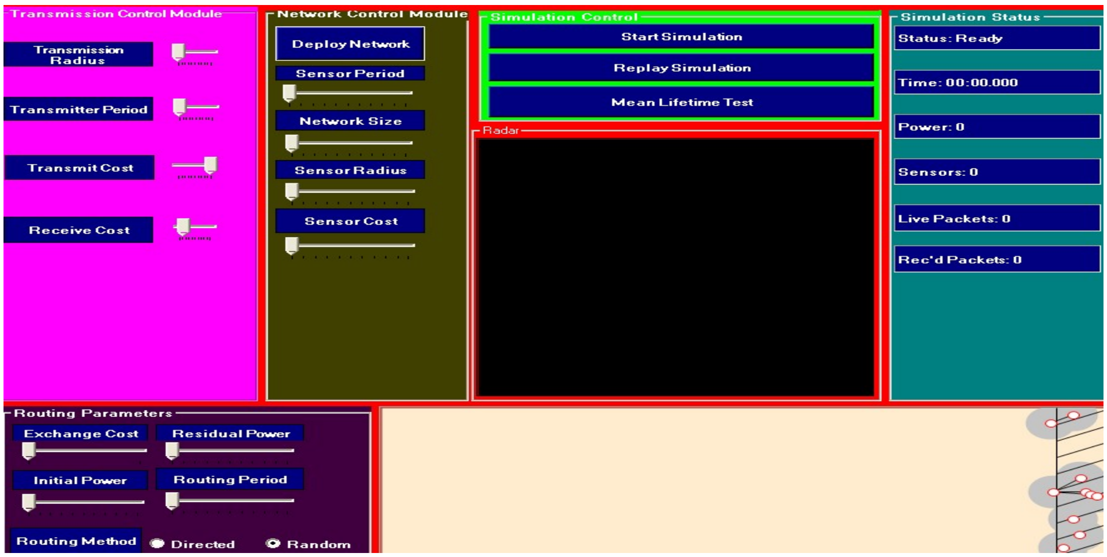

Figure 9: Setting up transmission cost to a very high level and deploying network

Receive Cost: The energy cost in receiving a packet. (This value is not scaled, as is the transmit cost.) (See Figure 10).

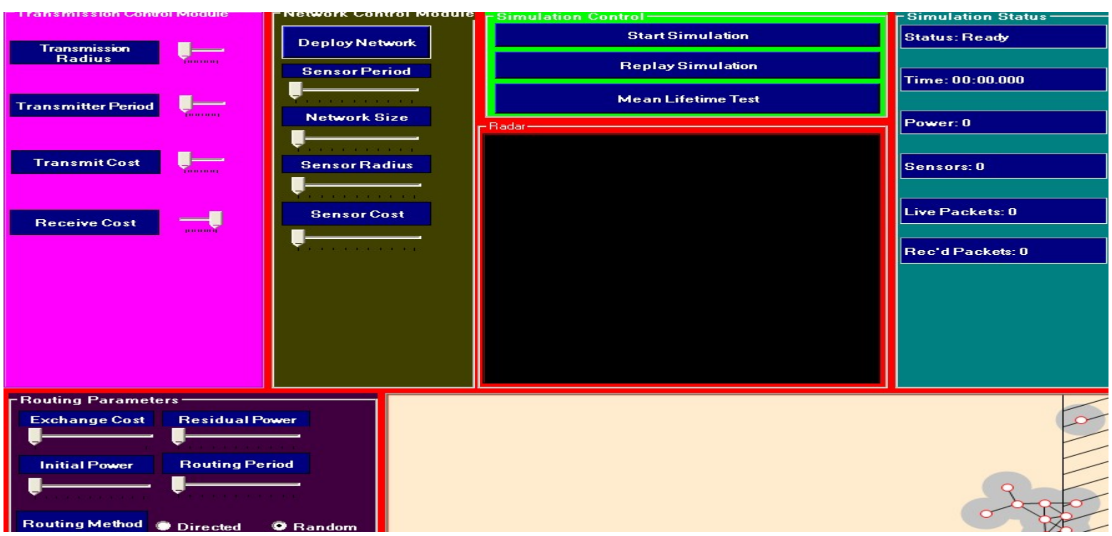

Figure 10: Setting up receiving cost and deploying network

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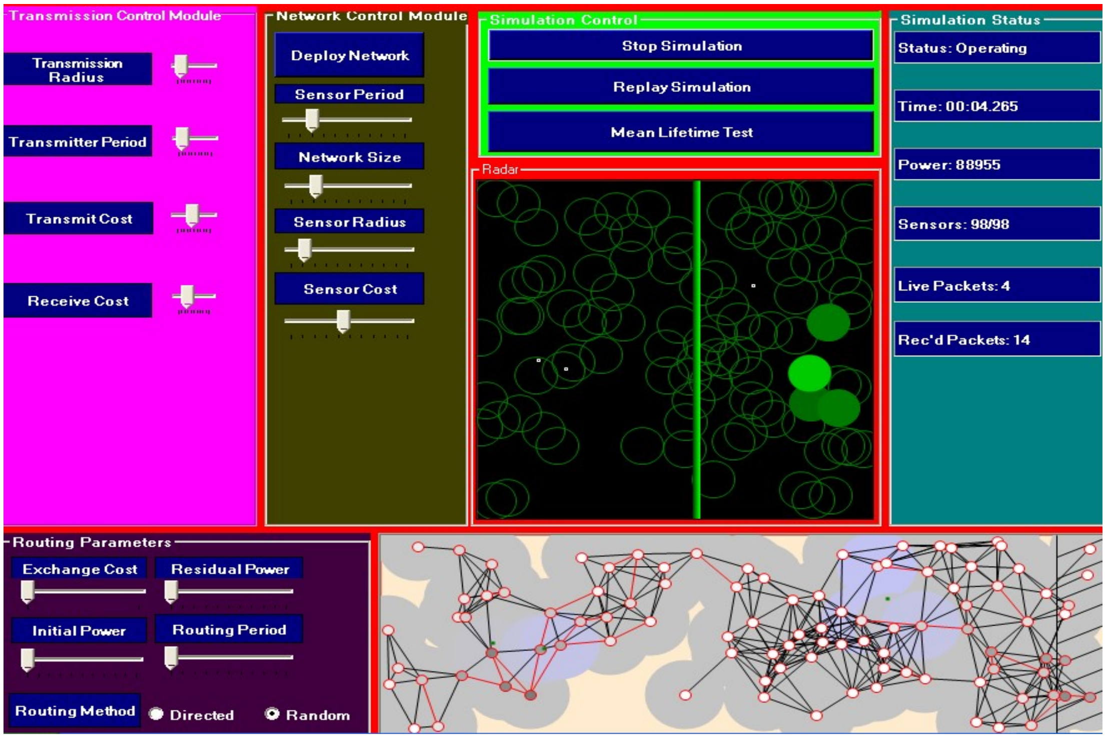

Figure 11: A display of the network simulator after all parameters has been set

Figure 11 shows a typical example of the simulator after setting all the parameters.

4. CONCLUSION

This paper presents a method that extends the life of the network by making an efficient packet-routing decision. The idea is that any node may be connected to more than one downstream node, and it may be more desirable to use one than the other. For instance, if several nodes are connected to downstream bottleneck node that is rapidly exhausted, the lifetime can be extended by reducing the traffic going through it (i.e., upstream nodes preferentially use alternative downstream nodes.) Of course, given that data generation rates are unpredictable - since it is not known in advance whether any sensor will detect little or much activity - the routing process must be dynamic. Therefore, it is useful for each node to recalculate its routing decisions periodically, based on the energy reserves of each downstream node.

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