# SWIPT-Based Routing Protocol for Lifetime Extension of Wireless Sensor Networks

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***Abstract*—The lifetime of the multi-hop wireless sensor network is determined by the time when the first power-depleted node occurs among several sensor nodes. The sensor node participates in data relay, and the closer to the sink node, the higher the possibility participating in the data relay, so it is likely to become an energy hole. The first time when the energy hole occurs is the wireless sensor network is stopped, and until this time is defined as the network lifetime. In this paper, we propose a message relay path algorithm to extend the lifetime of the network in multi-hop wireless sensor networks where nodes are energy-constrained. The proposed algorithm reduces the load on the nodes around the sink, extending network life and collecting a larger amount of data. We also validate the performance by adding the simultaneous wireless information and power transfer (SWIPT) of energy harvesting and compare the performance of the proposed algorithms through simulation.**

***Keywords—wireless sensor network, network lifetime, simultanous wireless information and power transfer (SWIPT), multi-hop, energy hole.***

## I. Introduction

A wireless sensor network for increasing energy efficiency serves to deliver data collected from each distributed sensor node. Most sensor networks collect data from a single sink node in a multi-hop environment. In a multi-hop wireless sensor network, ad-hoc on-demand distance vector (AODV) and capacity maximization (CMAX) algorithms are representative ways to establish a path between a sending node and a receiving node (sink node). AODV is a routing method that forms a path with a minimum hop to the sink, and CMAX is an energy-aware routing scheme that forms routes with minimum hops, including nodes with high residual energy [1] [2]. These many-to-one wireless networks have energy hole problems. This is because nodes around the sink consume relatively more energy and die early, causing the rest of the network to lose connectivity with the sink. The nodes of the sensor network are battery-powered, and the lifetime of the network is limited. In addition, the process of replacing the battery continues to require additional costs. To solve this problem, there is simply a way to place more sensor nodes around the sink, but this causes the problem of increasing costs as nodes are added. Therefore, the most important consideration for these networks is to save battery energy, which requires the use of energy recognition and energy-saving routing algorithms because some battery is consumed for each message transmission.

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In previous work, we used algorithms that divide the network into two rings and use different transport schemes called ring-based routing (RBR) scheme. The proposed algorithm mitigates the energy hole effect. This algorithm considers path loss to extend the lifetime by reducing the transmission distance of the energy load node. And we check the optimal results by adjusting the application range of algorithm [3].

In this paper, we integrate simultaneous wireless information and power transfer (SWIPT) of energy harvesting technology into the network and utilizes residual energy to extend the network lifetime. We use power splitting (PS) of SWIPT, PS technique achieves SWIPT by splitting the received signal into two streams of different power levels using PS component. One signal stream is sent to the rectenna circuit for energy harvesting, and the other is converted to baseband for information decoding [4]. This paper proposes a new message routing algorithm for extending the life of the network in energy-constrained multi-hop wireless sensor networks which we call RBR-SWIPT, and validates its performance through simulation. We also compare the proposed scheme with the existing basic routing algorithms and SWIPT.

The rest of paper is organized as follows. Section II introduces the system model used in this paper. In section III, we describe the proposed scheme. Section IV evaluates the performance of our algorithm based on simulation results, and concluding remark is offered in section V.

## II. System Model

In this paper, we consider a wireless sensor network consisting of one sink node and several sensor nodes as shown in Fig.1. All sensor nodes except the sink node transmit data measured at each location to the sink node. At this time, a small battery is mounted on the sensor node, and each node relies on battery power to sense and transmit. Therefore, the extent to which one sensor node can transmit data is very limited, and other nodes except around the sink node must transmit data through cooperative relays. Since relay transmission of data also consumes power, battery power is rapidly depleted as nodes frequently participate in relays. In addition, all sensor nodes use the round robin. It is assumed that one's data is sequentially transmitted, and a data transmission path is set by a central control device or a sink node. Also, SWIPT operates on nodes with high residual energy and transmit SWIPT energy together to nodes where energy holes are created.

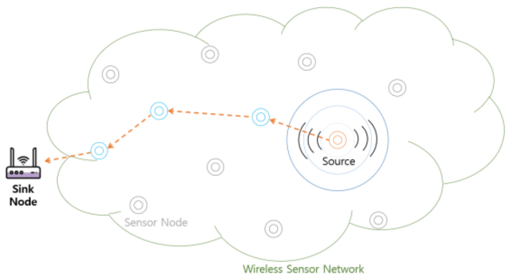


Fig. 1. System model.

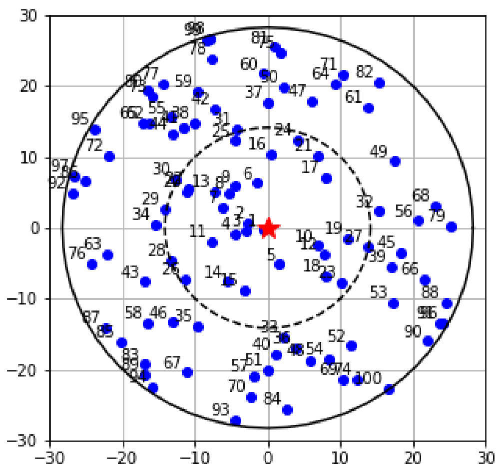


Fig. 2. Network model(r=15m, R=30m).

## III. Proposed RBR-SWIPT Protocol

In this section, we provide the proposed technique and performance. As shown in Fig. 2, the RBR scheme is divided into two areas around a sink node, and the data transmission paths of nodes belonging to each area are applied differently.

In the case of a typical minimum hop transmission, the energy consumption of the nodes near the sink is severe. Therefore, considering path loss, the inner circle transmits the maximum number of hops to minimize the energy consumption according to the distance, and the outer circle transmits the minimum number of hops to efficiently use the energy of the external node to extend the network lifetime.

The transmission power in operates considering a constant target signal-to-noise ratio (SNR), can be expressed as

$$\mathrm{SNR} = \frac{h \cdot P_{tx}}{P_N}, \tag{1}$$

where $h$, $P_{tx}$ and $P_N$ denote path loss model, transmit power, and noise power, respectively. The distance between the node is d. So, $h(d)$=1 for $(d \leq d_0)$, $h(d) = K/d_0^{\eta}$ for $(d > d_0)$, $K$ is ${d_0}^{\eta}(d_0 = 1m, \eta = 3)$. $P_N = \hbar TW$, $\hbar$ is Boltzmann constant, which is $1.38 \times 10^{-23}\ J/K$, T is noise temperature in K, W is Bandwidth. So, data rate R is

$$R = W \cdot log_2(1 + SNR), \tag{2}$$

then $P_{tx}$ is

$$P_{tx} = \frac{P_N}{h(d)}\left(2^{\frac{R}{W}} - 1\right). \tag{3}$$

So, transmit energy $E_{tx}$ is

$$E_{tx} = P_{tx} \cdot \tau, \tag{4}$$

where $\tau$ is time slot length.

In addition, the RBR-SWIPT uses SWIPT to mitigate the energy hole and extend its lifetime. When nodes outside the energy hole range transmit data to nodes near the energy hole, it uses a method of supporting energy by transmitting aid power for SWIPT together. Aid power when received from a node is defined as

$$P_{Aid}^{rx} = h(d) \cdot \alpha \cdot P_{Aid} \cdot \tau, \tag{5}$$

where $\alpha$ is energy attenuation factor.

## IV. Performance Evaluation

In this section, we provide the network simulation results. The physical layer of the model used in the simulation assumes a path loss model with a path loss exponent of 3, and the size of the network is set to 60m × 60m. The sink that collects all the data in the network is located in the center of the network. In addition, 100 sensor nodes are uniformly distributed in the network, and maximum transmission distance of each node is set to 10m. The starting energy for each node in the network is 0.05J, and node numbers are assigned in the order close to the close to the sink node. Simulation for each routing algorithm are repeated 30 times, and nodes excluding sinks for each simulation are randomly relocated. The length of the bandwidth used for transmission is 0.1MHz, and the time slot is set to 100ms. The lifetime of a network is set to the moment when the life of one node is over as first death lifetime (FDL).

The simulation results are shown in Figs. 3 and 4. Fig. 3 shows the result of measuring lifetime by r, which is the radius of the inner circle range of the proposed algorithm. When r/R is 0, it shows the same performance as CMAX, and it can be seen that the lifetime increases when the length of r/R increases to a certain extent. However, as soon as the length of r/R exceeds 0.4, it can be seen that the performance significantly decreases. This is a problem that occurs because when nodes above a 'r' range use the maximum hops, the energy consumption is further increased by using a specific node, which intensifies the energy hole problem. Therefore, it can be seen that adjusting the appropriate range helps improve performance. In addition, when comparing performance with AODV and CMAX, AODV exhibits a very low lifetime. In addition, it can be seen that the RBR-SWIPT performs better than the RBR scheme.

Fig. 4 shows the average of the residual energy for each node number. The graph represents an average of 30 iterations and compares RBR scheme and RBR-SWIPT protocol. According to the graph, it can be seen that energy is evenly distributed throughout, and RBR-SWIPT protocol has a longer life than the RBR scheme, so it has less residual energy.

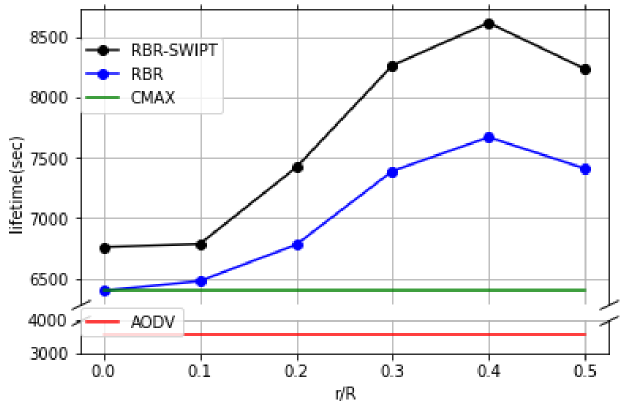


Fig. 3. Network lifetime according to r/R.

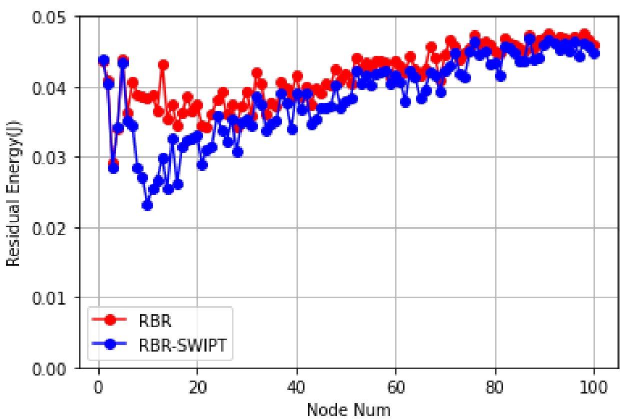


Fig. 4. Average residual energy by node number.

Fig. 5 illustrates the average lifetime (in seconds) of RBR-SWIPT compared to the baseline routing protocols. The graph shows the average lifetime for each algorithm. AODV shows the lowest lifetime, followed by CMAX, RBR scheme and RBR-SWIPT protocol. Through this, it can be confirmed that the RBR scheme performs better than the existing CMAX, and RBR-SWIPT protocol effectively increases its lifetime.

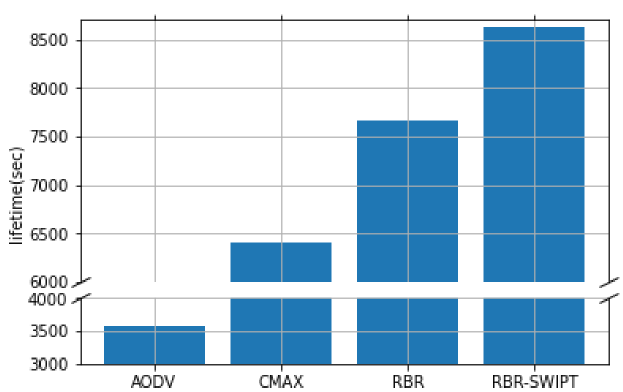


Fig. 5. Average lifetime for each algorithm.

## V. Conclusions

Many-to-one wireless networks had energy hole problems. This was because the nodes around the sink consume relatively more energy and die early, disconnecting the rest of the network and the sink. In this paper, We used the proposed algorithm to mitigate the energy hole. The proposed algorithm was divided into two areas around a sink node, and the data transmission paths of nodes belonging to each area were applied differently and we also added the SWIPT algorithm. We also compared the performance of this algorithm with AODV and CMAX to verify the superiority of the performance of the presented algorithm. In addition, it was confirmed that the energy hole problem was effectively alleviated through the average residual energy for each node number. And we compared each algorithm to confirm its superiority in performance.

For possible future research directions, we plan to another SWIPT algorithm. For example, controlling the amount of SWIPT energy. We try to apply this to different network sizes or different fading environments to see the results.

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