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Opportunistic large array concentric routing algorithms with relay nodes for wireless sensor networks☆

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ABSTRACT

This paper proposes two architectures, including an Opportunistic Large Array Concentric Routing Algorithm with Geographic Relay Nodes (OLACRA-GRN) architecture, and an Opportunistic Large Array Concentric Routing Algorithm with Relay Nodes (OLACRA-RN) architecture. First, the OLACRA-GRN architecture with the geographic information of relay nodes reduces node energy consumption and finds the optimum number of relay nodes to forward the data; an analysis of the characteristics of the energy model is also presented. Besides, the OLACRA-RN architecture without the geographic information of relay nodes is proposed, which can find the number layer of concentric circles in the sensing field. The optimal number layer of concentric circles is calculated according to the distance between the sink and field boundary. Simulation results show that our proposed OLACRA-GRN and OLACRA-RN architectures can effectively reduce node energy consumption more than Opportunistic Large Array Concentric Routing Algorithm (OLACRA) architecture.

1. Introduction

In recent years, with rapid technology development, increasingly sophisticated micro-embedded electronic devices and advances in wireless networks, more literature is being generated on wireless sensor networks (WSNs) applications. WSNs are comprised of a large number of wireless sensor nodes. These wireless sensor nodes require environmental monitoring and sensing abilities, and must be small and easy to deploy in a variety of environments, with a wireless communication function, low power consumption and low cost characteristics. Their applications include: home security, video surveillance, lighting control, industrial applications, environmental monitoring, battlefield surveillance, biological detection [1,2], and so on. In addition to the application of WSNs, another research direction is the energy efficiency of wireless sensors. Since WSNs are scattered in various places, a large number of these wireless sensors will have sensed data sent to the base station (BS) or a sink [3,4]. Additionally, Chen et al. [5] proposed LEACH architecture with IBCA and the hybrid architecture with IBCA to further extend the system lifetime. These two architectures can achieve the distribution of energy loads, and reduce energy consumption when data is transmitted by sensor nodes.

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Chen and Lai [6] suggested that sensor nodes (SNs) sending data to the sink node without calculating the distance may consume too much energy. In order to reduce the energy consumption of SNs, the multi-hop approach is used to find the relay nodes. These sensor nodes are called relay nodes. Muruganathan et al. [7] discussed a method for direct transmission protocol. This agreement must consider wireless sensor nodes and the distance to the sink. When the wireless sensor nodes send data directly to the sink, they consume too much energy, thereby affecting the wireless sensor node energy consumption rate. Therefore, in order to reduce energy consumption, help from other sensor nodes in forwarding data nodes can reduce the transmission distance; these sensor nodes are called relay nodes, with one turn passed to the next in one direction, they send data to the Base Station (BS) or sink, in a process called multi-hop transmission [8, 9] or indirect transfer. The multi-hop process not only consumes less energy but also extends the WSN life-time. Since wireless sensor energy is derived from a battery, once the battery is depleted of its limited power, the wireless sensor ceases to work properly [10].

These two transmission types have the same purpose which is to shorten the data transmission path to the sink, so the sensing node uses the forwarding method to adjacent nodes rather than direct transmission mode, thereby consuming significantly less energy; minimum energy consumption extends the lifecycle of WSNs. On the issue of energy efficiency, the current WSNs relevant agreements or algorithms' [11] main purpose is to reduce the wireless sensors' transmission energy consumption, and thus extend the reach of the whole life cycle of WSNs.

Kailas et al. [12] proposed an Opportunistic Large Array (OLA) algorithm to find numerous relay nodes. OLA refers to a large group of data forwarding relay nodes, which relay node data without coordination between themselves; when the node receives a broadcast from the source node, the node receiving the broadcast message sends the data broadcast until the destination node is reached. OLA is a kind of cooperative transmission routing. The drawback of the OLA algorithm is that it consumes too much unnecessary energy.

Thanayankizil et al. [13] proposed the Opportunistic Large Array Concentric Routing Algorithm (OLACRA) to improve Kailas et al.'s protocol. OLACRA is sink-centered, forming a concentric architecture. When the source node wants to transmit data to the sink, it will broadcast the message to the inner layer to form the OLA area. A source node uses OLA areas to transmit data to the sink node. However, if the number of layers is excessive, the outer layer will become very large. If the outer layer becomes too large, the link between the inner and outer layers may not be established. If no link has been established, then no data can be transmitted. This study therefore aims to change the OLA form to establish the node's link, with appropriate relay nodes not consuming too much energy. Thus, two architectures are proposed including an Opportunistic Large Array Concentric Routing Algorithm with Geographic Relay Nodes (OLACRA-GRN) architecture, and an Opportunistic Large Array Concentric Routing Algorithm with Relay Nodes (OLACRA-RN) architecture in order to determine the appropriate reduction of the number of relay nodes and layer size. By improving these aspects, the proposed algorithm can reduce node energy consumption of nodes.

The remainder of this paper is arranged as follows: Section 2 consists of an investigation of related research regarding WSN data transmission methods; Section 3 provides details regarding the proposed OLACRA-GRN architecture for improving transmission; Section 4 provides details regarding the proposed OLACRA-RN architecture for improving transmission; Section 5 contains the simulation results; and Section 6 offers conclusions.

2. Related work

2.1. Energy-Efficient Beaconless Geographic Routing (EBGR) routing algorithm

In recent years, many studies on routing algorithm, such as Karkvandi et al. [14] proposed the use of the greedy forwarding method to find a way to send data; when the node does not find neighbors to forward the information, it may result in the failure of greedy forwarding. Zhang and Shen [15] proposed Energy-Efficient Beaconless Geographic Routing (EBGR); geographic routing algorithms mainly employ sensor node one-hop neighbor nodes to determine the routing path transmission, thus avoiding maintenance of the overall network topology area and information overhead transmission of energy, in accordance with the characteristic adjustment algorithm to find the threshold of relay nodes for transmitting data to the BS.

EBGR geographic routing is shown in Fig. 1; first, node S wants to send data to node D, but the transmission range precludes node S from sending data to node D. After calculating the distance, it must search for the best relay node location, h, in the search range; through the RTS / CTS handshake mechanism it finds the most appropriate competent relay node, h, and forwards the data to node D.

2.2. First Order Radio Model [16] energy model

Heinzelman et al. [16] proposed the First Order Radio Model (FORM) to calculate total energy consumption in WSNs. This energy model is applied in our proposed OLACRA-GRN and OLACRA-RN. FORM architecture is shown in Fig. 2; the left block is the transmitting terminal, and the right block is the receiving terminal.

Assuming that the terminal transmits $n$bits at distance d to the receiving terminal, and the energy of transmitting terminal is $E_{Tx}(n, d)$, the formula of $E_{Tx}(n, d)$ is shown as:

$$E_{Tx}(n,d) = n \times E_{elec} + n \times \varepsilon_{amp} \times d^{\alpha} \quad (1)$$