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무선 센서망에서 생체시스템 기반의 전송노드 선택 및 다중 채널 전송 알고리즘☆

Bio-inspired Node Selection and Multi-channel Transmission Algorithm in Wireless Sensor Networks

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요 약

무선센서 네트워크(WSNs)는 일반적으로 수많은 센서노드들이 배치되어 데이터를 전송하며, 불필요한 데이터 전송으로 인해 에너지 낭비를 초래한다. 기존의 연구들은 주로 에너지 소모문제를 해결하는데 집중되었다. 하지만 실시간으로 정보전송이 필요한 어플리케이션에 대해서는 지연 보장 역시 고려되어야 한다. 본 논문은 생체시스템을 모방하여 무선센서망에서 에너지의 소모와 연시간을 줄이기 위한 BISA(Bio-inspired Scheduling Algorithm)를 제안한다. BISA는 에너지 효율성이 높은 라우팅경로를 탐색하고 다중채널을 이용해 데이터 전송경로를 다중화함으로써 데이터 전송을 위한 에너지소모와 지연시간을 최소화한다. 실험결과를 통해 제안한 알고리즘의 기존방식 보다 적은 에너지를 사용하며 동시에 요구지연 시간을 보장함을 확인한다.

☞ 주제어 : 무선센서네트워크, 에너지효율성, 생체모방알고리즘

ABSTRACT

WireWireless sensor networks(WSNs) are generally comprised of densely deployed sensor nodes, which causes highly redundant sensor data transmission and energy waste. Many studies have focused on energy saving in WSNs. However, delay problem also should be taken into consideration for mission-critical applications. In this paper, we propose a BISA (Bio-Inspired Scheduling Algorithm) to reduce the energy consumption and delay for WSNs inspired by biological systems. BISA investigates energy-efficient routing path and minimizes the energy consumption and delay using multi-channel for data transmission. Through simulations, we observe that the BISA archives energy efficiency and delay guarantees.

☞ keyword : Wireless sensor networks, node state, energy efficiency, bio-inspired algorithm

1. Introduction

Wireless sensor networks (WSNs)are composed of a large number of sensor nodes, where data is transmitted through multi-hop routing along with short-range communication. Owing to advantage that can establish networking system with low cost and relatively easy way through sensor nodes, WSN systems have been used for multiple purposes such as collecting information and real-time surveillance in many areas. However, sensor nodes have limited capacity of power by using compact battery and it is hard to replace battery of node once it has been deployed. Since the sensor node uses a method of collecting data by being spread to specific areas randomly and sending to other node, effective energy co nsumption problem has been pointed out as one of critical problems of sensor network.

Many researches have focused to solve this energy consumption problem. However, delay problem also should be taken into consideration for mission-critical applications. Specifically, when source node transmits data to sink node through multi-hop, receiving node should be awaken to receive data. When the receiving node maintains the awaken

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state for a long time, it can reduce transmission delay, but resulting in large energy consumption. On contrary, if node maintains sleeping state, there is no energy consumption but it cannot receive data from sending node for a long time, resulting in additional delay.

To solve delay problem, sensor network systems have used multi-channel. Multi-channel can solve the delay problem incurred when sending data simultaneously through a channel by expending the number of channels. However, the problem of selecting high efficient channel in data transmission remains for multi-channel based approach. In this paper, wepropose a new node scheduling algorithm for archiving energy savings while reducing delay using multi-channel in WSNs.

2. Related work

Researches to minimize energy consumption of sensor network can be divided into two methods in large. First, method of controlling energy by adjusting duty cycle has been proposed. S-MAC [1] protocol was suggested to minimize energy consumption by maintaining active time and sleeping time in a fixed period. However, active state is maintained even at the state of data transmission termination, which results in energy consumption. The work of [2] reduced energy consumption by not increasing active state through adjusting duty cycle of receiving node.Second, method of minimizing energy consumption through routing was proposed by minimizing transmission path between nodes. Also, method of sending data through shortest routing path based on cost was proposed [3,4,5,6]. However, if many nodes with identical hop exist, they select remote node as next node, resulting in energy consumption. Existing works for WSN have been mainly designed to maximize node life by conserving energy. However, lowering the energy consumption induces the additional delay.

Recently, many researches have been proposed to achieve a good tradeoff between energy consumption and delay. In order to reduce end-to-end delay, methods of sending control packets informing data transmission to receiving node before receiving node sends data were proposed [7,8,9]. However, many control packets induces additional energy wastes. To solve the problem, the work of [10] sends data to upper node in order from lower node by applying different duty cycle time depending on route depth. However, packet collision occurs upon packet transmission if there are several nodes at a layer because all of them have identical back-off time. Another approach for reducing delay has been proposed using multi-channel and distributing data transmission. LQ-MCMAC [11] suggested method that sends data with RSSI threshold value and selects channel with high transmission efficiency. Reservation based multi-channel CSMA MAC protocol [12] reserves transmission request when transmission is requested from other node during data transmission, which leads to minimize competition for transmission.

These existing works could conserve energy and reduce delay significantly. However, due to their large scale, they impose limitations when coordinating sensor nodes [13]. Even for the distributed networking protocols into the scalability issue, the performance of a large scale WSN deteriorates as the number of nodes increases. Moreover, they possess some problems of maintaining a certain level of functionality and performance.

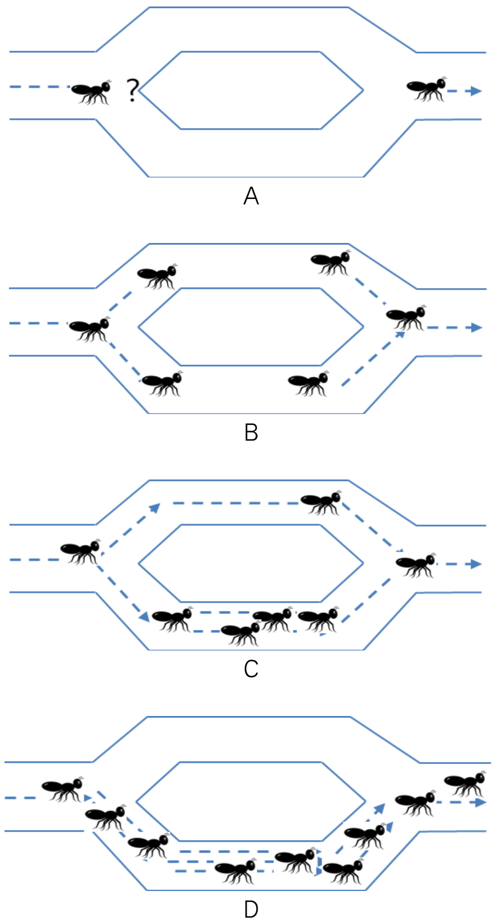
To address these concersn, we propose a bio-inspired node scheduling algorithm (BISA) in the multi-channel environment. Self-organized control inspired by biological systems has been receiving considerable attention as a new alternatives for the realization of robustness, scalability and adaptability. Biological systems are versatile and adapt themselves to environmental changes. Each entity of abiological system makes decisions based on local interactionswith their neighbors. For this reason, a number of methods have been proposed where the attributes of biological systemswere adopted to computer network systems. In this paper, we apply biologicalsystem to WSNs in order to save energy and reduce delay as well.

3. Bio-inspired Scheduling Algorithm

3.1 Ant Colony Optimization(ACO)

Ant Colony Optimization(ACO) algorithm introduced by Dorigo(1992) is a method to find a shortest path among many paths from starting point to final destination[14,15].

Fig.1 shows the process for ants to find a shortest path by selecting paths. After ants reach destination passing through many paths to arrive at the destination where foods are from the starting point, they discharge their pheromone on the path coming back to the starting point. Afterwards ants heading toward destination from starting point head for the destination following pheromone ants which have started before themand come back have discharged. Even though many ants travel through many paths, pheromone of remote path vaporizes due to ants' long travel distance and shorter distance has much accumulated pheromone owing to short travel distance. While ants travel through path with much pheromone, pheromone remains a travel path toward destination, determining the shortest path to the final destination.



(Figure 1) How real ants find a shortest path [16].

3.2 ACO Based Algorithm Structure

Sink node broadcasts packets and all neighboring nodes which have received packet renew path metric values with data included in packet and their data. Afterwards each node determines path metric value of its own, transmitting to neighboring nodes. The neighboring nodes save received path metric values and in case that they have data to send, they select node with the biggest path metric value among neighboring nodes and transmit. In order to apply ACO algorithm to our proposed scheme (BISA), we show the relevant entities of the ant colony system and our proposed BISA system in Table 1.

(Table 1) Mapping from ACO to BISA

ACO	BISA
Ant point of departure	Source node
Destination	Sink Node
Ant	Packet
Pheromone release	Path metric
Shortest path	Path metric values with the highest sequence of nodes

In BISA, by applying ACO method which is a kind of bio-inspired methods, packet is transmitted to the final destination, sink node through neighboring nodes in the sending node and calculation on the value of energy amount remaining and the number of hops which each node has is sent to neighboring node and node with the maximum value among received values is selected by forward node.

3.3 Initialization

By setting the number of hops of itself as 0 at sink node, packet broadcasting is conducted. As packet is transmitted to node, the number of hops increases by one and node receiving packet determines its number of hops by the number of hops written on packet and conducts broadcasting of packet written its number of hops to neighboring nodes. By repeating the process, all nodes on network set the number of hops.

3.4 Node Selection

Path metric is defined as F below

$$F = (E_0 - E_c) / H \quad (1)$$

E_0 is overall energy, E_c energy consumed up to now, and H the number of hops from the relevant node to sink node. F is a value dividing energy amount remaining at node by hop count value up to sink node. Each node informs its F value to neighboring nodes periodically and node having data to send selects node with the biggest F value as next node.

3.5 Channel Selection

Channel with RTT value smaller than threshold value of channel among channels which node has in the selected node is selected in priority and in case that all channels exceed threshold value, channel with the smallest RTT value is selected and data was transmitted. By overhearing pack sending and receiving of sending and receiving nodes with application of CSMA MAC protocol, RTT of channel is calculated and renewed.

Each node measures RTT(Round trip time) by channel and saves filtered RTT(RTTa) value using following formula:

$$RTT_{i,new} = (1-\alpha)RTT_{i,past} + \alpha RTT$$
$$RTT_{\alpha} = RTT_{i,new} \quad (0 < \alpha < 1) \quad (2)$$

Where RTT is the measured RTT value for channel i. $RTT_{i,past}$ is RTT value saved for channeli. $RTT_{i,new}$ is a newly calculated RTT value using $RTT_{i,past}$ and RTT.We introduce RTT threshold value, γ, which is a random value following uniform distribution within [$0,(2D_{req})/H$].

$$\gamma \sim U(0,(2D_{req})/H) \quad (3)$$

where D_{req} is delay requirement. By comparing RTTa value of selected channel with γ, in case that RTTa value has smaller value than γ, packet is transmitted through RTTa channel selected first. In case that RTTa value of channel is bigger than γ,however, packet is selected with comparison of RTTa value of other channel and γ, at that time RTTa value of other channel compares RTTa value of channel obtained through previous data packet transmission savedat the table of each node with γ. If RTTa of a channel is smaller than γ, packet is transmitted through the channel and in case of being bigger than γ, packet is transmitted by selecting other channel with the small RTTa value with comparing RTTavalue between channels.

(Table 2) Simulation Parameter

Variable Name	Values
Number of nodes	20 Nodes
Number of packets	10 Packets
Number of channels	10 Channels
Packet size	127 bytes
Data rate	20 kbps
Minimum channel quality	0.075
Maximum channel quality	0.75

4. Simulation Results

4.1 Simulation Configuration

To identify functions of proposed BISA, we compared with MCRT(Multi-channel real-time communication protocol) [17] and EER (Energy Efficient Routing) [18]. MCRT determines the shortest routing path between nodes by selecting path based on distance between nodes. EER selects next path from shortest path between source node and receiving node, while minimizing energy of the node by keeping sleep state.

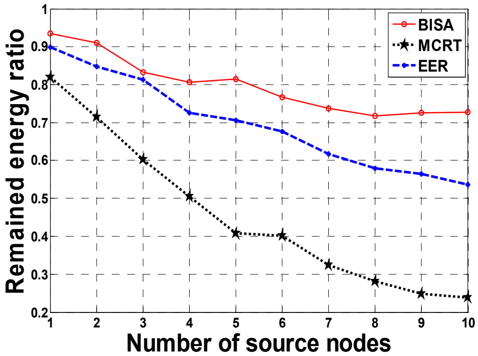
We simulate three methods using MATLAB. The simulation parameters are listed in Table 2. 20 sensor nodes are deployed randomly in a region that measure 100m × 100m. By setting the number of channels as 10, residual energy amount at node and delay are compared.

4.2 Simulation Results

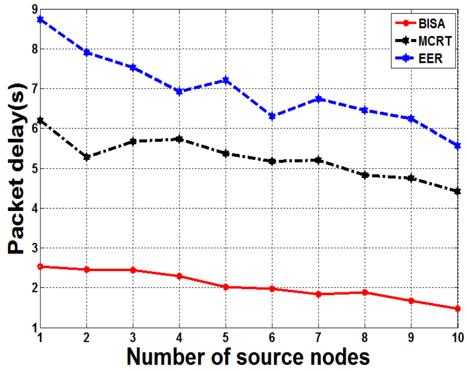
Fig 2 shows ratio of residual energy amount at 20 nodes in overall on the whole energy by varying the number of nodes. MCRT and EER algorithm show rapid reduction of remaining energy amount according to the increase of the number of receiving nodes. In BISA algorithm, even though the number of receiving nodes increases, a bit amount of energy decreases. This is because there is small re-transmission of data packet sent at each node in BISA. However MCRT algorithm wastes much energy as re-transmission of packet becomes much. EER also shows a larger number of data retransmission, but it shows higher energy efficiency than MCRT because of a fewerrouting path. Increasedre-transmission of node packet continues to energy depletion of node, causing loss of interim transmission path.

Fig 3 shows end-to-end delay by varying the number of nodes. We set the delay requirement to three seconds. BISA shows that the end-to-end delay is maintained under the delay requirement in spite of increasing the number of receiving nodes. However, MCRT and EER show that the end-to-end delay exceeds the required delay.

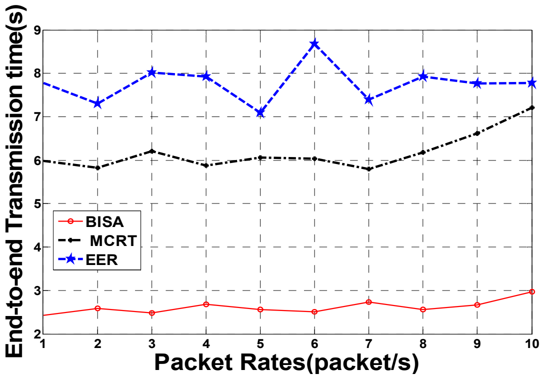
Fig 4 shows end-to-end transmission time by varying packet rates.We increase the number of sending packets from 1 to 10 per a second. BISA shows that the end-to-end transmission time lies under three seconds, but MCRT and EER do not guarantee delay requirement at all.



(Figure2) Average residual energy ratio varing the number of source nodes.



(Figure3)Average delay time varing the number of source nodes.



(Figure4) End to end transmission time varing the number of transmission packets.

5. Conclusions

We propose a new bio-inspired node scheduling algorithm (BISA) to improve energy efficiency while guaranteeing delay requirement. The proposed algorithm minimizes energy consumption through setting the shortest routing path with node hop and energy value. In addition, the proposed algorithm selects the channel based on the calculated RTT of channel. From the simulation results, we observe that BISA is more effective than the existing protocols in terms of energy consumption and transmission delay. In future, we plan to extend our research to realize our algorithm in WSNs.

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