# Proposal and Evaluation of an Information Dissemination Method Based on Flooding for Energy Efficiency in Wireless Sensor Networks

Hiroki Oda, Hiroyuki Hisamatsu, and Hiroshi Noborio

***Abstract*—In recent years, wireless sensor networks (WSNs) have been attracting increasing attention. Most of the sensor nodes in these types of networks are powered by batteries, which therefore necessitates that information dissemination be energy efficient. In this paper, we propose a new flooding method-based information dissemination method that tackles the issue of energy-efficient information dissemination in WSNs. By interpreting same message broadcasts from an adjacent node to a sending node as an acknowledgment of successful message transmission, we control message broadcasts and decrease the number of messages transmitted and received. We show by means of simulations that, in contrast to the conventional flooding method, our proposed method results in an improvement in the information delivery ratio with only a marginal increase in power consumption when packet loss probability is high. We also show that our proposed method results in less energy consumption in the overall network than the flooding method when the wireless radio range is long.**

***Index Terms*—Wireless sensor network, energy efficiency, information dissemination.**

## I. Introduction

In recent years, wireless sensor networks (WSNs) have been attracting increasing attention. WSNs comprise a number of sensor-equipped wireless nodes that monitor aspects of their surroundings, such as temperature and illumination. These nodes communicate wirelessly and form networks that operate without the need for communication base stations such as wireless LAN access points and cellular phone base stations. Because information collection and dissemination can be easily done using small wireless sensor nodes, WSNs are deemed to be applicable in various fields, such as agriculture and industry. In this paper, we tackle the issue of energy-efficient information dissemination in WSNs.

Most of the nodes used in WSNs are battery operated. In a sensor node, the electric power consumed during the transmission and reception of a message comprises a large proportion of the overall electric power consumed by that node, and can be as high as fifty percent [1]. As a result, the process of information dissemination, in which a node has to transmit and receive messages many times, rapidly depletes the battery used by a node. This results in a decrease in the number of hours the combined WSN can operate. Consequently, an information dissemination method that suppresses the transmission and reception of unnecessary messages in WSNs is urgently required.

The flooding method is the conventional information dissemination method utilized in WSNs [2]. In information dissemination via the flooding method, a send node first broadcasts a message to adjacent nodes and, if it is a message that is being received by the adjacent nodes for the first time, they rebroadcast it. This process is repeated until the message is disseminated to the entire network.

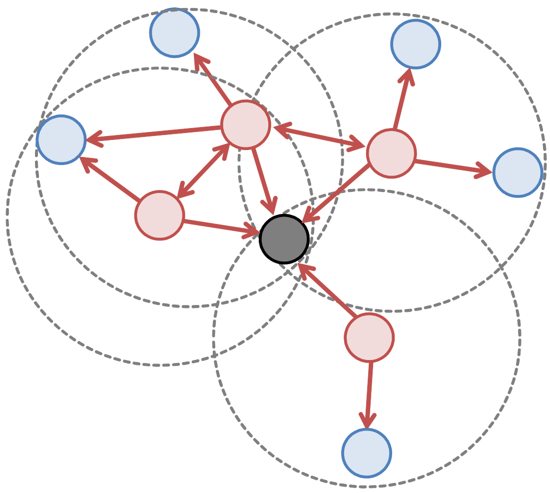


Fig. 1. Example of information dissemination via the flooding method.

Fig. 1 illustrates the process of information dissemination via the flooding method. First, the black node, which has a message to disseminate, broadcasts the message to the nodes adjacent to it (the red nodes in the figure). These adjacent nodes then rebroadcast the message to all the nodes adjacent to them (blue, black, and other red nodes in the figure).

However, in the flooding method, a sending node broadcasts messages without considering the status of the nodes adjacent to it. Consequently, even when all the adjacent nodes have already received the messages and the sending node does not need to broadcast them, it still does. This results in the adjacent nodes receiving the same messages multiple times and them, along with the sending node, consuming electric power needlessly.

A gossip method that overcomes this inherent problem of the flooding method has been proposed [3]. The proposed gossip method introduces a probability factor for the message being broadcast into the flooding method. Specifically, when a node receives a message that it had not previously received,

Manuscript received November 29, 2013; revised January 3, 2014. This work was supported by Dayz Inc.

Hiroki Oda is with the Graduate School of Information Science and Arts, Osaka Electro-Communication University, Osaka Japan. (e-mail: dt11a001@oecu.jp).

Hiroyuki Hisamatsu is with the Department of Computer Science, Osaka Electro-Communication University, Osaka Japan. (e-mail: hisamatu@isc.osakac.ac.jp).

Hiroshi Noborio is with the Department of Computer Science, Osaka Electro-Communication University. Osaka, Japan. (e-mail: nobori@isc.osakac.ac.jp).

it broadcasts it to adjacent nodes according to the broadcast probability. Consequently, compared with the flooding method, the number of times the same message is broadcast and received in each node decreases, which results in a corresponding decrease in power consumption. However, because the appropriate broadcast probability depends on the status of the network, determining a suitable probability is a difficult problem.

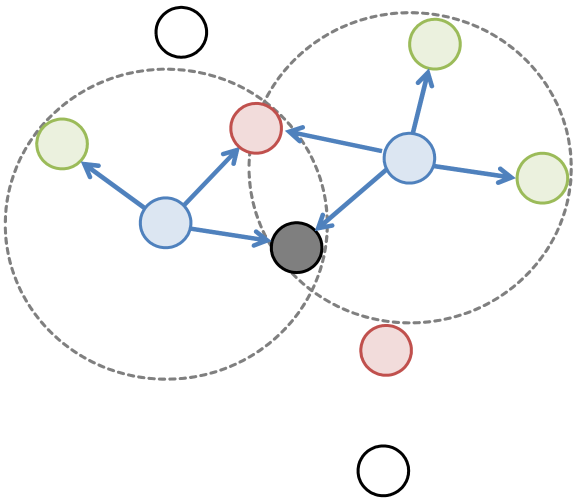


Fig. 2. Example of information dissemination via the gossip method.

Fig. 2 illustrates the process of information dissemination via the gossip method. First, the black node, which has a message to disseminate, broadcasts it to adjacent nodes (the blue and the red nodes), which then receive the message. The blue nodes, which satisfy the broadcast probability, then rebroadcast the message. Conversely, the red nodes, which do not satisfy the broadcast probability, do not rebroadcast the message.

In this paper, we propose a new flooding method-based information dissemination method for WSNs. In our proposed method, when a send node receives a message that has previously been broadcast to its adjacent nodes, this received message is interpreted as an acknowledgment for the message that was broadcast prior. If the sending node does not receive a sufficient number of acknowledgments, it is assumed that the message previously broadcast to the adjacent nodes was not received for some reason and so the sending node rebroadcasts the message. This mechanism realizes a high information delivery ratio in networks where packet loss probability is high. Further, if a node receives the same message as the one it is preparing to broadcast from different adjacent nodes, our proposed method assumes that the message has already been disseminated by the adjacent nodes, and so the message that was being prepared is not broadcast.

To evaluate the performance of our proposed method, we conducted simulations using networks in which nodes are located on a square lattice. Consequently, we show that the information delivery ratio of our proposed method improves power consumption in networks where packet loss probability is high compared with the flooding method. We also show that our proposed method results in less energy being consumed in the overall network than the flooding method when the wireless radio range is long.

The remainder of this paper is organized as follows. In Section II, we introduce works related to information dissemination. In Section III, we explain our information dissemination method. In Section IV, we evaluate the performance of our proposed method. Finally, we conclude and outline future work in Section V.

## II. Related Work

Several studies have been conducted on information dissemination in WSNs [4]-[7]. For example, the authors [4] proposed a flooding method-based information dissemination method for disseminating the information acquired by a node. Their proposed method reduces the number of sent and received messages at each node by dropping messages at a constant rate. However, because the method drops messages at each node without discretion, it cannot achieve a high information delivery ratio.

The authors [5] proposed an information dissemination method in which a sink node is used to collect information from nodes, which it then disseminates to the nodes in the network. In their proposed method, to achieve reliable message transfer, a sending node sends messages to a receiving node not by broadcast but by unicast, and the receiving node sends a feedback message back to the sending node. Because it uses feedback messages, it is reasonable to expect that the method can achieve a high information delivery ratio. However, it is also anticipated that as the number of messages being disseminated in the network increases, the energy consumption in the network will also increase.

The authors [6] proposed a method in which networks consist of multiple mobile sinks and sink nodes are used to disseminate information to the nodes in the network. Their method divides a network into several smaller networks and messages are disseminated only within each small network. As a result, their method can reduce the number of messages being disseminated in a network. However, it applies only to information dissemination in the small networks. Therefore, it would be difficult to extend it to the entire large network.

The authors [7] proposed an information dissemination method in which nodes transmit the information they acquire, such as temperature, humidity, and brightness, to a sink node that moves throughout the network. In this method, the information is collected by the nodes in some parts of the network and the sink node retrieves the information from them. Because this method assumes that the sink node has special characteristics, it would be difficult to apply it to information dissemination in the overall network.

## III. Proposed Method

When information is disseminated via the flooding method, the opportunity for adjacent nodes to receive a message increases when each node broadcasts a message two or more times. This is expected to correspond with an increase in the information delivery ratio. However, unnecessary message transmission and reception occur, resulting in the electric power consumption of each node increasing.

In our proposed dissemination method, we control the transmission of unnecessary messages. When a node receives a message that it had broadcast previously, this is interpreted as an acknowledgment that the message was broadcast successfully. If a node receives a certain number of acknowledgments, it stops broadcasting the message. Thus, our method can achieve a high information delivery rate, while restricting unnecessary message broadcasts. This prevents the electric power consumption of each node from increasing.

In our proposed method, a node broadcasts a message if it generates or receives one that needs to be disseminated. After broadcasting a message, the node remains on standby for a period of time. If, during the standby period, the node receives a message that was broadcast previously from adjacent nodes α times or more it assumes that the message was successfully broadcast to the adjacent nodes, and therefore stops broadcasting that message.

We give the standby period $T$ ( $\mu s$ ) after broadcasting a message by the following equation:

$$T = (SIFS + DIFS + CW_{\max} + CW) \times slot\_time) \times \alpha$$

where SIFS, DIFS, CWmax, and *slot_time* are parameters used to avoid packet collisions in CSMA/CA (which is used in IEEE 802.11 as an access control method), and *CW* is the random value of $CWmin \le CW \le CWmax$. *CWmin* is also a parameter that is associated with CSMA/CA.

Our proposed method determines that a message broadcast to adjacent nodes has failed when the same message as the one broadcast previously is not received $\alpha$ times or more within $T$ ( $\mu s$ ). When this occurs, the node rebroadcasts the message. The message is broadcast a maximum of $\beta$ times. If the node does not receive an acknowledgment $\alpha$ times or more, it determines that nearby nodes do not exist, and so it ceases to broadcast that message. The notations employed in our proposed method are summarized in Table I.

TABLE I: NOTATIONS USED IN OUR PROPOSED METHOD

| | |
|---|---|
| $\alpha$ | Threshold value for successful transmission |
| $\beta$ | Number of rebroadcasts |
| *T* | Standby time after broadcast |
| *DIFS* | DCF Interframe Space |
| *SIFS* | Short Interframe Space |
| *CW* | Contention Window |

## IV. PERFORMANCE EVALUATION

We evaluated our proposed method via simulations in order to verify its efficacy. Fig. 3 shows the network model used in the simulation. We used a network model comprising $100 \times 100$ square lattices, with each side measuring 100 (m), and placed sensor nodes on the square lattices. We selected a node at random and used it to generate a message, which was then disseminated throughout the network. In this paper, we compare he results of scenarios in which a message is spread using our proposed method with those of flooding methods. We evaluated two types of flooding methods. In the first flooding method, which we refer to as Flooding(1), nodes broadcast a message only once, whereas in the other method, which we refer to as Flooding(2), nodes broadcast a message twice. We conducted 50 simulations and measured the average total electric power consumed for message delivery to the nodes and the average message delivery ratio.

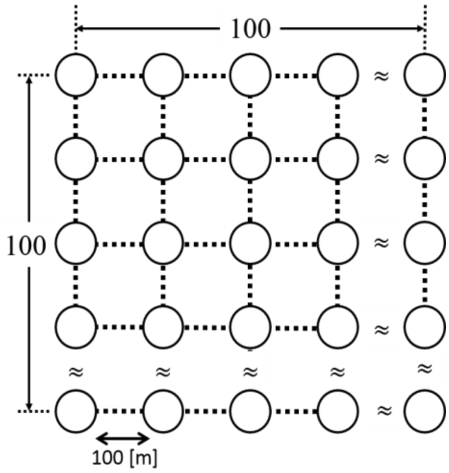



Fig. 3. Network model used in our simulations.

In our simulations, a sensor node communicated with adjacent nodes using the IEEE 802.11g wireless LAN standard. The Slot Time, Short Inter Frame Spacing (SIFS), Distributed Inter Frame Spacing (DIFS), $CW_{\min}$ , $CW_{\max}$ , and Data Rate used were 20 ( $\mu s$ ), 15 ( $\mu s$ ), 50 ( $\mu s$ ), 15, 1024, and 54 (Mbit/s), respectively. We used radio ranges for the sensor node of 100, 150, and 200 (m). The parameters used by our proposed method were $\alpha = 1$ and $\beta = 2$ . We used the same electric power consumption model [8], in which the model of a sensor node consumes $E_{elec}$ (nJ/bit) in the transmission or receiver circuitry, and $\varepsilon_{amp}$ (pJ/bit/ m$^2$) in the transmission amplifier. A sensor node expends electric power, i.e., $E_{Tx}(k,d)$ or $E_{Rx}(k)$ when broadcasting or receiving a $k$ (bit) message to or from a distance $d$ (m). These are given by the following equations:

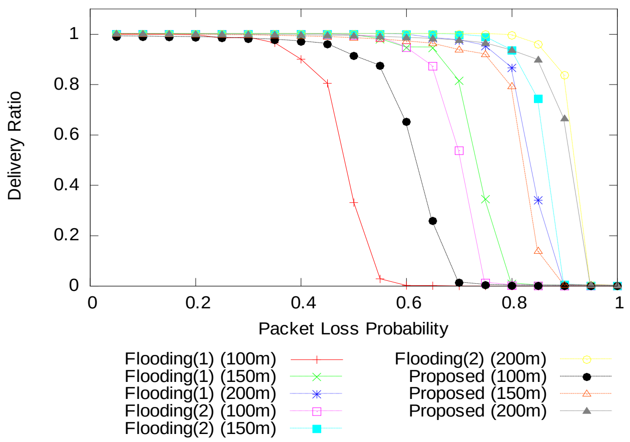
$$E_{Tx}(k,d) = E_{elec} \times k + \varepsilon_{amp} \times k \times d^2$$

$$E_{Rx}(k) = E_{elec} \times k$$

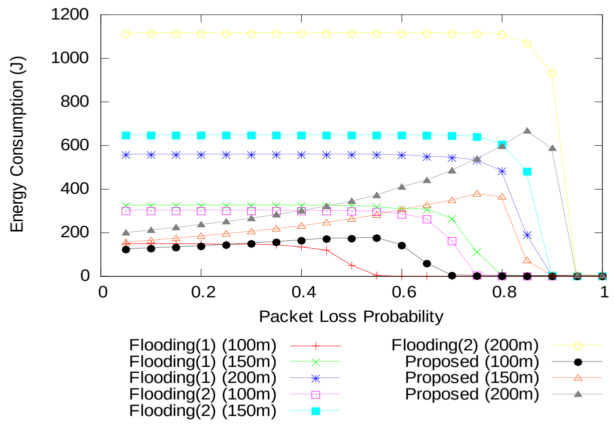
We set $E_{elec} = 50$ (nJ/bit) and $\varepsilon_{amp} = 100$ (pJ/bit/ m$^2$). The message size was 12,000 (bit), which comprised one packet. Table II summarizes the parameters used in the simulations.

TABLE II: PARAMETERS USED IN THE SIMULATION

| | |
|---|---|
| Proposed method | |
| $\alpha$ | 1 |
| $\beta$ | 2 |
| Network environment | |
| Wireless LAN Standard | IEEE 802.11g |
| Packet Size | 12000 (bit) |
| Radio Range | 100 (m), 150 (m), 200 (m) |
| *SIFS* | 10( $\mu s$ ) |
| *DIFS* | 50( $\mu s$ ) |
| $CW_{\min}$ | 15 |
| $CW_{\max}$ | 1024 |
| Slot Time | 20 ( $\mu s$ ) |
| Electric power consumption model | |
| $E_{elec}$ | 50 (nJ/bit) |
| $\varepsilon_{amp}$ | 100 (pJ/bit/ m$^2$) |



(a) Delivery Ratio



(b) Total Energy Consumption

Fig. 4. Simulation results.

Fig. 4 shows the simulation results for various packet loss probabilities for radio ranges of 100, 150, and 200 (m). Fig. 4(a) shows the message delivery ratio, while 4(b) shows the electric power consumed during the dissemination of a message in the network with various packet loss probabilities. First, our proposed method has high message delivery ratios, whereas the message delivery ratio for Flooding(1) declines with increasing packet loss probability, as shown in Fig. 4(a). With Flooding(1), each node broadcasts a message to adjacent nodes only once. If an adjacent node fails to receive the message, the message is not broadcast again. Consequently, the message delivery ratio with Flooding(1) declines when packet loss probability is high. By contrast, if an adjacent node fails to receive a message, our proposed method broadcasts the message to the adjacent node again. Thus, the message delivery ratio with our proposed method is high.

However, it can be seen that the delivery ratio of our proposed method is smaller than that of Flooding(2) when the packet loss probability is high. This is because the parameter $\alpha$ used by our proposed method is too small for a network in which the packet loss is high. We can improve the delivery ratio of our proposed method by increasing α, which means that our proposed method would require more acknowledgments for successful broadcasting. However, the more acknowledgments required by our proposed method, the more electric power consumed. As a result, we plan to determine the ideal parameter setting in future work. In contrast with our proposed method, Flooding(2) always broadcasts a message twice, even if the adjacent nodes have already received the message. Consequently, the delivery ratio with Flooding(2) is higher than that with our proposed method when packet loss probability is high.

Fig. 4(b) shows that the electric power consumed with our proposed method is smaller than that consumed with Flooding(1). This is because when the packet loss probability is small, any node that has a message to broadcast can receive the same message from different adjacent nodes before the node broadcasts that message. Our proposed method interprets this situation as the message having already being disseminated to the adjacent nodes, and therefore determines that there is no need to broadcast the message. Consequently, when the packet loss probability is small, the number of messages broadcast and the number of messages received are low, which results in electric power consumed with our proposed method being smaller than that consumed with Flooding(1).

Conversely, the electric power consumed with our proposed method is higher than that consumed with Flooding(1). This is because our proposed method broadcasts the same message twice when the packet loss probability is high and an adequate number of acknowledgments cannot be received. Note that the message delivery ratio with Flooding(1) is quite low in the region where the electric power consumption of our proposed method is comparatively large relative to Flooding(1). We strongly believe that it is most important to achieve a high delivery ratio in information dissemination methods.

Fig. 4(b) also shows that the electric power consumed with our proposed method is much less than that consumed with Flooding(2). This is because our proposed method constrains the number of messages broadcast and received using messages from the adjacent node broadcast as acknowledgment of successful transmission. As a result, the electric power consumed with our proposed method is much less than that consumed with Flooding(2).

In Fig. 4(a), it can be seen that, in our method, as the radio range increases, so does the information delivery ratio. However, it can also be seen in Fig. 4(b) that the electric power consumed with Flooding(1) and Flooding(2) is extremely high when the radio range is long. By contrast, the electric power consumed with our proposed method is small when the range is long. This is because our proposed method does not broadcast a message if a node receives the same message from different adjacent nodes before the node broadcasts that message. In our proposed method, the greater the radio range becomes, the fewer nodes broadcast messages, and the increase in the electric power consumed becomes small in the network.

## V. Conclusion and Future Works

In this paper, we proposed a new flooding method-based information dissemination method for WSNs. Our proposed method controls message broadcasts using the messages that adjacent nodes broadcast as acknowledgments. The results of simulations conducted show that, compared with information dissemination methods that are based on the conventional flooding method, our proposed method ensures a high information delivery ratio with only a marginal increase in the electric power consumed if the packet loss probability is high. Moreover, the increase in the electric power consumed with our proposed method is much smaller than that consumed with the flooding method when the range is long.

We are currently working on evaluating our proposed method via simulations of networks in which the nodes are randomly located. We also plan to compare the performance of our proposed method with that of the gossip method.

## REFERENCES


[1] Y. Agarwal, C. Schurgets, and R. Gupta, "Dynamic power management using on demand paging for networked embedded systems," in *Proc. the 19th Asia and South Pacific Design Automation Conference*, Jan. 2005, pp. 755–759.

[2] Y. Dalal and R. Metcalfe, "Reverse path forwarding of broadcast packets," *Communications of the ACM*, vol. 21, no. 12, pp. 1040–1048, Dec. 1978.

[3] S. M. Hedetniemi, S. T. Hedetniemi, and A. L. Liestman, "A survey of gossiping and broadcasting in communication networks," *IEEE Networks*, vol. 18, no. 4, pp. 319-349, 1988.

[4] S. Tilak, A. Murphy, and W. Heinzelman, "Non-uniform information dissemination for sensor networks," in *Proc. the 11th IEEE International Conference on Network Protocols*, Nov. 2003, pp. 295–304.

[5] S.-J. Park, R. Vedantham, R. Sivakumar, and I. F. Akyildiz, "A scalable approach for reliable downstream data delivery in wireless sensor networks," in *Proc. the 5th ACM international symposium on Mobile ad hoc networking and computing*, May 2004, pp. 78–89.

[6] H. Luo, F. Ye, J. Cheng, S. Lu, and L. Zhang, "TTDD: Two-tier data dissemination in large-scale wireless sensor networks," *Wireless Networks*, vol. 11, no. 1–2, pp. 161–175, Jan. 2005.

[7] E. B. Hamida and G. Chelius, "A line-based data dissemination protocol for wireless sensor networks with mobile sink," in *Proc. IEEE International Conference on Communications (ICC 2008)*, May 2008, pp. 2201–2205.

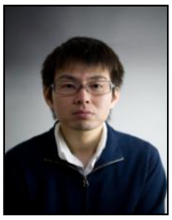
[8] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks," in *Proc. the 33rd Hawaii International Conference on System Sciences*, Jan. 2000, pp. 3005–3014.



**Hiroki Oda** was born in Osaka, Japan, in 1987. He received B.E and M.E. degrees from Osaka Electro-Communication University, Osaka, Japan, in 2009 and 2011, respectively. He is currently a doctoral student at the Graduate School of Information Science and Arts, Osaka Electro-Communication University.

His research work is in the area of transport architecture.

Mr. Oda is a member of IEICE, IPSJ and IEEE.


**Hiroyuki Hisamatsu** received M.E. and Ph.D. degrees from Osaka University, Japan, in 2003 and 2006, respectively. He is currently an associate professor of Department of Computer Science, Osaka Electro-Communication University. His research work is in the area of performance evaluation of TCP/IP networks.

Prof. Hisamatsu is a member of IEEE and IEICE.



**Hiroshi Noborio** was born in Osaka Prefecture, Japan, in 1958. He graduated in computer science from Shizuoka University, Shizuoka, Japan in 1982 and received the Dr. Eng. degree (equivalent of Ph.D.) in mechanical engineering from Osaka University, Osaka, Japan in 1987.

From 1987 to 1988, he worked as an assistant professor in the Department of Mechanical Engineering, Faculty of Engineering Science, Osaka University. He was a humboldt scholar and a visiting researcher in the Department of Electrical Engineering, Technical University of Munich. He is currently the dean of Faculty of Information Science and Arts and also a Professor in the Department of Computer Science, Osaka Electro-Communication University. His research interests span robotics, computer graphics, virtual reality, and medical engineering. He has published over 100 scientific papers and papers of conference proceedings.

Prof. Noborio is a member of IPSJ, IEICE, RSJ, ISCIE, JSMVR, JRSJ, JSCAS, SICE and IEEE.