A COOPERATIVE BROADCASTING METHOD FOR A SENSOR NETWORK

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ABSTRACT

Sensor networks and ad-hoc networks, which do not require a base station such as an access point, have a hidden node problem because nodes communicating at the same time cannot know each other's communication status. On other hand, in a wireless infrastructure network the access point manages the communication with the node using RTS (request to send) and CTS (clear to send). However, we cannot use the RTS/CTS method in broadcasting because the number of target nodes is not one but more than two. In this paper, we propose a broadcasting method based on RTS/CTS to avoid this problem. In this method the sender node selects the target node, and they communicate with each other. Neighboring nodes can listen to these packets. Then the sender node can broadcast its information to multiple nodes. We use the wireless nodes specified by IEEE 802.15.4 which is the physical layer's specification. Our experimental results show effective transmissions.

KEYWORDS

IEEE802.15.4, Sensor Network, Ad hoc Network, Broadcasting, a Hidden Node Problem

1. INTRODUCTION

In sensor networks and ad-hoc networks, which consist of only nodes, nodes can communicate with each other via the intermediate nodes with multiple hops. A node with a sensor sends its sensing values to the central node via other nodes in a sensor network. So each node is a static. This network topology is one of a mesh network [1]. The network where nodes move around is called MANET (mobile ad hoc network), and it is one of the ad-hoc networks [2]. For example, these networks are adopted for a vehicle-to-vehicle communication and a disaster scene communication [3–5]. Moreover these networks do not require an access point, so they can be also applied to a ubiquitous network [6]. In order to provide a continuous network for applications, some routing protocols are proposed. There are two main kinds of routing; one is a reactive type, and the other is a proactive type. AODV (ad hoc on-demand distance vector routing) [7] and DSR (the dynamic source routing protocol) [8] are reactive routing protocols, and OLSR (optimized link state routing protocol) [9] and TBRPF (topology dissemination based on reverse-path forwarding) [10] are proactive routing protocols. In addition, there are some routing protocols which use location information of nodes or values of acceleration sensors [11, 12].

In order to share the information to all nodes in the network, an effective flooding method is required. For example, OLSR which is one of the routing protocols for the ad-hoc network uses MPR (multipoint relay) nodes in order to flood the information effectively. In particular, if a

DOI : 10.5121/ijasuc.2011.2201

sender node use broadcasting or multicasting which sends a packet to multiple nodes in the same time, then the communication is efficient. The principal multicasting protocols are ODMRP (on-demand multicast routing protocol) [13], MAODV (multicast operation of the ad-hoc on-demand distance vector routing protocol) [14], AMRoute (ad hoc multicast routing protocol) [15], and CAMP (the core assisted mesh protocol) [16]. However, in sensor networks and ad-hoc networks, because there are no access points which manage the communication, the hidden node problem occurs, which means collisions of packets [17]. The RTS (request to send) / CTS (clear to send) method avoids this problem [18]. However it can apply only to unicasting. There are still problem in multicasting or broadcasting. In this paper, we propose a broadcasting method based on RTS/CTS which is a peer-to-peer communication method. In the Section 2, we introduce the communication in an ad-hoc network. A hidden node problem and RTS/CTS are described. And we expand it for broadcasting in Section 3. The experimental results in Section 4 show effective transmissions of our proposed method. Finally, we conclude this paper in Section 5.

2. COMMUNICATION IN AN AD-HOC NETWORK

2.1. A hidden node problem

Nodes in an ad-hoc network communicate with each other in order to share the routing information. Because a radio wave disperses uniformly from its source, the wireless communication is not unicasting but multicasting or broadcasting. When two or more nodes send packets at the same time, a packet conflict occurs. Usually, a node which wants to send a packet first checks whether the channel is busy or not. However, if the nodes cannot hear each other's signals they decide the channel is clear. As a result, the intermediate nodes between these sender nodes cannot receive a packet. This is called the hidden node problem. In order to avoid this problem, the sender node selects as small a transmitting power as possible. However, the sender nodes cannot decide the transmitting power in the first connection.

2.2 RTS / CTS

The hidden node problem means that the intermediate node receives two or more packets at the same time. By the receiver node giving a busy state to the neighboring nodes then the sender node of the hidden node problem finds the communication between other nodes. The packet of the sender node is called an RTS, and that of the receiver node is called a CTS. The wireless infrastructure network uses the RTS/CTS method in the communication between the access point and the client computer.

However, if and only if the receiver node is decided by the sender node such as by unicasting, we can use RTS/CTS packets. So there is still a hidden node problem in multicasting and broadcasting. In this paper, we propose a method of avoiding the hidden node problem in multicasting and broadcasting.

3. A BROADCASTING METHOD BASED ON RTS / CTS

We have expanded the concept of RTS/CTS to multicasting and broadcasting. First, the sender node transmits an RTS packet to neighboring nodes by broadcasting. Next, the nodes which receive the RTS packet reply with CTS to the sender node. The sender node selects the CTS nodes from the receivers. Then the sender node can communicate with the receiver node with a peer-to-peer connection. At the same time the neighboring nodes listen to these packets between the sender node and the receiver node. Finally, the sender node can send its packet to multiple nodes at the same time. As a result, the sender node and the receiver node transmit packets all over the network, and the neighboring nodes do not start another communication using the condition that the signal powers of all nodes are equal. So our proposed method avoids the hidden node problem.

If a communication error is detected, the receiver node can request a retry with ACK (acknowledgment) / NAK (negative acknowledgment). Therefore, the proposed method is robust against errors.

Figure 1 shows the packet format of the sender and receiver nodes. The size of a single packet specified by IEEE 802.15.4 is 125 bytes. We use 9 bytes as the header of a packet. Target ID and Sender ID mean the receiver node and the sender node. The state number means the status of nodes. First, the sender node sends the broadcast packet with the state number of 1 in order to decide the receiver node. Second, the nodes which received that packet send the reply packet with the state number of 2. Third, the sender node selects the receiver node from them. Then the sender node and the receiver node start to communicate with each other.

The receiver sends the same packet to the sender node like an echo. It copies the size and data from the sender's packet to its packet. It also exchanges the Sender ID and Target ID, and adds one to the ACK sequence number for its sequence number. Then the receiver node sends the packet to the sender node. Finally, the neighboring nodes can get data from both the sender node and the receiver node.

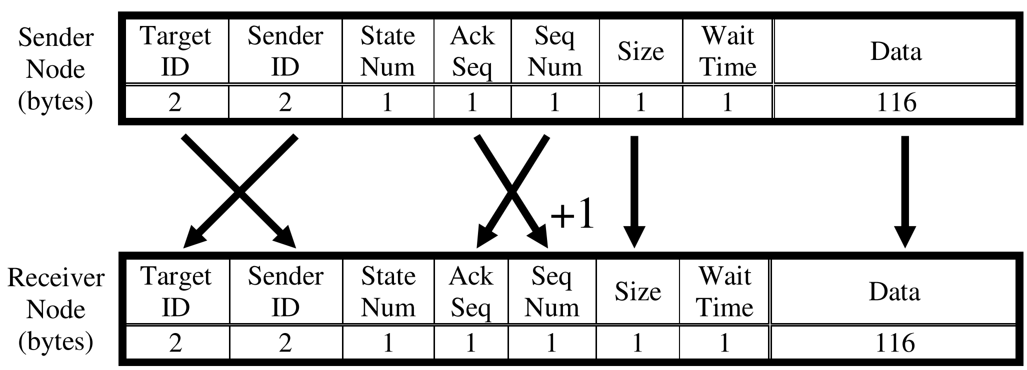


Figure 1 The packet format of sender and receiver nodes

Table 1 Specifications of SS-1 wireless module

Size	32 [mm] × 32 [mm] × 9 [mm]
Voltage	3.3 [v]
Electric current	2 [μA] for waiting 40 [mA] for sending
Modulation	2.4 [GHz] spread spectrum (IEEE 802.15.4)
Speed	250 [kbps]
Sensors	Acceleration sensor Temperature sensor
Serial ports	2 ports
g-Range = 1.5 g	800 [mV/g]
g-Range = 2 g	600 [mV/g]
g-Range = 4 g	300 [mV/g]
g-Range = 6 g	200 [mV/g]
Acceleration modes	Dynamic acceleration Static acceleration
Supply voltage (V_{DD})	-0.3 to +3.6

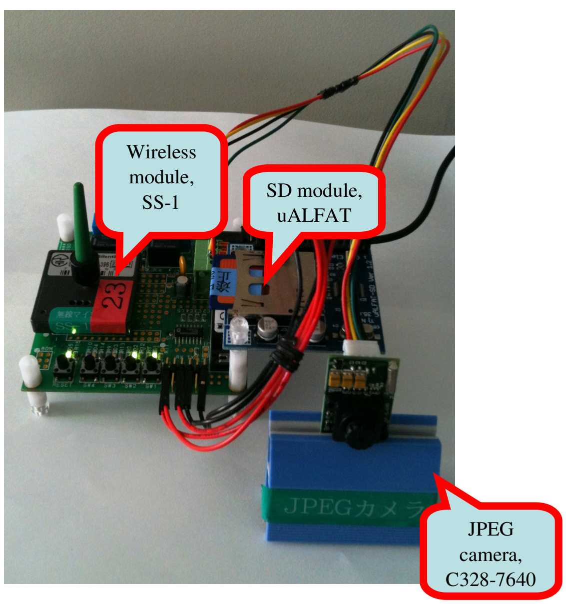


Figure 2 A wireless node using IEEE 802.15.4

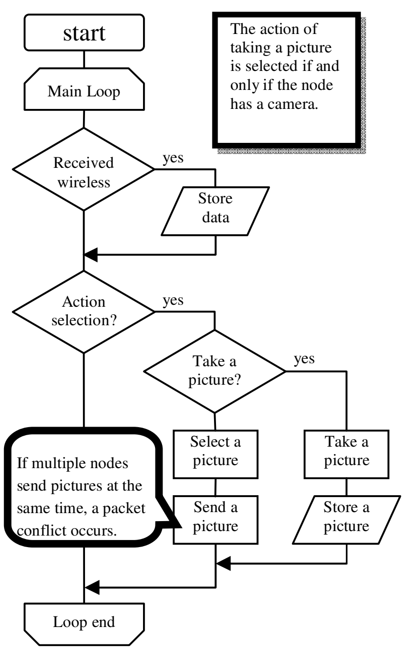


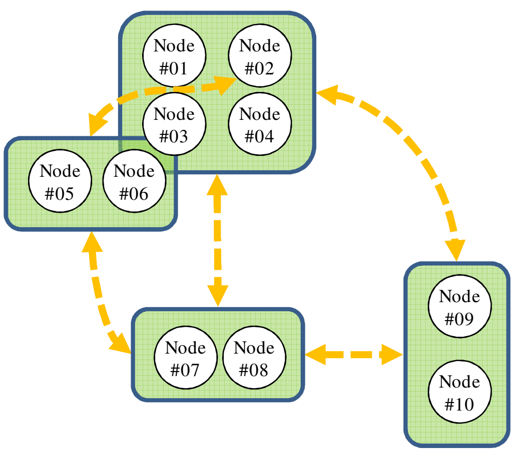
Figure 3 The flowchart of a picture sharing network system.

4. EXPERIMENTAL RESULTS

We applied our proposed method to a picture sharing network system, where wireless nodes have a camera and exchange pictures with each other in order to share all pictures [19, 20]. We use SS-1 modules as the wireless nodes, which are specified by IEEE 802.15.4 (shown in Figure 2. and Table 1). A node takes a picture in 10 seconds. While taking a picture whose size is 10 kB, it cannot receive another node's packet. After that, it sends the picture to neighboring nodes by broadcasting (shown in Figure 3).

We set up the nodes as shown in Figure 4. The grouped nodes in a green box mean that their signal powers are more than -75 [dBm], which means, the link is strong. The signal powers between the yellow arrows are from -75 [dBm] to -90 [dBm], that is, it means that they often loose a packet. Thus the hidden node problem will occur in communication between the green boxes.

If each node can receive all packets from another node, the number of pictures received is the number of nodes times the number of pictures taken. However, nodes cannot receive a packet while taking a picture and it is difficult to synchronize the communication between multiple nodes. If the number of pictures received is more than the number of pictures taken all nodes receive the sent pictures, and that means the picture sharing network system works well.



From \ To	1	2	3	4	5	6	7	8	9	10
1			-94.4	-95.0	-92.9	-95.0	-84.5			-32.7
2			-58.6	-47.6	-87.1	-70.5	-92.9	-42.1	-72.2	
3	-92.3	-59.5		-58.1	-89.2	-68.3	-92.5	-60.4	-68.8	
4	-90.2	-51.3	-59.4		-72.3	-75.9	-89.4	-41.5	-73.9	-85.5
5	-95.0	-95.0	-95.0	-92.7		-74.9	-66.1	-91.3	-95.0	-81.1
6		-74.1	-69.3	-74.0	-76.2		-82.5	-81.3	-75.6	
7	-85.1	-93.5	-94.6	-89.8	-66.6	-82.8		-92.9	-95.0	
8		-42.9	-60.8	-38.8	-81.3	-81.7	-92.0		-70.0	
9		-75.6	-71.4	-74.1		-77.2	-92.2	-70.5		
10	-35.6		-33.0	-95.0	-82.7	-91.0	-95.0			

(a) Connections between the groups of nodes (b) Received signal powers in nodes

Figure 4 The experimental conditions

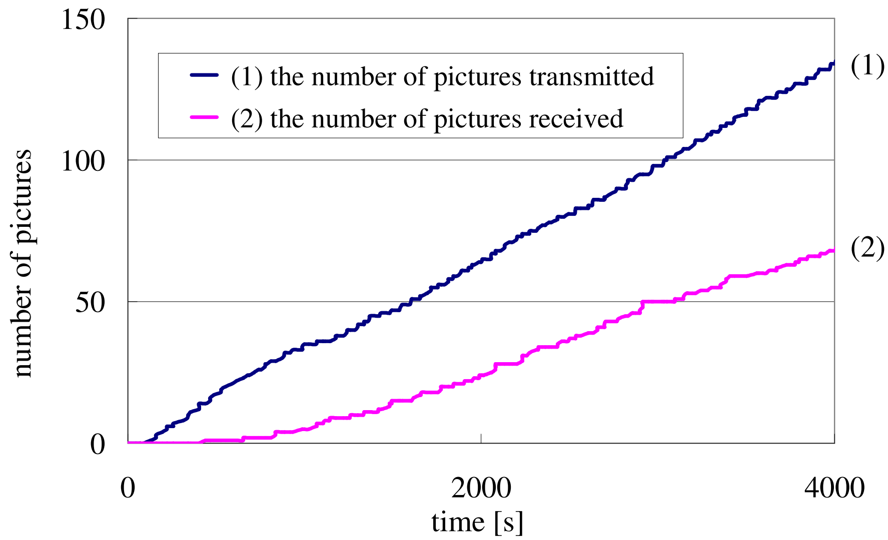


Figure 5 The number of pictures transmitted and received by broadcasting only

We compared three methods; first was the broadcasting only method where the nodes transmit the pictures using broadcasting, second was broadcasting using the receiver's check which add the ACK function to the broadcasting only method. Third was the proposed method which is based on a p2p connection.

Figure 5 shows the details of the broadcasting only method. Nodes receive less pictures than the pictures sent because there are many packets conflicts. Thus the line of the number of the pictures received is under the line of the number of the pictures transmitted. In order to avoid the packet conflicts, each node sends a start packet. After it starts broadcasting, the sender node does not listen to other nodes' packets. Figure 6 shows the result of the broadcasting using the receiver's check method. The performance of the rate between transmitted and received is better than the broadcasting only method. However the number of pictures received is under than the number of pictures transmitted.

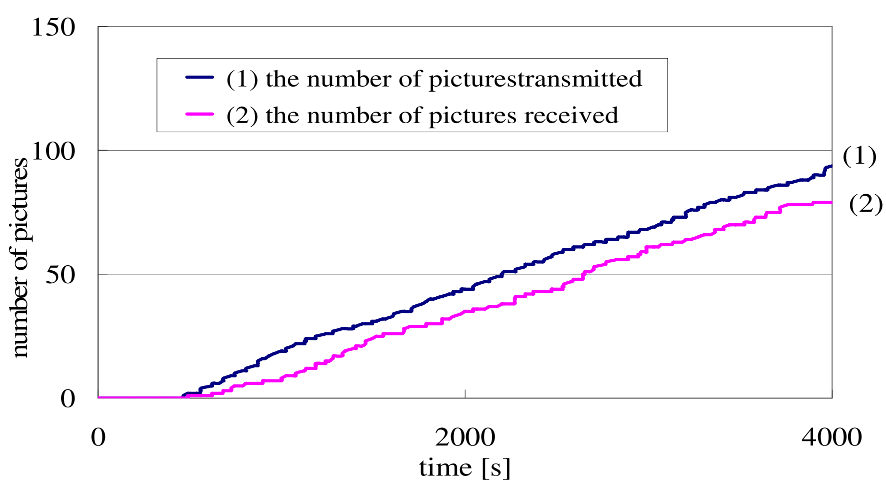


Figure 6 The number of pictures by broadcasting using the receiver's check

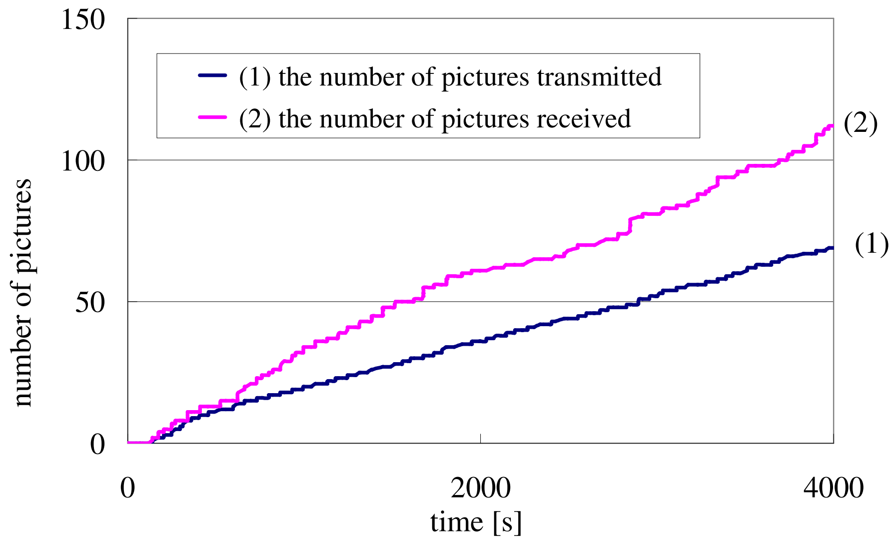


Figure 7 The number of pictures by the proposed method

The performance of our proposed method is shown in Figure 7. The number of pictures received is more than the number of pictures transmitted. Figure 8 is an illustration of the performances of the three methods. The vertical axis indicates the number of pictures received divided by the number of pictures taken. The performance of the conventional methods using broadcasting is under 1. On the other hand, the picture sharing rate of our proposed method is over 1. Thus nodes communicate with each other efficiently and avoid the hidden node problem.

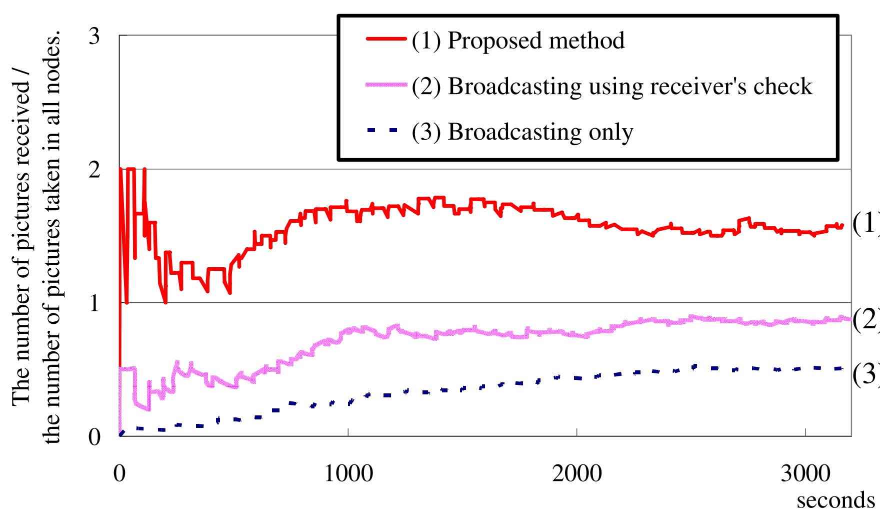


Figure 8 The performance of the three methods

5. CONCLUSION

There is a hidden node problem in sensor networks and ad-hoc networks which consist only of nodes. In conventional wireless networks, the RTS/CTS method is used to avoid this problem. However, because the network is peer-to-peer it does not work well in ad-hoc networks. In this paper, we proposed a broadcasting method based on RTS/CTS for sensor networks and ad-hoc networks. The sender node uses RTS packets in order to select the receiver node from neighboring nodes. During the communication between the sender node and receiver node, the neighboring nodes listen to their packets. Then the sender node can send its packet to multiple nodes at the same time efficiently. Experimental results show effective transmissions of our proposed method which can transmit the data to at least one node, and it means that the number of received node are more than one of the conventional method.

In this paper, we selected the node with the strongest signal power. For the future work, we should consider another selection. For example, the weakest power, random selection, machine learning selection, and so on. And we do not consider the moving of nodes, so we must move the nodes adaptive in certain scenario.

ACKNOWLEDGEMENTS

This work was supported by MEXT HAITEKU (2006) and KAKENHI (21710188).

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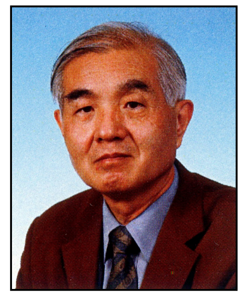

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