A Route Discovery Method Based on Received Power of Repeater Nodes for Sensor Networks in a Multipath Fading Environment

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***Abstract*— In this article, a route discovery method based on received power of repeater nodes for sensor networks in a multipath fading environment is studied. When each repeater node received Route Request Message, the message is decided whether accept or not by referring to received power information in Physical Layer. In the destination node, the most optimal route is selected from some route candidates according to the following criteria: received power level, number of hops and sequence number. From the results of computer simulations, it has been clarified that the proposed method has advantages in the route effective time and data distribution ratio comparing with the conventional method even if the route discovery time is lengthened by about 3 seconds.**

Keywords-component; AODV, Route discovery method, Received power monitoring, Route effective time, Data distribution ratio

I. INTRODUCTION

A wireless sensor network (WSN) is comprised of spatially distributed autonomous sensors on each node to monitor conditions and cooperatively pass their data through the network to a main location. The WSN has adhoc and routing functions which enable to determine the optimal route in any situations. The WSN can pass their data to the distant nodes through the multihop wireless networks

So as to construct multihop wireless networks, various routing protocols have been proposed, e.g. AODV (Ad Hoc On-Demand Distance Vector) defined in MANET (Mobile Ad-hoc Network).

In AODV, when Request To Send (RTS) of data is generated, the multiple candidates which is reachable to the destination nodes are searched. The route with the maximum sequence number and the least number of hops is selected from them. AODV discovers, establish and refresh the route by sending and receiving the route discovery request (RREQ) and Route Reply (RREP). Since AODV selects the route with the new route information and the least number of hops, the transmission delay is small, whereas the data distribution rate of links with the small received power value among the repeater nodes is low. The problem is pointed out that the route disconnection occurs soon after the route has established. Many countermeasures are proposed for this problem.

In this article, we propose the improved method which selects the route referring to the received power information added to RREQ in each hop. In the proposed method, it is determined whether RREQ is accepted or not by referring to the received power among the nodes when each node receives RREQ. For instance, when RREQ is transmitted, the repeater nodes detects the received power and the RREQ packet is discarded in the case that the received power level is smaller than the threshold received power value of RREQ. In this article we evaluate the proposed method by computer simulations referring to the criteria as follows: the data distribution time, the route discovery time and the route effective time. Our evaluation clarifies that the proposed method is more effective than the previous one.

II. PREVIOUS ROUTE DISCOVERY METHODS

In MANET, many routing protocols are proposed for the route discovery. Protocols are classified into the Reactive type and the Proactive type. AODV and DSR (Dynamic Source Routing) are examples of Reactive type and OLSR (Optimized Link State Routing) and DSDV (Destination Sequenced Distance Vector) are examples of Proactive type.

The Reactive type protocol constructs the route after receiving RTS. It can reduce the power consumption and is appropriate to the mobile terminal. On the other hand, the Proactive type protocol sends packets continuously, detects the adjacent node and controls the routing table. Hence the Proactive type nodes are appropriate to the continuous communication networks.

Reactive type AODV starts the route discovery process after the RTS of data is generated. The source node generates RREQ and broadcasts it to the adjacent node. At this time, if there are destination nodes nearby, TTL (Time To Live) is set to 1 and is transmitted so as to prevent useless spreading of RREQ. In AODV, TTL is decremented after passing a node and RREQ is discarded at the time when TTL is 0. In the case that RREQ does not return in a given period of time, TTL is incremented and the source node broadcasts RREQ again. Thus by gradually spreading the searching area, the destination nodes transmit RREP in unicast to the source node referring to the route which RREQ has passed. When the bidirectional sequence has finished and the source node has received RREP, the route establishment has finished [1]. AODV discovers and constructs the route on demand without referring to the received power between links. Therefore the problem has been pointed out that the route is disconnected soon after routing has finished. Many countermeasures for such problems have been proposed [2] [3]. Such countermeasures treat the problems when the problem occurs in routing.

So as to construct more stable route at the route discovery, we propose a method to construct more stable route between the links.

III. PROPOSITION OF A ROUTE DISCOVERY METHOD REFERRING A RECEIVED POWER

We propose a method referring to the received power of each node on the route. In the proposed method each node refers to the received power of the route. It can avoid the disconnection in a short time which has been the problem in the previous method. Figure 1 indicates the flowchart of the proposed method.

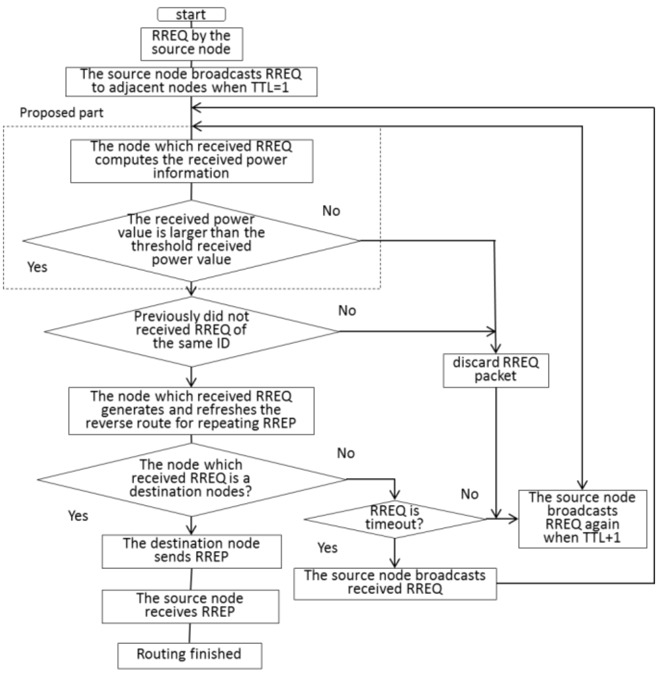


Figure 1 flowchart of the propose method

In the proposed method, RREQ is set as the threshold received power value at the time when RREQ is received. RREQ is decided whether accepted or not by comparing the received power information transmitted from Physical Layer with its threshold value, when each node receives RREQ. RREQ is discarded if the received power is smaller than the threshold value at the time when RREQ is received.

When all RREQs are discarded and RREPs do not arrive at the source node in a fixed period of time, TTL is incremented and the source node sends RREQ again.

In the case that the received power of each node at the time of receiving RREQ is larger than the threshold received power value of RREQ, forwarding process of RREQ by the repeater nodes which receives RREQ and generation, transmit and other treatment afterwards of RREP are same as those of AODV. However, in a case that the node receives RREQ which was repeated by the repeater nodes, decision whether accepts or not is made and processed in the same manner as the previous one. The processes above are made by the all repeater nodes which have received RREQ.

Thus by making a decision referring to the threshold received power value, each node has enough margins in received power, which implies that the totally stable routing is enabled.

IV. THE RESULT OF THE COMPUTER SIMULATION

A. *4.1 The conditions of simulation*

We evaluat by computer simulation utilizing OPNET so as to clarify the effectiveness of proposed method.

Parameters	value
the number of nodes	10
The area of nodes	200×200(m)
Frequency	2.4(GHz)
Transmission rate	250(kbit/s)
Received power	10(dBm)
Receiver sensitivity	-95dBm
Transmit & receive antenna gain	0(dBi)
Transmit & receive antenna height	1.5(m)
Propagation model	2-independent Rayleigh distribution
Amount of transmitted data	1kbit/sec

Table 1: Simulation conditions

Parameters utilized in the simulation is indicated in Table 1. Each parameter of simulated sensor networks is based on ZigBee standard [4][5]. In this simulation, 10 fixed nodes are arranged, the area of nodes is set to 200m x 200m and the distance between nodes is equally set to 30m or 50m as in Figure 2.

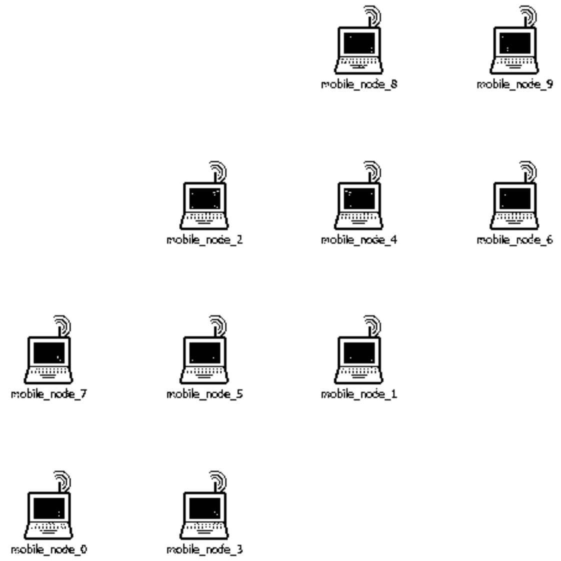


Figure 2: Sample arrangement of nodes

In Figure 2, The node 0 is a source node and the node 9 is a destination node. Transmitted power is 10dBm and the receiver sensitivity is -95dBm. Antenna gain of the sender and the receiver is 0dBi and the height of the antenna is 1.5m. The propagation model is 2-independent Rayleigh distribution. 1kbit data is periodically transmitted from the source node to the destination node in 1 second. Simulation period of time is 600 second.

Evaluated criteria are as follows: average time between the transmit of RREQ by the source node and the establishment of the route (the route discovery time), average time between receiving the RREQ by the source node and the confirmation of route disconnection after receiving Route Error (RERR) (the route effective time) and ratio of the total amount of received data to the total amount of transmitted data in the simulation (the data distribution time).

B. 4.2 Optimal threshold value of RREQ

So as to construct a route which is effective for longer period of time, optimal threshold received power value must be determined when each node receives RREQ. We compared previous AODV with that of proposed method by changing the threshold received power value of RREQ from -92.5dBm to -85dBm with 2.5dBm intervals in computer simulation. In this simulation, Doppler frequency of each node is set to 10Hz so as to be Quasi-stationary.

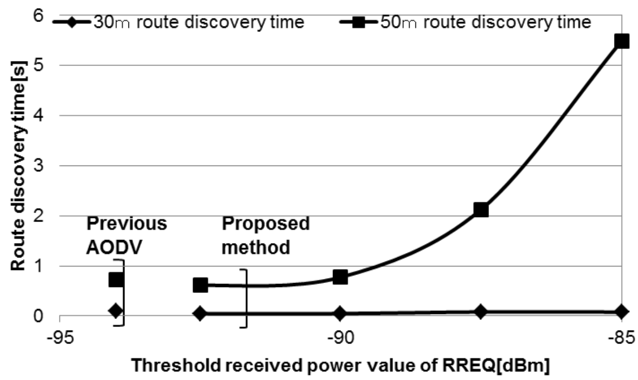
Figure 3 (a)-(c) indicates the simulation results compared with the previous AODV. Figure 3 (a) indicates the transition of the route discovery time. The route discovery time is longer than that of the previous method if the threshold received power value is larger. Especially in the case that the distance between nodes is 50m, increase of the route discovery time is larger than that in the case of 30m.

The reason is considered to be as follows: If the threshold received power value is larger, the number of RREQ which passed the test of the received power is smaller. In the case that the distance between the nodes is 30m or 50m, the shortest route reachable to the destination nodes passing node 5 and node 4 cannot be established, thus the route discovery time is longer. Figure 3 (b) indicates the route effective time.

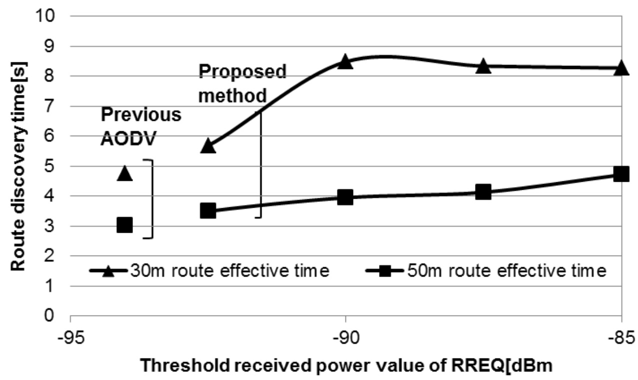
If the threshold received power value is higher, the effective time is higher. The reason is considered as follows: Increase of the threshold received power value makes the system immune to the change of the received power and thus the constructed route is able to survive for a longer time.

Figure 3 (c) indicates the data distribution time. If the threshold received power value is higher, the data distribution time is higher. The threshold value peaks at -87.5dBm and decreases if it is larger than that. Especially if the distance between the nodes is 50m, the value reduces more quickly. The reason is that the route discovery time is larger and the transmittable period is relatively shorter. Thus the optimal threshold received power value of RREQ is determined to -87.5dBm. Although the threshold received power value with the maximum route effective time is -90dBm, the data distribution time is too small and is not optimal.

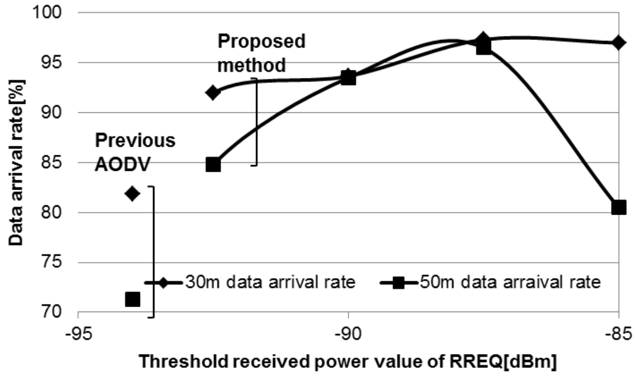
On the other hand, Figure 3 (c) indicates that the route effective time is improved in the case that the data distribution time is -87.5dBm. We determine this value as the optimal threshold received power value of RREQ.



(a)Route discovery time

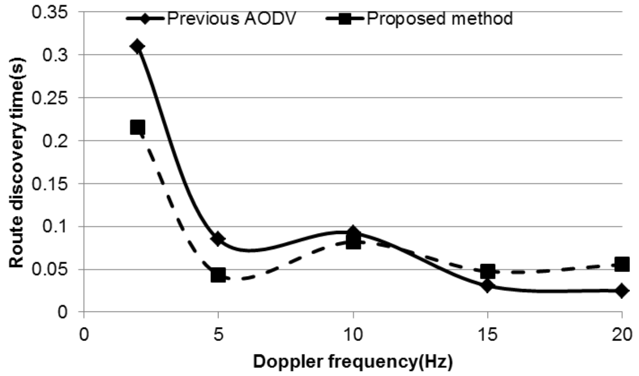


(b)Route effective time

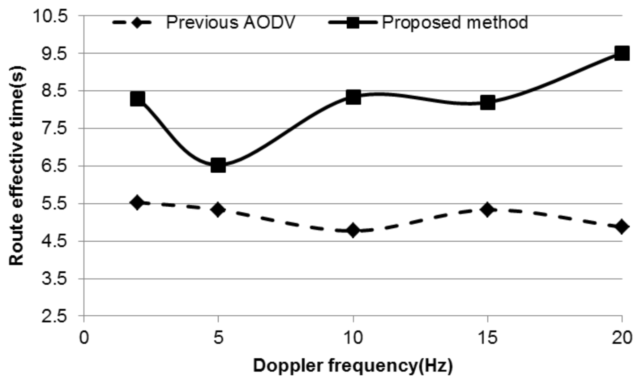


(c)Data distribution ratio

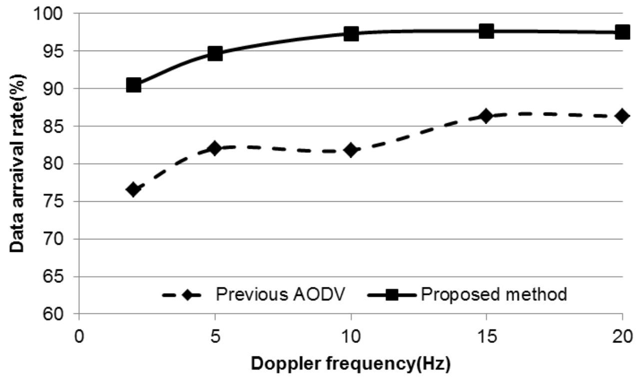
Figure 3 Changing threshold received power value of RREQ



(a)Route discovery time

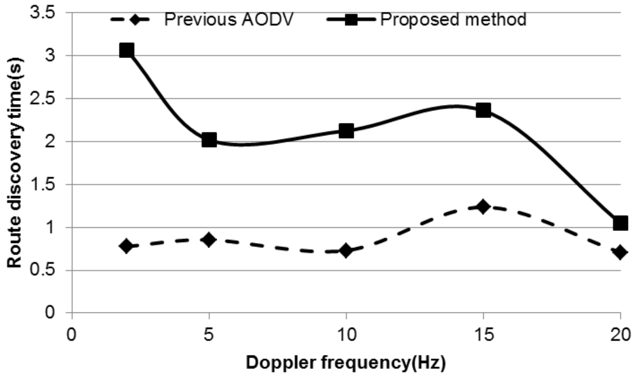


(b)Route effective time

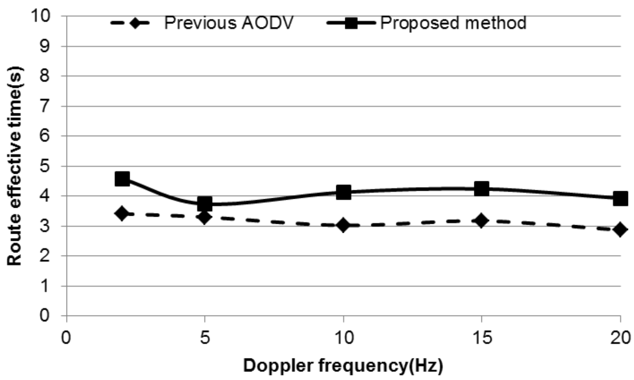


(c)Data distribution ratio

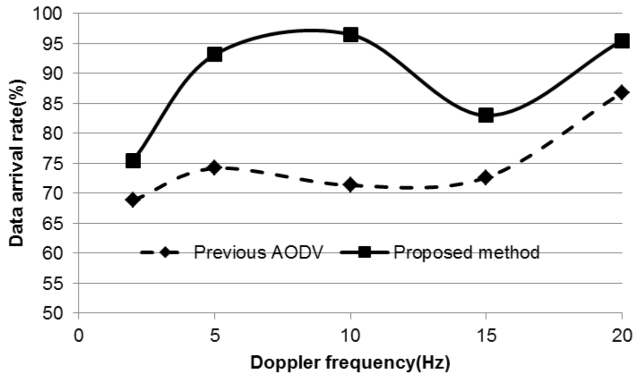
Figure 4 Changing Doppler frequencies (the distance between nodes is 30m)



(a)Route discovery time



(b)Route effective time



(c)Data distribution ratio

Figure 5 Changing Doppler frequencies (the distance between nodes is 50m)

C. *4.4 In the case that Doppler frequency is changed*

In the simulations in subsection 4.2 above, the threshold received power value of RREQ is -87.5dBm. Utilizing this value, we evaluate each criterion in the case that Doppler frequency of each node is changed and compare them with those of previous method. Doppler frequencies of the propagation path in the fading channel are set to 5 values 2Hz, 5Hz, 10Hz, 15Hz, 20Hz. Figure 4, 5 indicate the evaluation of the proposed and the previous method in the case that the distance between nodes is 30m, 50m, respectively,

The route discovery time is indicated in Figure 4, 5 (a). Figure 4 (a) indicates that the number of RREQs which can pass the test about the received power is 30m in the case that the distance between nodes, because the distance is small and the average received power value is large. For that reason, the route discovery time is 1/10 in the case of 50m and the difference from that of the previous method is small. However, in the case that the distance between the nodes is larger, the average received power is smaller than that in the case that the distance is small. Thus the number of RREQs which passed the test decreases and Figure 5(a) indicates that the route discovery time increases by at most 3 sec in the case that the distance between the nodes is 50m.

Figure 4, 5 (b) indicates the route effective time. If Doppler frequency is larger, the route discovery time and the route effective time decrease in both previous and proposed methods. The reason is considered as follows: If the fluctuation of the fading is faster, the interval between larger values of received power is smaller and the route can be easily constructed. At the same time, the period of time with large received power values is shorter and thus the route is disconnected.

Figure 4, 5 (b) indicates that the route effective time of the proposed method is better than that of the previous method in the case that Doppler frequency is changed. In the case that the distance between nodes is smaller, the received power is larger and Figure 4 (b) indicates that it is improved by at most 4 sec compared with that of the previous method.

Figure 4, 5 (c) indicates the data distribution time. If the Doppler frequency is higher, the amount of received data is larger except for the case that the distance between nodes is 50m and the Doppler frequency is 15Hz. The reason is considered as follows: the route discovery time has the above-mentioned relation with the route effective time and AODV transmits the data and reconstructs the link when the link is disconnected in transmitting the data

Thus in this simulation model, where the data is transmitted every 1 second, the time between the detection of broken link and the reconstruction of the route is shorter than 1 sec. In total simulation, if the route discovery time is shorter, the period of time where the data can be transmitted and received is longer. Thus larger amount of data can be received and the data distribution time is better if the Doppler frequency is higher. By comparing the proposed method with the previous one, the proposed one is improved by 10-15% in the case that the distance between the nodes is 30m and is improved by 5-25% in the case of 50m, which implies that it is improved when Doppler frequency is changed. As a result, in the proposed method, the route discovery time is longer and the route effective time and the data distribution time is improved from those of the previous method.

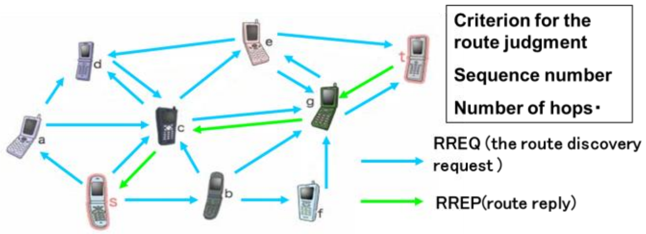


Figure 6 The previous AODV method

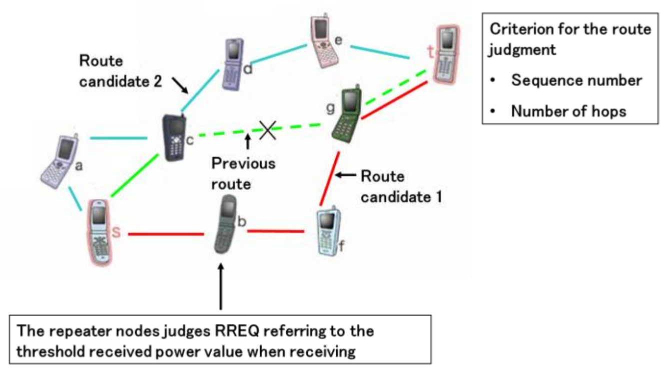


Figure 7 The proposed method

V. CONCLUSIONS

The route discovery method referring to the received power level obtained from the physical layer is proposed. From the computer simulation of the proposed method, the route discovery time is longer than that of the previous one by 3 sec at most in the case that the distance between nodes is 50m. The route effective time is better by at most 4 sec in the case of 30m and is improved in the case of 50m. The data distribution time is better by 15% in the case of 30m and 25% in the case of 50m, which implies that the effectiveness of the proposed method. Considering the data distribution time, improvement is larger in the case of 30m than that in the case of 50m, which implies that the improvement of the proposed method is larger in the case that the distance between the nodes is large.

As a future work, we will study the increases of the power consumption monitoring the received power of the physical layer. Furthermore, we will suppose that each node moves randomly instead of fixed like this simulation and we will also make more detailed simulations under the fading environment.

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REFERENCES

[1] Charles E. Perkins, Elizabeth M. Belding-Royer, Samir Ranjan Das, “Ad hoc On-Demand Distance Vector(AODV) Routing”, RFC3561, Jul. 2003.

[2] Kenich Nagao, Yusuke Kadowaki, Yasushi Nagao, “Multi-Hop Transmission Performance of Improved Cognitive Temporary Bypassing for Wireless Ad Hoc Networks” IEICE Technical Report, RCS2008-168, pp. 103-107, December, 2008

[3] Yusuke Kadowaki, Kenich Nagao, Yasushi Nagao, “Dynamic Multi-Hopping Method in Wireless Ad-Hoc Networks”, IEICE Technical Reports, RCS2008-168, pp. 103-107, December, 2008

[4] IEEE Std 802.15.4-2006, “Part 15.4:Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs),” 2006.

[5] ZigBee Alliance : http://www.zigbee.org/

[6] Takahiro Nishina, Yoshihiro Kainuma, Ryousyho Kou, Kenko Ota, Hideaki Matsue, “A Route Discovery Method Based on Received Power of Repeater Nodes for Sensor Networks”, IEICE Technical Report, RCS2010-285, pp. 211-216, March, 2011

[7] Hiroyuki Kunugi, Ken Aoki, Hideaki Matsue, “Performance evaluation of AODV routing protocol in ad-hoc wireless communication systems” IEICE Technical Report, RCS2005-320, pp. 253-258, March, 2006

[8] Ratish J. Punnoose, Pavel V. Nikitin, Daniel D. Stancil. “Efficient simulation of Ricean Fading within a Packet simulator” Vehicular Technology Conference, September 2000.

[9] Makoto Sugita, Yoshihiro KAINUMA, Kenko OTA, Hideaki MATSUE, “A Route Discovery Method Based on Received Power of Repeater Nodes for Sensor Networks”, 26th of the International Conference on Information Networking (ICOIN), pp. 1-6, February 2012.