HIGH CONTRIBUTION NODE SELECTION FOR COGNITVE RADIO NETWORKS

Hiroto Yasuda (AWCC, The University of Electro-Communications: Chofu-shi, Tokyo, Japan; yasuda14@awcc.uec.ac.jp); Takeo Fujii (AWCC, The University of Electro-Communications: Chofu-shi, Tokyo, Japan; fujii@awcc.uec.ac.jp)

ABSTRACT

In this paper, we consider the secondary multi-hop cognitive radio networks under the existence of the primary system. In order to support a fluctuated primary interference within the networks, we propose a method to select high contributing relay nodes by using a contribution ratio derived by using the balance of the number of hops of the route request packet (RREQ) and that of the route reply packet (RREP) during the initial route establishment. The selected node is decided in each node by comparing the total number of hops of RREP and RREQ from each transmitter with the number of minimum hops of the route in the initial route plus some margin. By using the proposed method, we can select the appropriate nodes for maintaining the secondary networks.

1. INTRODUCTION

Cognitive radios are wireless communication systems that can adaptively change the communication parameters of a transmitter and a receiver according to the recognized surrounding radio environment [1][2]. By using cognitive radio techniques, temporal and spatial unused spectrum can be reused for secondary cognitive radio systems even if the spectrum is not originally allocated to the secondary users. Cognitive radio technology is effective for improving the spectrum utilization by sharing the spectrum between a primary system and a secondary system. Therefore, cognitive radios are expected to be a solution of the shortage of the spectrum resource. In order to realize such frequency sharing system, inter-system interference should be mitigated. In particular, the giving interference from the secondary cognitive radio system toward the primary system should be minimized.

In these days, secondary multi-hop cognitive radio systems have attracted attention because of its flexibility and the ease of establishing communications without large giving interference toward the primary systems and [3][4]. Multi-hop communication is a method to utilize wireless links of neighboring nodes for relaying, and it can reduce the interference toward the shared spectrum system because of the small power transmission of each secondary node. When there are some wireless connections established by primary users in the spectrum, it is necessary to establish the multi-hop communication of the secondary users without interrupting the communication of the primary users. By using the small power transmission, the interference toward the primary systems can be minimized and the multi-hop networks can avoid the interference toward the primary system because the interfered area can be avoided by route selection of multi-hop networks.

In order to realize a communication from the source node to the destination node in wireless multi-hop networks, at least one relay route should be decided before a data transmission. However, in the cognitive radio networks, since the primary users transmit the signals intermittently, the interference situation on the relay route is fluctuated. Therefore, the optimal route is changed by the status of the primary users. In multi-hop networks, these routes should be decided without a control station.

In this paper, in order to support fluctuated primary interference within the networks, we propose a method to select appropriate relaying nodes by using contribution ratio [5] derived by using the balance of the route request packet (RREQ) and the route reply packet (RREP) during the initial route establishment. This ratio will be valuable in terms of avoiding interference, such as mutual interference between primary user's network and the own. In the proposed method, the route establishment method based on the RREQ and RREP like ad-hoc on-demand distance vector (AODV) protocol is used for selecting the high contribution nodes among the source node to the destination node. In this method, the number of hops from the source node and the number of hops from the destination node are used for deciding a contribution ratio of each node. For deriving the number of hops, we utilize the exchanging of the RREQ and RREP. First, the RREQ is flooded from the source node to the destination node and we can calculate the number of hops from the source node in each relay node. After that by flooding the RREP from the destination node to the source node and we can calculate the number of hops from the destination node. As a result, in the proposed method, a contribution ratio of each node is decided by counting up the hops from the source node and the hops from the destination node by exchanging the RREQ and RREP.

If the communication state is varied due to the location change or the intermitted transmission of the primary user, the proposed method can establish the tolerant communication links by setting an appropriate margin to the contribution ratio. By using the large margin, if the interference exists within the communication link from the source node to the destination node, the new communication route can be established by using selected nodes with rerouting the interfered area.

In order to evaluate the performance of the proposed method, we show the results of computer simulations. Here, we utilize the proposed high contribution node selection method under the interference from the primary system. From the results of the computer simulation, we can confirm that the flexible and robust secondary system can be established by using the proposed node selection method.

2. MULTI HOP COGNITIVE WIRELESS NETWORKS

In order to avoid the interference toward the primary system and to expand the communication area, multi-hop wireless networks are suitable for the secondary cognitive communication. If one hop large power direct communication is used for secondary communication, high sensitivity sensing technique should be used because the interfered area from the secondary system becomes large. On the other hand, if a multi-hop wireless network is used for the secondary system, the communication area can be expanded by using the multi-hop relay with power limitation for avoiding the interference toward the primary system. Therefore, in this paper, we utilize multi-hop wireless networks for the secondary system. The system image of multi-hop secondary networks is shown in Fig. 1.

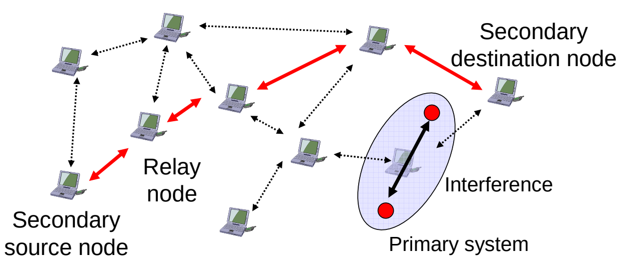

Fig.1 Multi-hop secondary networks under the primary system.

In a spectrum sharing cognitive radio system, the secondary users establish the communication link from the source node to the destination node under the existence of the primary system. In order to support a rapid topology, on-demand protocols like AODV have been considered for multi-hop wireless networks. In AODV, the multi-hop route is established by exchanging the RREQ and RREP. In this method, since the RREQ is flooded from the source node, a lot of packets are transmitted in a wireless channel for adaptation to the surrounding environment. In particular, if the primary users transmit the signals intermittently, the interference situation on the relay route is rapidly fluctuated. If the original RREQ and RREP method is used, all nodes should flood the RREQ for finding a new route.

3. POPOSED HIGH CONTRIBUTION NODE SECLECTION METHOD

In this paper, in order to solve the problem shown in the previous section, we propose a high contribution node selection method used for finding the appropriate route without a large number of RREQ in spite of the location change or the intermitted transmission of the primary system. Here, in order to estimate the contribution ratio of each node, we utilize the flooding packet from the source node and the destination node, respectively, based on the RREQ and RREP method. In the proposed method, in the initial phase, the high contribution node selection is performed cooperated with a RREQ and RREP route finding method by using the all nodes. After that the route is maintained by using the high contribution nodes selected by the proposed node selection method.

In the first step, the source node broadcasts RREQ with appropriate maximum time to live (TTL) for finding the destination node by flooding manner. The surrounding relay node which receives RREQ records a source node ID and the number of hops from the source node M as a hop count to the memory if the RREQ packet is the first time to receive or a hop count is smaller than the value of stored in the memory. Then the relay node retransmits the RREQ containing decreased TTL and increased hop count with avoiding collision by using a carrier sense. The destination node which can correctly receive RREQ broadcasts RREP by flooding manner as well as RREQ. In the original RREQ and RREP method, the RREP is transmitted by unicast manner because the route is already established by RREQ. However, in the proposed method, in order to decide the contribution ratio of the node, we apply flooding to RREP. RREP contains the number of minimum hops from the source node to the destination node obtained by the hop count stored in the RREQ. The relay node which receives the RREP operates the same procedure of the node receiving RREQ. Then the node sums up the hop count from the source node M which is already store in the memory, and that from the destination node N which is obtained by RREP. Then M+N value calculated in each node is defined as a contribution ratio. The image of definition of the contribution ratio is summarized in Fig.2. If the relay nodes have lower contribution ratio, they are regarded as high contributing nodes to the communication from the source node to the destination node. On the other hand, the nodes have higher contribution ratio, they are regarded as low contributing nodes. Each node can know the minimum hops α from the source node to the destination node by using the stored data in the RREP. When the source node receives RREP, it can know that the route is found with minimum hops α in the current surrounding environment. In the proposed method, in order to support the fluctuated interference situation from the primary system, we define a margin β for deciding whether each node relays the data packet or not.

If the different minimum hop is counted by RREQ and RREP, the lower value is selected for calculating α and the higher value is selected for calculating α+β. These values are contained in the data packets for data transmission. Relay nodes which receive the data packets can know the contribution ratio and the margin, and they can know their own status by checking the following equations,

$$\begin{cases} M + N \geq \alpha + \beta \\ M > 0 \\ N > 0 \end{cases} . \qquad (1)$$

The above equations are checked in each node. If the above equations are satisfied, the node is regarded as selected high contribution node.

The number of selected relay nodes increases by choosing larger margin β, so that the system is tolerant to the interference fluctuation of the primary system. On the other hand, if the smaller margin is selected, a smaller number of relay nodes is selected so that the power consumption for route maintenance can be reduced.

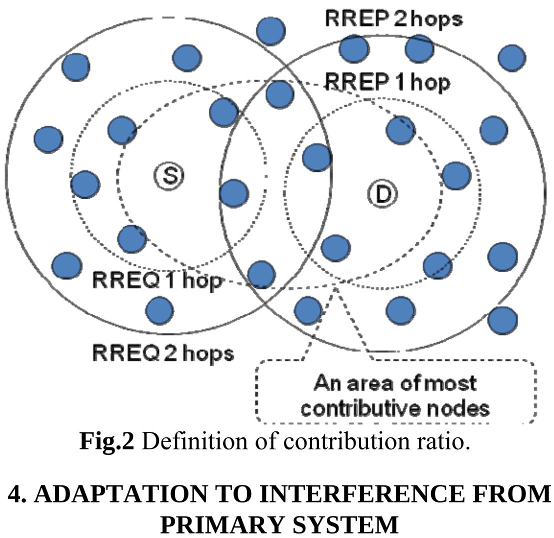

Fig.2 Definition of contribution ratio.

4. ADAPTATION TO INTERFERENCE FROM PRIMARY SYSTEM

In the previous section, we have proposed the node selection method based on the contribution ratio of each node. In the cognitive radio environment, the interference situation is frequently changed because the location and the active duration of the primary users are not stable. Therefore, the system is required to adapt such wireless environment. In our proposed system, we consider two methods for adaptively dealing with the interference from the primary system. The first is a method to enlarge the β value and to assign more number of relay nodes. By increasing such margin, the communication link can be reestablished even if the interference of the primary users exists. The second method is performed when the first method does not work well. This method redefines the contribution ratio by operating the RREQ and RREP flooding again. If these two methods are used with multi-stage processing for accommodating the route against the change of wireless environment will be found.

By using the proposed node selection method, we can easily reestablish the route from the source node to the destination node without large number of control packet like RREQ and RREP for flooding. We show the example procedure of the route reestablishment as follows,

1. Route is disconnected due to changing the interference situation of the primary system
2. RREQ and RREP are exchanged to find the route with selected high contribution nodes derived by equations (1). At the first case, β is decided as the initial value decided in advance.
3. If the route can be found, the route reestablishment is success and ends the process.
4. If the route is not found, the RREQ and RREP are exchanged by increasing the value of β.
5. Repeat 3 to 5 until the process is ended or β is reached to the certain value decided in advance.

By using the above procedure, we can find the route with the appropriate number of RREQ and RREP under the primary interference situation.

5. SIMULATION RESULTS

Then we evaluate the performance of the proposed route establishment method. Conditions of simulation are listed in Table 1. Transmission power is the same in all nodes, and the relay nodes are located in random position in the 400m times 400m simulation area. The number of relay nodes is 300 and the one pair of the source node and destination nod is prepared in the simulation area. The source node and the destination node are located with 200m apart. The carrier frequency is 5GHz, and the propagation loss follows 3rd power low. Whether the connection between neighbor nodes is available or not is decided by comparing to the required signal to interference plus noise power ratio (SINR). If the received SINR is higher than the required SINR, the connection of these nodes is succeeded. On the other hands, if the received SINR is lower than the required SINR, the connection of these nodes is failed. In order to average the results of route establishing under the different node location, we perform the simulations 1000 times of reallocation.

Table 1 Simulation Conditions.

Simulation field	400m x 400m
Number of nodes	Relay:300 + src&dest:2
Distance between src&dest	200m
Frequency	5GHz
Propagation loss	3rd power low
Noise	-95.0dBm
Required SINR	15dB

5.1 Example of Selected Nodes

First, we evaluate the distribution of contribution ratio M+N in the simulation area by using the exchanging the RREQ and RREP. Figure 3 shows a distribution node map achieved by the proposed node selection method. The horizontal axis means an x axis, and the vertical axis means a y axis of the simulation area. The unit of each axis is written by meter. This figure shows one snap shot when the transmit power of all nodes is 11dBm and the number of minimum hops α from the source node to the destination node is 10. Black dots mean the nodes whose contribution ratio is the same as the number of minimum hops α=10. These nodes are selected preferentially as the most contributive nodes. White dots mean the nodes whose contribution ratio is 11. In the proposed node selection method, the selected nodes are decided by using the margin β from the minimum hop α as shown in equation (1). When β is set at 0, only the nodes whose contribution ratio is 10 are selected. When β is set at 1, the nodes whose contribution ratio is 10 or 11 are selected. Therefore, increasing the margin β means that the larger number of nodes is selected. The margin can be used for route reestablishment when the situation of the primary system is changed.

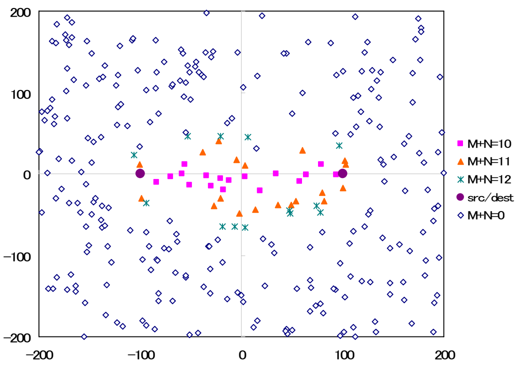

Fig.3 Selected nodes without interference.

5.2 Example of Selected Nodes under the Interference

Then, in this subsection we show the selected nodes under the interference of the primary system. In this simulation we consider the node selection under the interference node whose transmit power is 10dBm at the center of the source node and the destination node. In this case, we assume the transmit power of each node is 14dBm. Figure 4 shows a distribution node map achieved by the proposed node selection method using the exchanging of RREQ and RREP. This figure shows that the relay nodes between the source node and the destination node are selected with avoiding the interfered area. Black dots mean the nodes whose contribution ratio is the same as the number of minimum hops α=6. White dots mean the nodes whose contribution ratio is 7. From this figure, we can confirm that the exchanging RREQ and RREP can select the high contribution node for communication from the source node

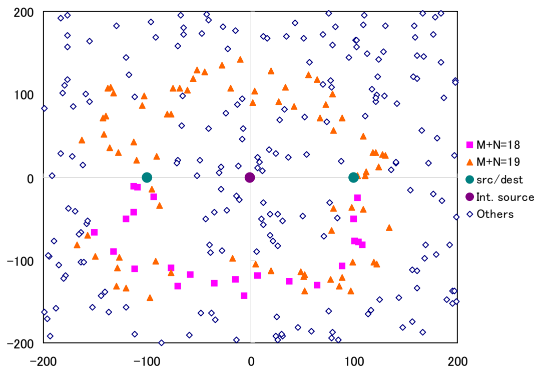

Fig.4 Selected nodes with interference.

to the destination node even if the interference node exists in the communication area.

5.3 Node Selection Error Ratio

Next we derive the ratio of node selection error using the process shown in Section 3 by exchanging RREQ and RREP using the all nodes. Here, we derive the ratio of at least one RREP is returned to the source node. Figure 5 shows node selection error ratio with each transmission power of node 0~25dBm. The horizontal axis means a contribution ratio M+N, and the vertical axis means a transmit power in dBm. The continuous line of the figure means an unreachable ratio of RREQ or RREP packets when the flooding among all nodes is executed, and the broken line means that when an interference source whose transmit power is 5dBm exists and the flooding among the nodes which have appropriate contribution ratio. The continuous line indicates that all flooding packets arrived when the TX power is 14dBm, and the broken line does the same in 20dBm. This ratio will improve when adaptive power transmission is applied.

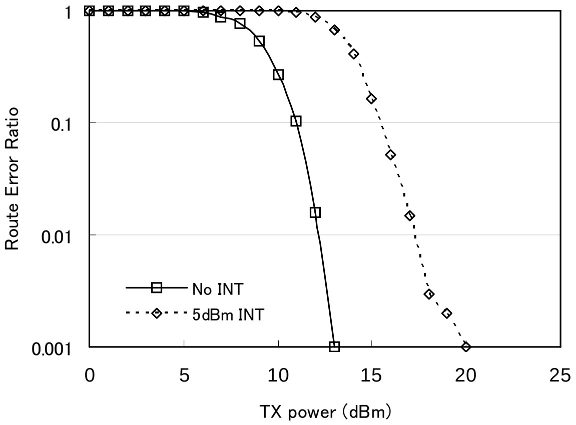

Fig.5 Node selection error ratio.

5.4 Selected Nodes

Figure 6 shows the number selected nodes when the transmit power of all nodes is 11dBm. The horizontal axis shows the contribution ratio M+N, and the vertical axis shows the number of nodes which have the contribution ratio less than the horizontal value. Note that nodes whose contribution ratio is zero are not included in the figure. The continuous line shows the performance without interference node and the broken line shows the performance with interference node whose transmit power is 5dBm at the center of the source node and the destination node. From this figure, we can confirm that the number of selected nodes can easily increase by selecting nodes whose contribution ratio is large. Increasing the number of nodes can tolerant to the change of interference situation when the communication link from the source node to the destination node is disconnected because the route finding method by using these selected nodes can be performed. However, the increasing number of nodes requires additional power consumption and the time for finding the route. Therefore, if the fluctuation of the interval and the level of the interference are not large, the smaller number of nodes should be used for connection reestablishment.

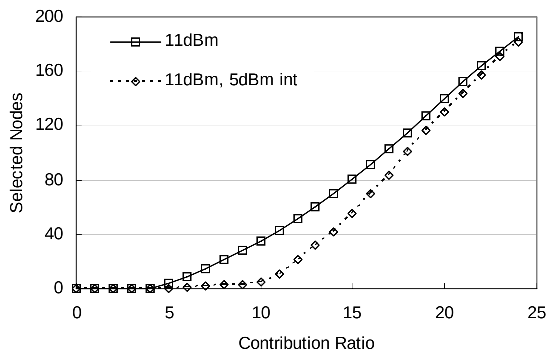

Fig.6 Selected nodes.

5.5 Effect of Margin

By using the node selection method, we can find the route from the source node to the destination node by exchanging the RREQ and RREP by using the selected nodes according to the equations (1). As shown in Section 4, we show one utilization method of the node selection for establishing the route from the source node to the destination node under the existence of the primary interference. Here, we derive the performance of the route establishment ratio when the interference situation is changed after first node selection procedure is performed. Here the transmit power of each node is 11dBm. In this simulation, first, node selection is performed when the interference node does not transmit the signal. Then we can calculate the contribution ratio of each node. After that the interference node whose transmit power is 5dBm is appeared at the center of the source node and the destination node. Then we find the route by exchanging the RREQ and RREP by using selected nodes derived by using equations (1). Here, the margin β is set at 0 to 5. The route error ratio is shown in Fig. 7. From this figure, by using the appropriate margin we can reduce the number of nodes for establishing the route even if the primary interference exists. Actually, if the interference power becomes large, the communication may be unavailable. In that case, the route can be found by using extra margin with minimum waste of route finding control packets.

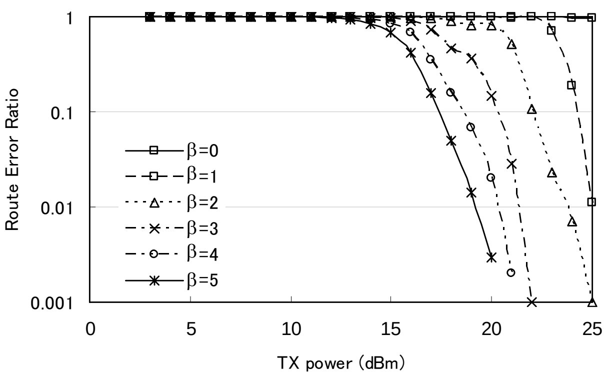

Fig.7 Effect of margin.

6. CONCLUSION

In this paper, we have proposed a node selection method for secondary cognitive radio. The proposed method limits the number of nodes used for the reestablishing the route from the source node to the destination node with avoiding an affection of the primary interference on the secondary multi-hop relay network. We derive the performance of the proposed method by using computer simulations. The proposed method can select the nodes which are suitable for relay the data from the source node to the destination node by applying the contribution ratio for each node. The contribution ratio is derived by exchanging the RREQ and RREP and counts up the number of hops of RREQ and RREP from these initial transmitters. By considering some margin from the minimum hops from the source node to the destination node, high reliable node selection can be realized in the proposed method. We confirm the effectiveness of the proposed node selection method used for the route reestablishment by using some margin when the primary interference is appeared after the initial route is established without primary interference. By using the proposed method, the number of nodes transmitting the RREQ and RREP can be reduced in the route reestablishment procedure.

7. REFERENCES

[1] J. Mitra III, G. Q. Maguire JR., “Cognitive radio: making software radios more personal,” IEEE Personal Commun., pp.13--18, Aug. 1999.

[2] S. Haykin, “Cognitive radio: brain-empowered wireless communications,” IEEE Journal Selected Areas Commun., vol.23, no.2, Feb. 2005.

[3] T. Fujii, Y. Kamiya, and Y. Suzuki, “Multi-band ad-hoc cognitive radio for reducing inter system interference,” Proc. IEEE PIMRC 2006, Sept. 2006.

[4] T. Fujii, “Power limited multi-band multi-hop secondary communication system for cognitive radio network,” Proc. CROWNCOM 2007, Aug. 2007.

[5] E. Kojima, T. Fujii, Y. Kamiya, and Y. Suzuki, “A new relay nodeselection scheme to reduce power consumption,” 3rd IEICE Ad-hoc Network Workshop, pp.3-13-16, Jan. 2006.