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Priority-Based Blind Rendezvous Scheme for Post-Disaster Scenario Networks

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Abstract: In this paper, we propose a priority-based blind rendezvous scheme for the post-disaster scenario networks based on Cognitive Radio Networks technology. In the event of a disaster, the communication infrastructure will be destroyed, and communication will be cut off. The proposed scheme aims to quickly recover a communication link in the disaster situation where the destroyed environment. The communication link is restored, it will be able to quickly send the relevant information about the disaster environment condition and the other information to prevent secondary damage. Our proposed scheme, each node evaluates the priority of the data in the transmission data buffer, and then this priority is used to generate the rendezvous sequence. The generated sequence is used to rendezvous by the node that communicates with each other.

Index Terms: Cognitive radio Networks, Rendezvous, Post-Disaster Scenario, Priority.

I. INTRODUCTION

Natural disasters take the lives of many people at once [1]. The further problem is that secondary damage also occurs, like a tsunami and aftershocks. The recent Indonesian earthquake, Sep. 20, 2018, a massive quake hit the island nation's Central Sulawesi province [2]. The earthquake occurred at 7 am on September 28, and a magnitude 7.5 earthquake occurred at 10:02 am after a 6.1 magnitude earthquake. This second earthquake caused a tsunami of 3 to 7 meters high, causing more damage. In some areas, the height of the tsunami has been observed up to 11m. According to the report, more than 1,400 people have killed, and the death toll is likely to rise and at least 800 people are seriously injured [3]. Most of the dead and missing persons were caused by the secondary effect (tsunamis and secondary earthquake) rather than direct earthquakes.

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Table 1. Number of deaths by disaster type (1994-2013)

Disaster type	Deaths	Rate
Earthquake	750,000	55%
Storm	250,000	18%
Flood	160,000	12%
Extreme temperature	160,000	12%
Drought	22,000	2%

To prevent the secondary effect victims, the new network technology is needed to address the situation after the disaster environment, and this is to need a new scenario. Because a method of correspondence needs to change various for the disaster condition (such as earthquakes, floods, typhoons, and hurricanes) for survivors. We need to prevent the secondary victims by the communication link restores in the disaster environment. The communication link restore is most important urgent tasks for the damaged communication infrastructure. Because the emergency notification message sending is the most important base solutions to prevent the secondary damages after the first disaster situation for the victims. The communication link failure is a major problem, and it is needed to reconnect the new links to send urgent messages to survivors. Wireless communication technology can be more easily reconfigured communication link than the other solution in various changes in a disaster environment [4].

Cognitive Radio Network (CRN) has been widely researched in various fields [5], [6]. CRN is an emerging technology for disaster environment, and it is a suitable technology to solve the disconnected link problem. There are two CRN nodes want to transmit data with each other, they must exchange the control messages on a vacant common channel (assume this channel is must not occupy by the own licensed user). This process is called blind rendezvous (or rendezvous). To sum up, blind rendezvous is the method of the exploration of the common channels by each node for data transmission.

The blind rendezvous is a key technology to solve the problem for the leak of the frequency spectrum. This technology is concerned with the decentralized control channel in asynchronous environments in CRN. Because the blind rendezvous don't need the centralized control channel

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for the operation. The rendezvous is exploring a common channel by a two (or more) cognitive radio nodes, and they transmit data through the common channels in CRN. The blind rendezvous is a method to establish a communication link without using additional channels, like a dedicated control channel (centralized control channel). Each node establishes a link to communicate with other nodes in the blind rendezvous problems. This process is similar to reconstruct the link in the after-disaster scenario or the destroyed communications infrastructure.

CRN node has the data buffer for data transmission. The data buffer is used to data send and receive. The various types of data will be stored into the data buffer of the node according to the assigned mission, like a military, healthcare, and security [7]. Each data has a different priority according to their importance factor; the emergency data, the urgent data, and the normal data [8, 15-21]. In our proposed scheme, the priority of the data is applied to the link generation, so that the emergency data can be transmitted more quickly than the other priority data.

II. THE PROPOSED SCHEME

In this section, we propose a priority-based blind rendezvous scheme to communicate with other cognitive radio nodes in the post-disaster scenario networks.

A. Definition

We define some factors to readily understand our scheme. There is two type of nodes in the CRNs; Primary User (PU) is the owner of the channels and Secondary User (SU) is a temporary user. The PU is the licensed owner of the occupied channels. But they don't use the channels every time. If the PU is not used the own channels, the SU borrow the channels temporary, and they transmit their data. If the PU want to use their own channels for data transmission, the SU evacuates the channel of the PU as fast. Then the SU find the other vacant channels for remaining data transmission.

The definition of the priority depends on the importance of the data. For example, the important data is as follows; detected data of the vital life signal after the earthquake or sensed data by evaluation systems for the disaster environment. And the priority is the most important attributes in the priority-based blind rendezvous scheme because it is the base factor of the blind rendezvous sequence generation scheme. Table 2. The type of priority shows the type of priority in the property based blind rendezvous scheme.

Table 2. The type of priority

Level	Priority	Data	Mode
P1	Emergency	the life-supporting data and the anomaly sensing data.	real-time mode
P2	Urgent	the life-supporting data and the monitoring data.	non-real-time mode
P3	Normal	the non-life-supporting data and the normal data.	non-real-time mode

The priority is divided into three types in our proposed scheme: Emergency, Urgent, and Normal. And each priority denoted by {P1, P2, P3}. First, the priority of the P1 has an emergency priority, and it is concerned with the life-supporting data, and the anomaly sensing data for a real-time mode. Second, the P2 has an urgent priority, and it is something to do with the life-supporting data, and monitoring data for a non-real-time mode. Finally, the P3 has a normal priority, and it is the non-life-supporting data, and the normal data for a non-real-time mode. In the priority-based blind rendezvous scheme, the priority of the data is related to the disaster environment, and we must check the priority of the data in the data buffer before generating the rendezvous sequence.

A time slot is the same period of the time in the blind rendezvous.

Time to rendezvous (TTR) is the base factor in the blind rendezvous. It means the number of time slots in the blind rendezvous process. Each time slot is divided into the time t that the t is a non-zero positive number.

Maximum-time to rendezvous (M-TTR) is the maximum time that is spent, the time spent to succeed in the rendezvous.

Available channel means not occupied channel by any other nodes (or users) in the blind rendezvous.

N is the number of available channels. If there are three available channels, it is denoted by N=3, and the available channel list is {CH1, CH2, CH3}.

Rendezvous sequence means the channel list for exploring the common channels to succeed the rendezvous. And the succeeds of the rendezvous means that two nodes transmit the signal through the common channel. The sequence is ordered by the proposed sequence generation scheme.

The time lag means the differences by two nodes different start time for the rendezvous. Assume there are two nodes (node A and node B), and they want to make a link for data transmission. Node A starts at time slot 1 for the rendezvous and Node B starts at time-slot 3, there is two time-lag.

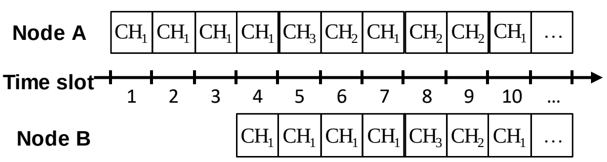

Figure 1. Example of the time lag

Priority sequence is located the first part of the proposed rendezvous sequence for fast rendezvous. As mentioned earlier, the priority in the priority sequence depends on the data priority in the data buffer. If the priority is P1(emergency) then it has consisted of the first channel in the available channel list, and it is repeated for N times. The priority sequence is used to guarantee fast rendezvous than another related rendezvous scheme in the first round.

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Input: 1) N (the number of available channels)
       2) S (the available channel set)
       3) P (the priority level of the data)
Output: array (the blind rendezvous sequences)
Set index to 0;
Set temp to N;
Set array to 0;
Set to P;
for i from 0 to N do
  array[index++] ← S[priority];
end for
for j from i to N do
  array[index++] ← S[j];
   for k from temp – 1 to 0 do
      array[index++] ← S[k];
   end for
  temp ← temp – 1;
end for
for l from 0 to N do
  array[index++] ← S[0];
end for
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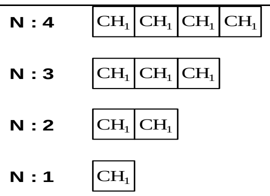

Figure 2. Example of the priority sequence

Group sequence is a group channel set, it has consisted of the available channel. Each group sequence is reverse order sets of the available channel and it decreases gradually the count of the channel list. If N is 4, the generated group sequence is {CH1, CH4, CH3, CH2, CH1, CH2, CH3, CH2, CH1, CH3, CH2, CH1, CH4, CH1}.

Figure 3 shows an example of the group sequence.

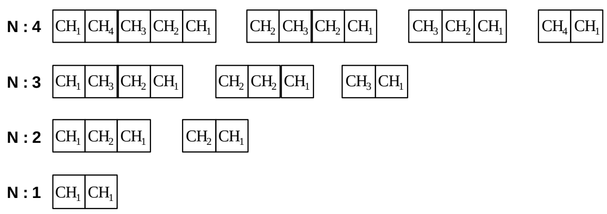

Figure 3. Organization of the group sequence

Guard sequence is located in the last part of the proposed sequence. It uses for preventing the rendezvous fail, and it is made by the first channel in the available channels.

B. Sequence generation scheme

In the post-disaster scenario network, we need to make another scenario than the normal situation environment. To do this, we need to consider a few factors.

The data of the nodes is stored into the data buffer for the data transmission and each node can check the priority of the data. Assume there are two cognitive radio nodes to communicate with each other in the post-disaster scenario network. We first check the available channels in the disaster environment. If there are 3 available channels, then the channel list is channel 1(CH1), channel 2(CH2), and channel 3(CH3). Follow the sensing result of the available channel, the N is 3, and the channel set is denoted by {N1, N2, N3}.

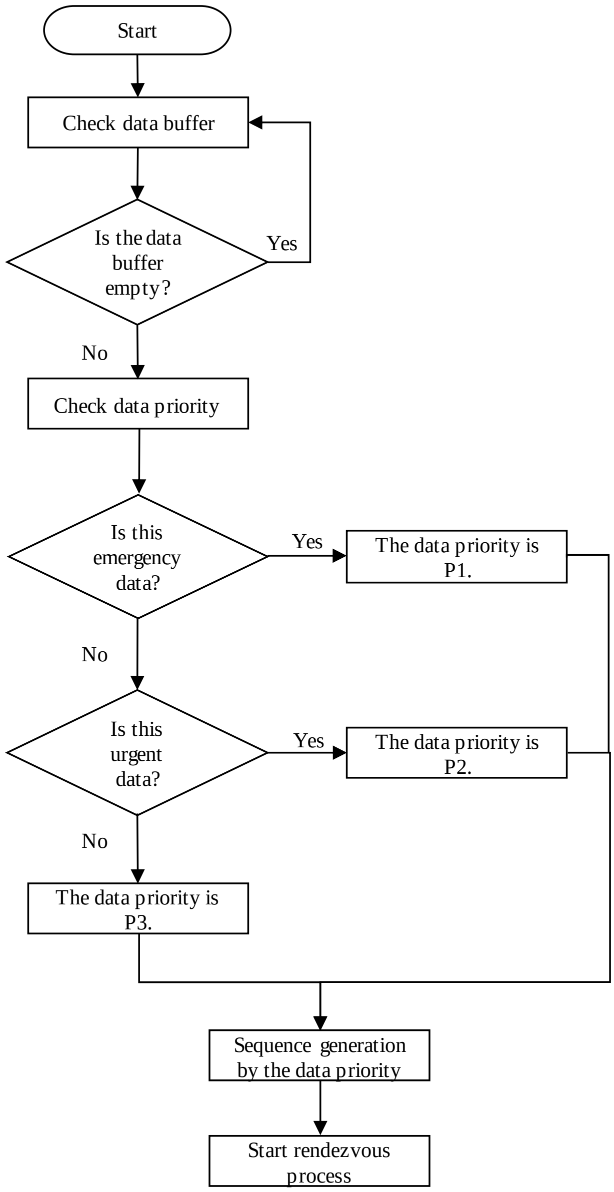

Figure 4. The priority level check process for the data in the proposed scheme

Table 3. Pseudocode of the priority-based blind rendezvous sequence

Each node can make the sequence for the rendezvous by the priority-based blind rendezvous scheme. The sequence consists of three parts: the priority sequence, the group sequence, and the guard sequence. In the first step, each node must check the priority of the data in the data buffer. Follow the checked priority, we choose the channel number of the priority sequence. If N is 3, and the priority level is P1, then the generated priority sequence is {CH1, CH1, CH1}.

The second step, we can generate the group sequence. Each group in the group sequence is reverse ordered by channels and it is repeated by the number of channels. If the N is 3, then the sequence generated by the group sequence generation algorithm is as follows: {CH1, CH3, CH2, CH1, CH2, CH2, CH1, CH3, CH1}.

The third step, we make the guard sequence by a seed value. The seed value is the first channel of the available

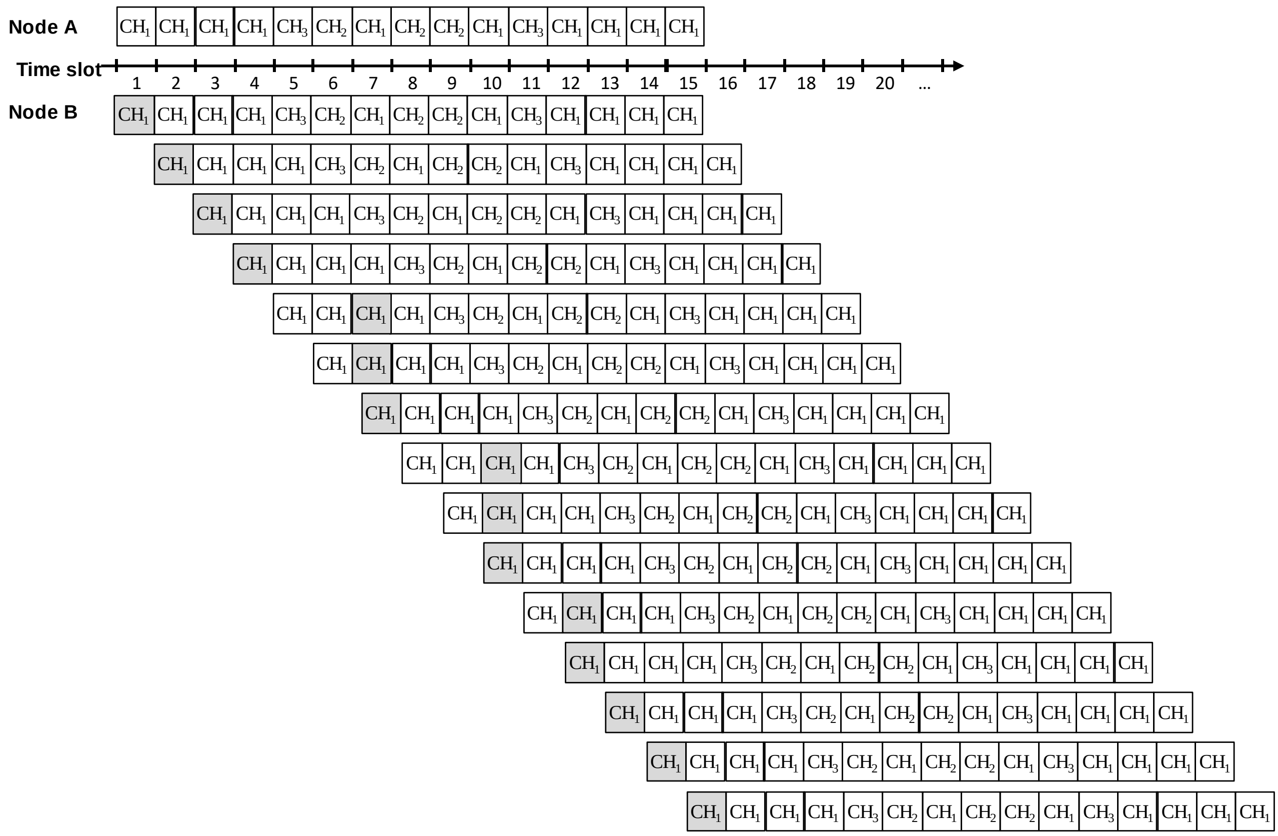

Figure 5. The process of the priority-based blind rendezvous scheme when different start time

channel. If N is 3, and the available channel set is {CH1, CH2, CH3}, then the seed value is CH1. The seed value is repeated N times in the guard sequence. If N is 4, then the guard sequence is {CH1, CH1, CH1, CH1}.

Finally, we can generate the priority-based blind rendezvous sequence by assembling the priority sequence, the group sequence, and the guard sequence. Assume the available channel set is {CH1, CH2, CH3}, and the N is 3. The priority level is P1, then the generated priority-based blind rendezvous sequence is {CH1, CH1, CH1, CH1, CH3, CH2, CH1, CH2, CH2, CH1, CH3, CH1, CH1, CH1, CH1}.

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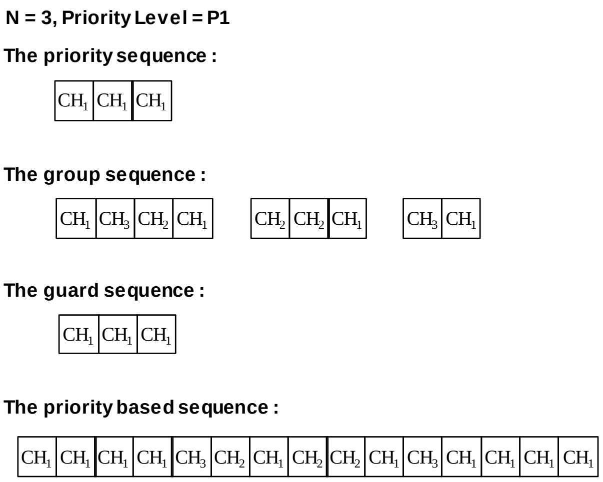

Figure 6. Example of the priority-based blind rendezvous sequence

In the normal environment, the sequence generation algorithm becomes the HS-GRSP [9] scheme. If the earthquakes or the other disaster has occurred, the nodes change the sequence generation algorithm from the HS-GRSP to the priority-based blind rendezvous sequence. The sequence generation algorithm is changed dynamically according to the disaster environment. If the environment is normal, N is 3, then the sequence is {CH1, CH3, CH2, CH1, CH2, CH2, CH1, CH3, CH1, CH1, CH1, CH1} by the HS-GRSP.

III. EVALUATION

This section, we have done the simulation for the evaluation of the priority-based blind rendezvous scheme. The evaluation of the rendezvous algorithm has been performed with TTR in the various papers [10] – [12]; SBR [13], and CRSEQ [14]. The criteria of the performance evaluations are MTTR and Average Time to Rendezvous (ATTR). ATTR means the average time required to succeed in the rendezvous within MTTR.

$$L = \frac{N^2 + 7N}{2} \tag{1}$$

Where L is the length of the priority-based blind rendezvous sequence, and N is the number of available channels. The result of the calculation is the same as the MTTR. It means the proposed scheme is possible to rendezvous within the MTTR.

Figure 5 depicts the process of the priority-based blind rendezvous scheme. In the figure, node A and B have different start time in that scenario, but it has successful rendezvous within MTTR (or a single period).

Figure 7 shows the simulation result of the ATTR of the various rendezvous schemes. The SBR and the proposed scheme represents similar trends in the result, so it is more fast rendezvous than the CRSEQ. The CRSEQ shows a rapid change, it means the result of the CRSEQ is much-delayed rendezvous when the number of channels is growing in the simulation result.

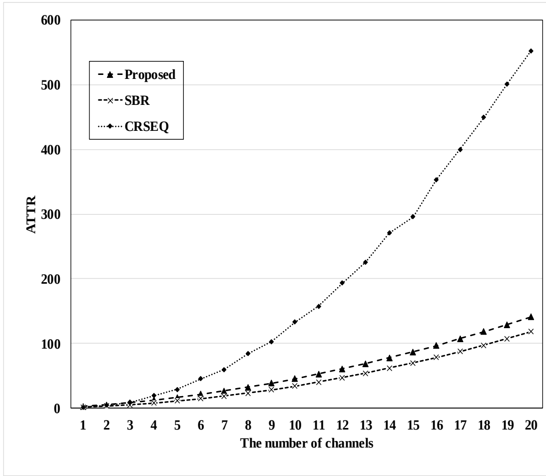

Figure 7. The simulation result of the ATTR

Figure 8 shows the simulation result of the MTTR. In this figure, the CRSEQ shows rapidly increasing MTTR when the channel is increasing. And the SBR has much more MTTR than the proposed rendezvous schemes when the channel is increasing. It means the priority-based blind rendezvous schemes guarantee the rendezvous within the MTTR and faster rendezvous than the other rendezvous scheme.

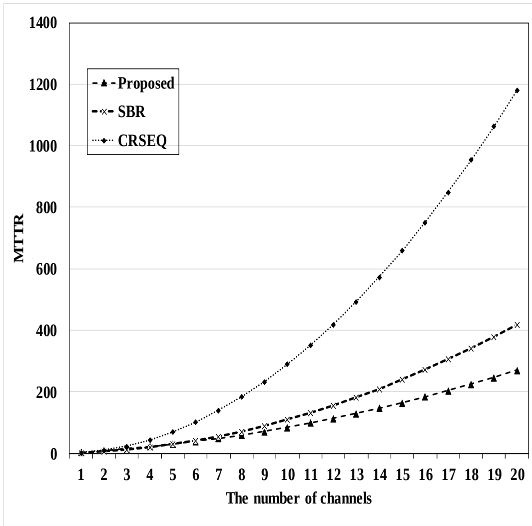

Figure 8. The simulation result of the MTTR

From the results of each simulation, it was confirmed that the proposed scheme rendezvous within MTTR (a period of time). Accordingly, the simulation result shows that it can rendezvous within a limited time in a special environment of an after-disaster by the priority-based blind rendezvous scheme.

IV. CONCLUSION

In this paper, we propose a priority-based blind rendezvous scheme suitable for post-disaster environments.

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The natural environment is rapidly changed, and the disaster more occurs increasingly. Therefore, it is necessary to study the communication scheme in the secondary damage environment after the disaster.

The proposed scheme considers about the priority of the data each node. And, the priority is the source for the rendezvous sequence generation scheme. By the priority, each node uses a different rendezvous sequence for the rendezvous in a post-disaster environment. We evaluate the TTR of the proposed scheme through the simulation with other rendezvous schemes. Through this mechanism, we guarantee the rendezvous within an MTTR (or a single period).

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