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A Novel Approach of Channel Selection Based Cognitive Radio in HF Communication

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Abstract. Short-wave communication is a crucial issue in military communication. To improve the performance of short-wave communication, modern communication technology has been utilized. However, a fundamental problem for short-wave is the quality of link restricting the development of short-wave. In this paper, we introduce cognitive radio to the short-wave and proposed a novel algorithm to choose the link based on learning historical information. With the knowledge of historical information, good links can be selected to enhance the reliability of short-wave communication. Finally, simulation results show that our proposed algorithm can considerably improve the short-wave communication performance.

Keywords: CR, HF, network, select channel, Short-wave.

1. Introduction

Short-wave communication is one of the more mature modern technology of communication. High-Frequency (HF) is the only active independent of the network hub and a remote relay system. In the event of war or disaster, a variety of communication networks may be susceptible to be damaged, the satellite may also be attacked. Either technologies of communication for the survivability of its communications capacity and autonomy can't compare with HF, so HF communication has great significance for the military communication [1].

With the increasing demand for communication and data transfer rate of the increasingly high demand, HF communication system for wireless spectrum is corresponding increase, leading to HF communication of spectrum resources is becoming increasingly nervous, seriously hampered the development of HF communication. On the other hand, there are different degrees idle for many spectrums that have been assigned to existing HF communication system in time and space, leading to HF spectrum efficiency and channel utilization rate are so poor. Thus, this paper introduces cognitive radio(CR) technology to HF communications systems, and combined with real-time channel evaluate(RTCE)techniques, so as to resolve the shortage of current HF channel utilizing rate and poor quality links for HF communications system [2].

In principle, cognitive radio can work through its interactive communications environment to automatically change their perception of sending and receiving parameters to dynamically reuse available spectrum. Cognitive radio wireless can give the effective transmission of signal information in the field of civil and military, so it can be up against the increasingly crowded wireless communications systems and achieve efficient using of spectrum resources, coexistence and compatible.

Chapter II introduces the Cognitive Radio Technology. Chapter III gives the next generation ALE concepts. Chapter IV elaborate describes the model design and algorithm analysis. Chapter V gives the

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simulation results so as to demonstrate the feasibility of these methods and their advantages. Finally, it makes a summary and prospect at the end of this paper.

2. Introduction to Cognitive Radio Technology

2.1. The origin and concept of cognitive radio

Cognitive radio was first coined by Doctor Joseph Mitola in the dissertation, “Cognitive Radio an Integrated Agent Architecture for Software Defined Radio”， for his doctor degree. The core idea is as follow,

Cognitive radio is a goal-driven framework in which the radio autonomously observes the radio environment, infers context, assesses alternatives, generates plans, supervises multimedia services, and learns from its mistakes. This observe-think-act cycle is radically different from today’s handsets that either blast out on the frequency set by the user, or blindly take instructions from the network. Cognitive radio technology thus empowers radios to observe more flexible radio etiquettes than that was possible in the past.

2.2. The main problem of cognitive radio

Cognitive radio technology is envisaged to solve the problems in wireless networks resulting from the limited available spectrum and the inefficiency in the spectrum usage by exploiting the existing wireless spectrum opportunistically. CR networks, equipped with the intrinsic capabilities of the cognitive radio, will provide an ultimate spectrum-aware communication paradigm in wireless communications. However, CR networks impose unique challenges due to the high fluctuation in the available spectrum as well as diverse quality-of-service (QoS) requirements. The research focuses and main challenges of CR include spectrum sensing, spectrum analysis, spectrum decision, spectrum sharing, spectrum mobility management, route design of cognitive wireless networks, security and cross-layer design, etc.

3. Next Generation Ale Concepts

So far, the function of automatic link establishment has already been used in high frequency communications, which can provide a sound technical support for cognitive radio to implement frequency selection and spectrum management. In high frequency communications, the available frequency is closely related to time and location. In order to improve the successful transmission rate and quality of communication, a thorough change must be imposed on the traditional method of artificial frequency selection for high frequency communications. Based on cognitive radio technology, new spectrum management system can integrate the functions of spectrum sensing, spectrum feature abstract, spectrum decision together to implement dynamic spectrum allocation. Figure 3 provides the flow chart of the proposed cognitive system for high frequency communication [3] [5].

3.1. Frequency pre-selection

Based on the statistics of history and empirical data, spectrum management of high frequency can abstract the available frequency resource. According to the propagation prosperities of high frequency and transmission characters of communication intervals, the process of frequency pre-selection can delete the unavailable frequency set and abstract the most valuable frequency set for future use, which can improve the efficiency of spectrum management.

3.2. Spectrum monitoring

Following frequency pre-selection, real-time spectrum monitoring can implement spectrum sensing and signal estimation of the selected frequency. According to the distribution of interference and statistics of occupancy, one can obtain the information of spectrum holes and data of best frequency for communications.

3.3. Spectrum decision

Spectrum sharing of cognitive radio can reallocate spectrum holes based on dynamic spectrum access, which can significantly improve the spectrum utilization of high frequency communications.

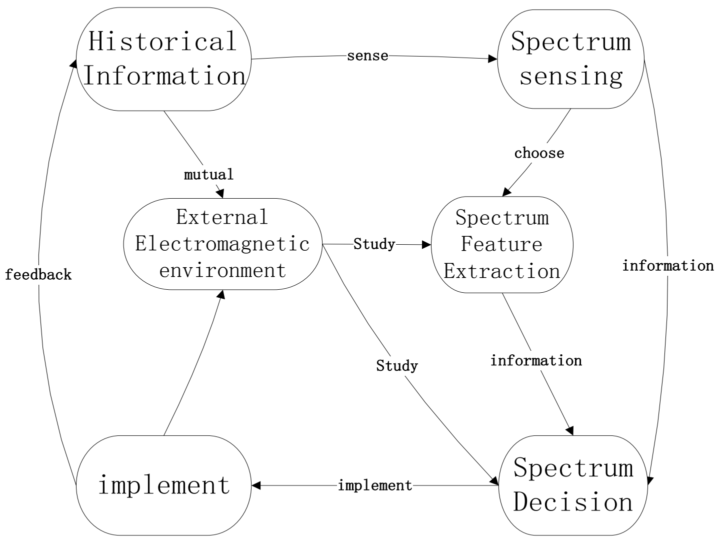

Fig. 1: The cognitive flow chart for HF communication

4. Model Design and Algorithm Analysis

As shown in picture 2, this article focuses on the quality of HF communication complexity for channel variety, and selecting is a difficult situation. Thus the idea is the introduction of cognitive radio channel selection, so as to effectively improve the communication reliability. The system model used in this paper is: The user history information collected first, then learning the history information to choose the N channels, which had better performance at this time before [4]. Then sensing electromagnetic environment and detecting the quality of HF channel with real-time. At last, selecting an optimal communication channel and giving a feedback to the history information table, which give a support to the future communications for information extraction as a data.

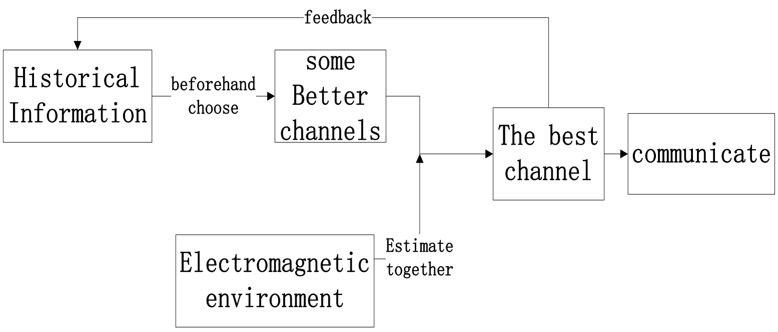

Fig. 2: Model Design

We consider a small range of HF network, so the HF channel fading model is reduced to Rayleigh fading at this time. Then HF channel plus β_n is exponentially distributed.

$$f_g(x) = e^{-x}, x \ge 0 \tag{1}$$

It used channel access mechanism with sensing transmission in this paper. Thus, it is block-fixed for duration of T and change randomly in the next period. In addition, we denote the length of the required time for exploring channels as T_s, then $\tau = T_s / T$ denote the fraction of exploring overhead.

As the fixed number channel scheme, if the channel numbers are N_x, and the transmit power of transmitter(Shortwave Radio) is P, then the throughput of a slot is:

$$C = (1 - N_x)\tau \log(1 + P \max\{\beta_n\} / \sigma^2) \tag{2}$$

this σ^2 is Gaussian noise power, obey the Gaussian distribution with mean of 1.

When considering the coexistence with the primary users, to ensure the primary user proper communication, assume that each license channel us occupied by the primary receiver and the interference perceived by the primary receiver must be kept below a threshold Q. Then the transmitting power of the secondary transmission on the nth channel is given by $p_n^{tx} = \min\{p, Q/\alpha_n\}$, where P denotes the peak power of secondary transmitter .Correspondingly, the received SNR on the nth channel is given by $\eta_n = P_n^{tx}\beta_n/\sigma^2$.Thus, the received SNR sequence $\{\eta_n\}_{n=1}^{n=N}$ are i.i.d. with the following common probability distribution function[6]:

$$f(\eta) = \frac{1}{P}(1-e^{-\frac{Q}{P}})e^{-\frac{\eta}{P}} + \frac{Q}{P}\frac{(Q+P+\eta)}{(Q+\eta)^2}e^{-\frac{Q+\eta}{P}}, \eta \geq 0 \tag{3}$$

As the optimal stopping scheme, the goal of the user is to choose a time to stop to maximize the expected throughput. Our problem belongs to the optimal stopping problem by finite bound, since the user must stop at the last channel. Generally, we define the following function at each channel exploring stage n as:

$$V_n^{(N)} = \begin{cases} R_n(\eta_1,...,\eta_n), & , n = N \\ \max\left\{R_n(\eta_1,...,\eta_n), E[V_{n+1}^{(N)} \middle| \{\eta_i\}_{i=1}^n]\right\}, & n < N \end{cases} \tag{4}$$

As, $R_n(\eta_1,...,\eta_n) = (1-n)\tau\log(1+\max\{\eta_n\})$ denotes the throughput of sensing n channel.

Where $E[V_{n+1}^{(N)} | \{\eta_i\}_{i=1}^n]$ represents the expected throughput that the user can achieve after observing the SNR sequence $\{\eta_i\}_{i=1}^n$.Thus, the optimal stopping time for exploiting multichannel diversity is given by [7]:

$$N^* = \min\{1 \leq n \leq N : R_n(\eta_1,...,\eta_n) \geq E[V_{n+1}^{(N)} | \{\eta_i\}_{i=1}^n]\} \tag{5}$$

So, with HF communications and suppose qualification:

$$\begin{aligned} E[V_{n+1}^{(N)} | \{\eta_i\}_{i=1}^n] &= s_{n+1}E_\eta[\log(1+\max\{\eta_n^{\max}, \eta\})] \\ &= s_{n+1}\int_0^\infty \log(1+\max\{\eta_n^{\max}, \eta\}) f(\eta) d\eta \end{aligned} \tag{6}$$

By the algorithm and analysis, we completely use the way based on the optimal stopping scheme to choice the HF channel.

5. Performance Simulation

As shown in picture 3, T=100ms, T_s=5ms, transmit power of transmitter P=10dB. First we consider the situation which is only the primary user choosing channel. As seen from the result of the simulation, we can make the conclusion that, when the selected channel numbers more than 10, the performance by choosing the fixed number of channels decreased in evidence. Visible, we only need to get within10 channels with the best of historical information, so that the number of pre-selection can effectively reduce, in order to prevent waste of resources and improve efficiency.

Next, the condition for simulation is also that T=100ms, T_s=5ms, transmit power of transmitter P=10dB, Q=0dB. (-Δ-)it stands for primary user, which can first choose the best channel and neglect the other interference. As shown in picture 3, if we take three of historical information, we can maximize the throughput of its time slot, more than three the performance will decrease. So, primary user only need to re-selected three channels with better historical information to conduct the final choice. If choice more than three will cause attenuation of the overall system performance and waste of resources. (-o-)it stands for cognitive user, it needs to take into account the interference of the primary user. Therefore, it can be seen from Figure 4, we need to pre-select 5 channels of history information, which are more than the primary user, so as to achieve the best results. And the red and black (——) stands for the throughput of optimal stopping scheme for primary user and cognitive user. We can achieve the throughput is better for optimal stopping scheme, but at this stage we can't achieve the goal in terms of the ability of HF communications technology. From the actual situation, judging to pre-select which numbers of channels with history information is more interesting for us.

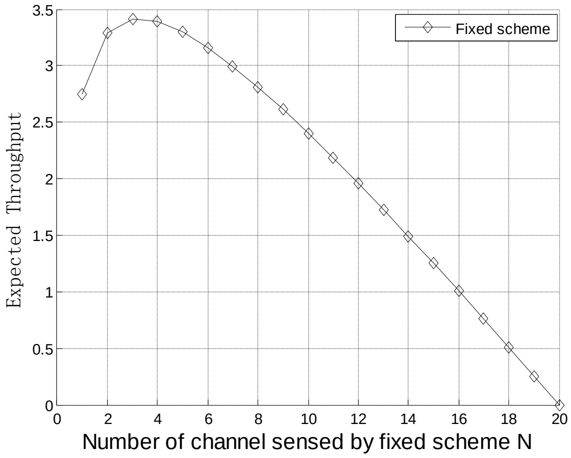

Fig. 3: The throughput of the fixed number of channels

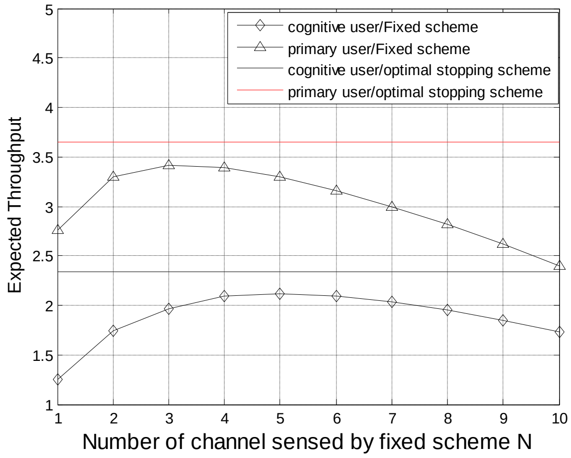

Fig. 4: The throughput of fixed and optimal stopping scheme

6. Conclusion and Future Work

At present, the development for the technology of HF communications is nice. Its anti-jamming and anti-destroying performance and operation data for transmission capacity have been raised to be a new level. HF communications in the military has been increasingly widely used. But its spectrum management and channel selection are still limited the development of HF communication. Especially issues for selecting channel of the group of digital network communication. It is directly related to overall system performance for HF communication. To dynamically choose communication frequency is an important issue to be solved for the development of HF communication. In this paper, with the idea of cognitive radio, we do some useful exploration for spectrum management and channel selection of HF communications. The starting point is the use of existing ideas and technology to meet the new requirements of modern digital HF communications and networking technology, to improve the reliability of HF communication. Particular approach is: first we study the historical information, combined with the surrounding environment, and use the RTCE technology to choose the optimal channel. The simulation effective validated to take a limited number of channels can meet the communication needs. And the theory of optimal stopping mechanism for the system can achieve optimal results. It has practical value and significance for the future of HF spectrum management and channel selection.

7. Acknowledgment

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