



A Communication Channel Selection Algorithm Considering Equilibrium

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Abstract. In order to overcome the problems of accuracy and low efficiency of the communication channel selection algorithm, a communication channel selection algorithm considering the balance is proposed. The communication channel selection algorithm considering the balance first needs to collect the data of the communication network, and extract the channel impulse response and power delay spectrum from the original data, and then select the noise floor of the channel impulse response and power delay spectrum. And multipath search and analysis of channel fading characteristics, and finally through the communication channel selection algorithm for optimal channel selection to realize the communication channel selection algorithm considering the balance. The comparison of experiments verifies that the channel selection accuracy and efficiency of the communication channel selection algorithm considering the balance is always higher than the ALOHA algorithm.

Keywords: Equilibrium · Communication channel · Selection algorithm

1 Introduction

Mobile communication is premised on the use of radio waves. In this field, the available spectrum is limited, so it must be used effectively. This requires starting from the three basic factors of frequency, time and space [1]. For this purpose, it is necessary to adopt a dense method represented by narrowband transmission in the frequency domain, a multiplex scheme in the time domain, and a frequency reuse scheme in the space domain. The multiplex mode of the time domain is called channel selection, and it is widely used in various mobile communication systems [2]. With the increasing demand for communication services such as wireless Internet access and mobile TV, it is becoming the direction of wireless communication development to increase the channel transmission rate as much as possible under limited spectrum resources [3]. However, the overhead of the OFDM guard interval makes the improvement in spectral efficiency not particularly noticeable. Researchers have found another technique for improving spectral efficiency from the airspace: MIMO. The research of information theory shows that when working in a rich scattering wireless environment, if multiple

antennas are used at the receiving end and the transmitting end of the communication system, the obtained multi-input and multi-output system can make full use of airspace resources. Under the premise of not increasing the system bandwidth and transmit power, the channel capacity and spectrum efficiency of the system are greatly improved, so as to effectively counter the influence of wireless fading [4]. MIMO and OFDM seek solutions to improve spectrum utilization from the airspace and frequency domain, respectively, so they can be combined to further increase the information transmission rate with limited resources. However, in actual communication, the channel capacity of the feedback channel is limited, and sometimes the channel change is fast, so that the channel information cannot be transmitted back to the transmitting end in time, so the transmitting end cannot completely obtain the CSI. At the same time, it is hoped that the smaller the amount of backhaul required by the channel selection algorithm, the better. The existing channel selection algorithm has a large amount of backhaul information, and some channel selection algorithms have low balance. Therefore, a communication channel selection algorithm considering equalization is designed.

2 Data Collection

The communication network consists of N nodes, each with multiple RF communication interfaces [5]. There are n channels in the network, one of which is dedicated to control information, and the other $n - 1$ channels are used for data packet transmission. The control channel is used to resolve contention for the data channel, and the data channel is used to transmit data packets and acknowledgement frames. A radio communication interface in a node is assigned to a control channel, which is called a control interface. In addition to receiving and sending broadcast routing messages, the control interface also sends and receives information such as available channels needs to be switched, the broadcast of the local update message is triggered [6]. At the same time, the control channel also sends and receives RTS and CTS messages. The remaining RF communication interfaces are assigned to data channels, called data interfaces. The data interface performs data collection through data transmission and data reception. The node consists of four RF communication interfaces, one control interface, one data receiving interface, and two data sending interfaces.

3 Data Processing

After completing the data collection, the first step in data processing is to extract the channel impulse response from the original data [7]. The channel impulse response reflects the small-scale propagation characteristics of the wireless fading channel, and is also the basic premise for extracting other channel parameters, and plays an extremely important role in data analysis. By collecting the raw data, we can get the impulse response CIR of the channel, which is the first step in our analysis of the data. The second step is to analyze the fading characteristics of the channel through CIR.

The measurement data collected from the receiving end in the actual channel measurement is called original data, and the baseband signal is obtained after down-conversion, analog-to-digital conversion and quantization. After preliminary correlation processing, it is converted into a large number of independent CIRs, and accurate extraction of multipath component information from CIR is the basis of channel selection [8]. Since the system response is included, in order to more accurately obtain the channel characteristics of the current measurement scenario, our first step is to remove the system response. Extracting the multipath component information mainly includes two steps. First, the noise floor is accurately selected, the noise sampling points are removed, and then the remaining sampling points are multipath searched to determine the number and position of the multipath. Since the electromagnetic propagation environment experiences reflection, diffraction and scattering during electromagnetic wave propagation, the channel impulse response is a set of multipath components dispersed in the time domain and the delay domain, defined as $h(t, r_1)$. It reflects the propagation characteristics of the wireless channel, and r_1 represents the corresponding multipath component. The average processing in the time domain for $h(t, r_1)$ results in a channel impulse response that is only a function of delay, as shown in Eq. 1.

$$h_{av}(r_1) = E_1[h(t, r_1)] \quad (1)$$

The power delay spectrum, also called the multipath intensity spectrum, represents the power at the multipath delay. The power delay spectrum can be obtained by squaring $h_{av}(r_1)$, as shown in Eq. 2.

$$p(r_1) = |h_{av}(r_1)|^2 \quad (2)$$

4 Noise Floor Selection and Multipath Search

The obtained channel impulse response and power delay spectrum contain a large amount of noise in addition to the multipath component. Therefore, the noise floor selection and multipath search of the data are continued. In order to calculate the appropriate noise floor, the setting of the noise threshold is very important [9, 10]. Because the noise threshold is too low or too high, it will cause inaccuracy in the number of multipaths extracted later. For example, when the selected noise threshold is high, due to more random factors in the actual measurement process, a certain portion of the lower power multipath component may be misidentified as noise and filtered out. When the selected noise threshold is low, the higher decibel noise may be misjudged as multipath component information, resulting in an estimated number of multipaths. Generally, the methods for selecting the noise threshold in the post-measurement data analysis mainly include the static threshold setting method and the dynamic threshold setting method [11, 12]. The static threshold setting method is to select a specific fixed constant as the noise threshold between the average noise and the power of the strongest path, which is an estimate of the difference between the two. However, this

method has a large error when there is an interference signal or a shock hum. Another method of dynamically setting the threshold is to dynamically select the noise threshold as the channel noise power changes. Combining these two methods to improve, and based on practical experience to set the engineering parameters, it is more suitable for the correct selection of noise floor in the actual channel measurement data analysis.

After the noise threshold is determined by the above method, the number of multipaths detected by different multipath search methods will be different, that is, the correct selection of the multipath search method determines the accuracy of the multipath extraction analysis in the later stage. Generally, according to the signal bandwidth of the channel, different methods of detecting multipath are classified into local maximization, threshold limiting method and cluster identification method. The first method of local maximization is to perform a peak search for a signal whose power is higher than the threshold after setting the noise threshold by a specific method, and define each signal peak of the search cable as a multipath component. This method is more suitable for channel measurement when the signal bandwidth is narrower, and its multipath resolution is low. In the 5G communication system standard, in order to meet the requirements of high speed and large capacity, the measurement bandwidth is selected to be large, and the resolution of multipath is very high. Therefore, after the noise threshold is accurately set, the noise sampling point is filtered out, and the signal higher than the threshold can be used as the multipath component. This method is the threshold limiting method. Finally, in the cluster identification multipath component method, the path components having characteristic parameters such as the same delay and leaving angle are considered to be in the same cluster, and are generally used for channel measurement of ultra-wideband signals. Through the above introduction, according to the conditions such as the bandwidth required for measurement, it is reasonable to use the threshold limit method for multipath chords.

5 Analysis of Channel Fading Characteristics

The distance between the transceiver antenna, antenna loss and height, carrier frequency and other factors are the influencing factors of large-scale fading. Large-scale fading can usually be divided into two parts: path loss and shadow fading. When electromagnetic waves propagate in space, path loss occurs due to the propagation of the apex. Path loss also includes penetration loss, line-of-sight loss, non-line-of-sight loss, and the like. The free-space propagation mode is suitable for the completely unobstructed line-of-sight between the transceivers. Usually, the free-space propagation loss is defined as the ratio of the transmitted power to the received power, as shown in Eq. (3):

$$p_r = \frac{p_t G_t G_r \lambda^2}{(4\pi d)^2} \quad (3)$$

Where G_t , G_r respectively represent the transmit antenna gain and the receive antenna gain, P_t , P_r respectively refer to the transmit power and receive power, d denotes the distance between the transmit and receive antennas, and λ denotes the electromagnetic

wave wavelength. It can be seen from Eq. (3) that the free-space propagation path loss is proportional to the square of the distance d between the transmitting and receiving antennas, and inversely proportional to the square of the wavelength λ . For a narrowband system, the wavelength range of the electromagnetic wave is small, so the free space path loss can be considered to be only related to the distance; However, for broadband systems, the influence of carrier frequency on path loss cannot be ignored due to the large range of wavelength variation. In general, frequency and distance are irrelevant.

6 Algorithm Description

$G(V, E)$ represents the undirected graph corresponding to the communication network, where V is the set of nodes in the network, E is the set of links in the network; $d(u, v)$ represents the Euclidean distance between node u and node v . R_T represents the communication radius of the node; R_I represents the interference radius of the node; ch_i represents the i -th channel; $CAS(v)$ represents the set of available channels of node v .

Where node u and node v satisfy:

$$d(u, v) \leq R_T \quad (4)$$

When any data interface in node u works on channel ch , the data interface of node v also works on channel ch ; then node u and node v are said to be neighbors.

A set consisting of all accessible neighbor nodes is called a set of neighboring neighbor nodes. The neighbor node formula can be expressed as:

$$\forall d(u, v) \leq R_T(x(u_i^{ch})) = 1 \quad (5)$$

Where i and j are data interfaces and 1 indicates that node u is operating on channel ch .

When two links use the same channel, and one endpoint of at least one link is within the interference range of one or both endpoints of the other link, then the two links are said to interfere with each other.

When the channel is not occupied by the data transmitting interface and the data receiving interface and is allowed to be used by the node, such a channel is referred to as an available channel.

If each element in the set is an available channel of a node, then such a set is said to be a set of available channels for that node.

To simplify the analysis, make the following assumptions.

- 1) The nodes in the network are randomly distributed in the two-dimensional plane area;
- 2) All data interfaces can both send and receive data;
- 3) All data channel transmission bandwidth and other transmission performance are the same;
- 4) The channels in the network are all orthogonal channels.

In the case of a large network topology, when each node in the network needs to know the topology information of the entire network, the entire network needs to pay a large price to broadcast and update the information of the node. If the topology of the network changes from time to time, the cost of maintaining the node information of the entire network is unacceptable due to the limited storage and computing power of the node. Therefore, the paper adopts the theory of relative balance, that is, only considers the local range of nodes and their neighbor nodes, and the cost is relatively small. At the same time, it can be seen that the higher the number of available channels, the greater the probability of being used, and the more conflicts that occur. Based on this probability theory, all nodes select the optimal channel each time they send data, which can avoid channel selection conflict between adjacent links and improve data transmission efficiency. The overall steps are as follows:

- 1) Establishing a usable neighbor node available channel list according to the set of available neighbor nodes and the set of available channels;
- 2) Establishing a priority queue and selecting an optimal channel by using a channel list available to the neighbor node;
- 3) Channel negotiation and data transmission and reception are performed using the improved RTS/CTS protocol.

The available neighbor node available channel statistics table is obtained based on the number of available neighbor node sets, counting the number of times the available channel appears in the available channel set of the neighboring node. When any node joins the network, the source node sends a broadcast message through the control channel to notify the surrounding available channel set of the neighbor node. After the neighboring node receives the broadcast message of the source node, if the source node is not in the set of existing neighbor nodes of the destination node, the source node is added to the set of accessible neighbor nodes of the destination node, and the set of available channels of the source node is added to the set of available channels of the source node of the accessible neighbor node.

During the data transmission, when the destination node receives the CTS message. If the destination node receives a type of CTS packet, the destination node deletes the channel contained in the CTS packet from the available channel set of the destination node storage source node. And subsequently updating the available channel list of the neighboring node of the destination node; When the destination node receives the second-class CTS packet, the destination node adds the selected channel included in the second type CTS message to the available channel set of the source node stored in the destination node, and then uses the available channel list of the neighboring node of the new destination node. The node counts the number of available channels in the available neighbor nodes through the set of available neighbor nodes and the available channel sets of the neighboring nodes, and establishes and updates its own available neighbor node available channel list. The available channel table for the neighboring nodes is a line structure, and the elements in the table are represented by structures, each with two fields: the channel and the number of occurrences.

In the local topology diagram of the example network, the available channel set of node a is $\{ch_1, ch_2, ch_3\}$, the available channel set of node b is $\{ch_1, ch_2, ch_3\}$, and the available channel set of node c is $\{ch_1, ch_2\}$, the set of available channels for node d is

$\{ch_1\}$. Node a and nodes b , c , and d occupy channels ch_4 , ch_5 , and ch_6 , respectively, for communication. For the establishment of the available channel list of the neighboring node, the result of the local topology of the example network that can pass the available channel list of the neighbor node is shown in Table 1.

Table 1. Available channels of the neighboring nodes of the example network

Channel	Number of occurrences
ch_1	3
ch_2	2
ch_3	1

Suppose the total number of channels in the network is n and the total number of network nodes is N . Since the available channels of the neighboring nodes of each node do not exceed the actual number of channels of the network at most, and the worst case number of neighboring nodes of a single node in the network is the number of remaining nodes in the network. Therefore, when the statistics of the available channels of the neighboring nodes are known, the worst time complexity of the available channel statistics is $O(nN)$; the channel priority queue is used by the heap sorting algorithm, and the time complexity is $O(\log N)$. When the network is initialized, the time complexity of the network is $O(nN)$. After each node receives the broadcast message of the neighbor node, it modifies and reorders the existing available channel statistics, and the time complexity is $O(\log N)$.

7 Optimal Channel Selection

The available channel list of the neighboring nodes is only the number of times the source node appears the available channels, but the available channels with the fewest occurrences in the table are not necessarily in the set of available channels of the source and destination nodes. Therefore, the priority queue of the set of available channels of the destination node is established according to the available channel statistics table, and the source node selects the optimal channel from the priority queue.

The establishment process of the available channel priority queue: According to the information in the available channel table of the neighboring node, the source node establishes the available channel priority queue according to the principle that the available channel in the destination node has fewer occurrences and higher priority. If the queue is empty, the source node has to wait for the appropriate available channel to arrive. The source node dequeues the priority queue squad head element each time to see if it is in the source node's available neighbors available channel set. If not, the queue head element of the queue is dequeued, and the queue head element of the queue is taken until the acquired channel is in the available channel set of the source node. Figure 1 is a flow chart of the optimal channel selection process.

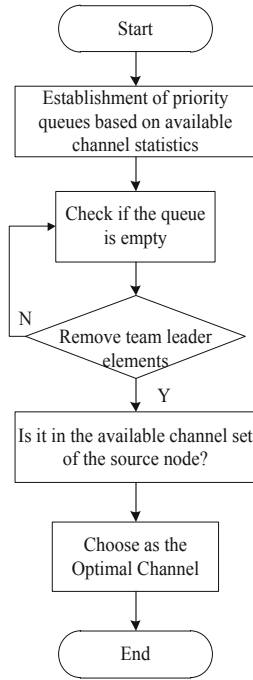


Fig. 1. Optimal channel selection process flow

When the optimal channel is selected for data transmission, the improved RTS/CTS protocol is used for channel negotiation and data transmission and reception control. The improved RTS/CTS protocol uses an improved RTS message and two types of improved CTS messages. The node negotiates the channel using the improved RTS and CTS messages before transmitting the data. After the transmission is complete, the channel is released using the improved CTS.

The above process mainly includes 4 steps:

- 1) The source node sends an RTS message through the control channel, where the RTS message includes the selected channel to stipulate the channel to be transmitted.
- 2) After receiving the RTS message, the destination node sends a CTS packet to indicate that the destination node will select the channel for data transmission if it agrees to use the channel for transmission.
- 3) After receiving the CTS packet, the source node also sends a CTS packet to notify the neighbor node that the channel will be used for data transmission.
- 4) When the data transmission is completed, the source node and the destination node sequentially send the second type CTS packet to release the occupied channel.

During the above data transmission process, all nodes that receive CTS messages modify the set of available neighbor nodes and the set of available channels. When a type of CTS message is received, the selected channel included in the CTS message is

deleted from the set of available channels, and the available channel list of the neighboring node of the destination node is updated. When receiving the second-class CTS packet, the destination node adds the selected channel included in the second-class CTS packet to the available channel set of the source node stored in the destination node, and updates the available channel list of the neighboring node of the destination node.

8 Experimental Results and Analysis

This simulation experiment uses NS3 as the simulation tool, and uses C++ language to write the simulation code. The orthogonal channel (OFDM) is used as the multi-channel, that is, the data is transmitted simultaneously for every two channels without interference; Randomly distributed nodes are used, that is, neighbor nodes of nodes are randomly generated. The number of packets per node is set to 2,500. Through the ALOHA algorithm as a comparison, each experiment was repeated 10 times, and the average value was taken as the final result. When the data buffer queues of all nodes in the network are empty, the experiment stops running and is considered as one experiment completion. The simulation parameters are shown in Table 2.

Table 2. Simulation parameter Table

Parameter	Numerical value	Parameter	Numerical value
SIFS	10 μ s	DIFS	20 μ s
Symbol time	32 μ s	Slot time	60 μ s
Packet length	1460 bytes	Basic data rate	6 Mbps

According to the set value of the simulation parameters, the simulation results are shown in Fig. 2 and Fig. 3.

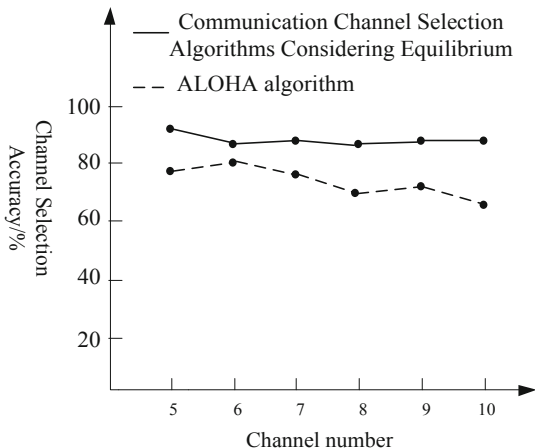


Fig. 2. Channel selection accuracy when the number of network nodes is 10.

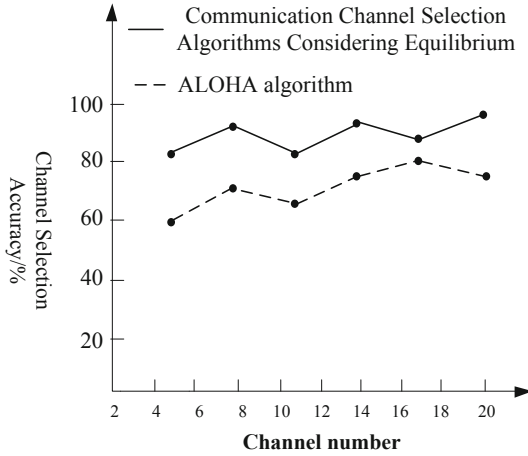


Fig. 3. Channel selection accuracy when the number of network nodes is 20.

A comparative analysis of Fig. 2 and Fig. 3 shows that under the condition that the number of network nodes is 10 or 20, the selection accuracy of the proposed communication channel selection algorithm is higher than that of the comparative ALOHA algorithm, which fully explains the proposed consideration of balance. The communication channel selection algorithm has been greatly improved in performance, which can meet the needs of network communication channel selection.

In order to further verify the performance of the proposed channel selection algorithm, in the above experimental environment, the channel selection efficiency is used as the experimental comparison index, and the proposed channel selection algorithm is compared with the ALOHA algorithm. The comparison results of channel selection efficiency when the number of network nodes are 10 and 20 are shown in Fig. 4 and Fig. 5.

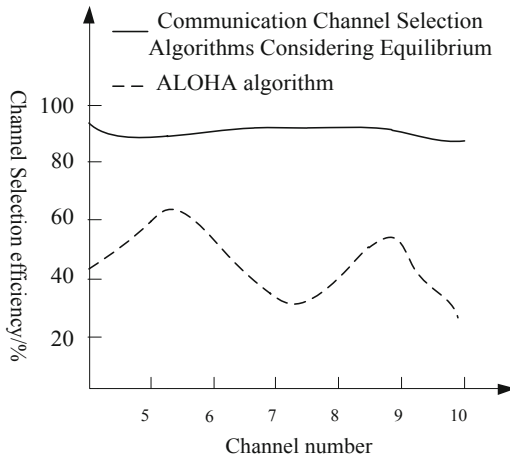


Fig. 4. Channel selection efficiency when the number of network nodes is 10

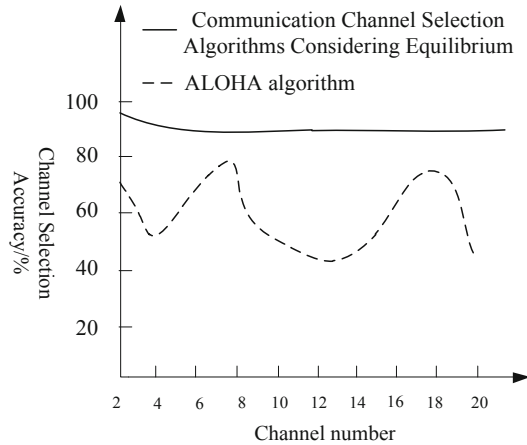


Fig. 5. Channel selection efficiency when the number of network nodes is 20

It can be seen from Fig. 4 and Fig. 5 that the performance of the proposed channel selection algorithm is relatively stable, and the proposed channel selection algorithm has a higher level under the two network node numbers. The ALOHA algorithm has strong volatility and is difficult to maintain a stable communication state. Therefore, it is fully proved that the proposed channel selection algorithm has high channel selection performance.

9 Conclusion

Aiming at the problems of traditional communication channel selection algorithms, the paper proposes a new communication channel selection algorithm considering balance. The following conclusions are proved from both theoretical and experimental aspects. The algorithm has a higher selection when selecting communication channels. Accuracy and selection efficiency. Therefore, it is fully proved that the proposed communication channel selection algorithm has high application performance.

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