The New Model of Cognitive Radio Network and Implementation of Immune Algorithm

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Abstract: To solve the shortage defects of wireless spectrum source of Internet of things, an idle spectrum resources and immune sorting selection method based on the subjective and objective weight is proposed by using cognitive radio network technology. Firstly, the radio cognitive idle spectrum system is relied on to make the spectrum system modeling of Internet of things for the generation of objective and subjective weight perception, graph coloring of allocation of Internet of things and rectangular arrays; Then, the immune weight solving process is optimized and the weight setting rationality is improved; And idle spectrum performance of the spectrum resources is analyzed again, and it has the stability; Lastly, MATLAB is used to make simulation experiment. The result shows: the algorithm can not only make effective allocation to spectrum resources, greatly improving the spectrum utilization, but also meet radio transmission demand of Internet of things with high network throughput capacity and improve the transmission rate of Internet node with the stability.

Keywords: Idle spectrum; Node transmission; Subjective and objective cognitive systems; Perception

1. Introduction

Radio spectrum is a scarce non-renewable resources. The rapid development of the Internet of Things has brought everyday life with great convenience. Radio transmission is the main transmission manner of Internet of things, so Internet of things has huge demand for radio spectrum, but it also bring great challenge for the use of radio spectrum resources[1-2]. As the demand for radio communication services continues to grow, the radio spectrum resources become scarcer . Currently, most of the spectrum resources are assigned to the user in static form, so the spectrum band is divided into two parts: the licensed band and non- licensed band [3-5]. Nowadays, the vast majority are licensed spectrum bands, such as broadcast TV bands, bands of mobile communications operators, bands of military and public security departments and other bands . Allocation and use of spectrum is determined by the radio regulatory agencies. Traditional static spectrum resource allocation , to some extent, solve the disorder of the spectrum resource utilization , but it also lead to the selfish use of spectrum resources, that is other non- authorized users is not allowed to use it by the authorized users [4-8] . And recent studies show that some licensed bands spectrum utilization is very low. According to data of FCC, existing spectrum utilization is about 19 % to 89%, especially the average utilization below the band 2GHz is only 6.8%. Thus, the spectrum resource shortages and waste exist at the same time. To make efficient use of spectrum resources, a variety of advanced wireless communication theory and techniques have been proposed, such as adaptive coding and modulation technique, multi-antenna technology, multi-carrier multiplexing technique and so on. These technologies, to a certain extent, solve the problem of low utilization of spectrum resources, but due to the constraint of Shannon capacity, performance improvement is limited and this problem is not solved fundamentally [9]. Therefore, new technology must be sought to solve the shortage problem of spectrum resources.

The traditional cooperative perception structure , assuming that all cognitive users distribute independently and share the same average SNR , data fusion center does not distinguish the cognitive users and consolidate averagely all sensory data. After the energy fusion is made, the average value is used as the judgment data .But in actual communication, the cognitive users are in different location .After influenced by the different characteristics of the channel, the SNR and the distribution character of cognitive accuracy of the cognitive users is different. Besides, some malicious users tamper the perception data and cooperative perception have problems such as spectrum sensing data tamper attacks and other issues , so the spectrum cooperative perception scheme based on the objective and subjective weight collation. The perception weight value is assigned to different cognitive users to reduce the impact of cognitive users of low perception. and attackers who tamper sensory data on the judgment of fusion center .The perception structure is shown in Figure 1,on the basis of the traditional cooperative perception structure, the weight fusion process is increased. According to this, when single cognitive user work in different average SNR, different weight values are given to each cognitive user dynamically. After sensory data is sent to the data fusion center by cognitive users, the fusion center will assign different weight values to deal with sensory data of different cognitive users and then make a decision .Compared with the traditional cooperative spectrum perception method, it can greatly improve the detection performance of the primary users.

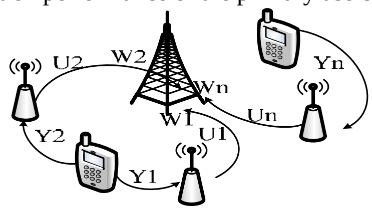

Figure 1. Spectrum cooperative allocation perception structural graph based on objective and subjective weights

2. Fusion Modeling of Subjective and Objective Weight

2.1. Generation of subjective and objective perception weight

Supposing the weight value of the first perception of all the cognitive users is $p_i(1)=2$ .After each perception, the i_{th} cognitive user will get a new weight value $p_i(m)$, (m is greater than 2), $p_i(m)$ represents the weight value of m_{th} perception of i_{th} cognitive user. After every perception, the cognitive user will update weight value $p_i(m)$. The relationship between weight value $p_i(m-1)$ and the last moment $p_i(m)$ is shown as the following formula:

$$p_i(m)=\frac{p_i(m)\delta_i(m)}{p_i(m)\delta},(m\geq 1) \quad (1)$$

$$p_i(m-1)\delta=\frac{1}{M}\sum_{i=11}^{M}p_i(m-1)\delta_i(m-1),(m\geq 2) \quad (2)$$

In the formula $p_i(m),\delta_i(m-1)$ separately represents the instant SNR of the m_{th} $(m-1)$ perception of m_{th} cognitive user. The weight value $p_i(m)$ of very cognitive user changes according to the above formula. As the formula (1) (2) show that the perception weight value $p_i(m)$ of cognitive user rely on the weight value and SNR of the last moment. The following conditions is required:

The sum of perception weight value $p_i(m)$ of cognitive users is a constant, that is satisfying:

$$\sum_{i=1}^{M}p_i(m)=M \quad (3)$$

The perception weight value of cognitive users is between 1 and M , that is satisfying:

$$p_i(m)\in[1,M] \quad (4)$$

For any cognitive user p_i , assuming the number of available idle spectrum resource is M and the attribute characteristics of each idle spectrum resource use norms to describe, therefore, the available spectrum resources and spectral attribute constitute a decision matrix $p=\left[p_{x,y}\right]_{s\times v}$ of $s\times v$. Assuming the attribute feature weight vector of idle spectrum resource is $p=(p_1,p_2,p_s...p_v)$, to calculate the corresponding weight of each attribute p_s and use the corresponding decision matrix p to weight, then the priority of decision-making programs is got.

According to the above scheme, when the SNR cognitive user is low, the weight value of cognitive user will subsequently reduce and influence the perception weight of the next moment. So, when cognitive radio data fusion center make data fusion, the impact that the cognitive user has on the comprehensive judgment will also reduce; when cognitive user has larger SNR, the weight value of this cognitive will become large and influence the perception weight of the next moment. At this time, the impact of cognitive user on the comprehensive judgment of the fusion center strength to achieve the purpose that fusion center treat different cognitive users with different SNR in a different way through weight value.

Thus, how to determine the weight of each attribute is a key issue. Weight setting directly affects the accuracy of multi-objective decision ordering. The relationship between the spectral database and dynamic spectrum divider in the objective and subjective cognitive weight systems is shown in Figure 2:

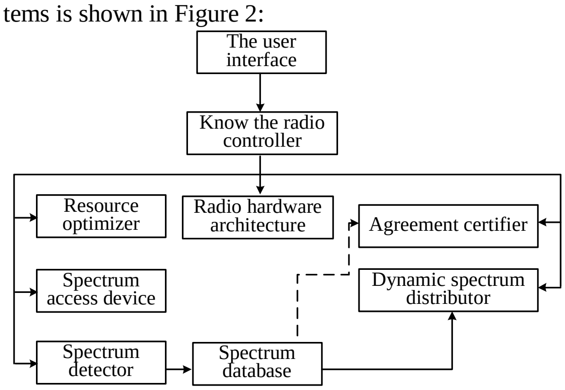

Figure 2. The relationship between spectrum data and allocation of subjective and objective weight

The cognitive network can access the idle licensed bands by opportunity and ,when authorization system enlist this band again, the cognitive system can switch to other idle spectrum; there is no information interaction between cognitive system and authorization system and cognitive system identify the idle spectrum resource through spectrum detection mechanisms; cognitive system has multiple cognitive network adjacent to each other so that adjacent cognitive network can not access the same spectrum resources, or they will produce the same frequency interference among themselves. As it shows in Figure 3, the spectrum agent will be responsible for completing dynamic spectrum allocation mechanism among multiple Internets; The cognitive base station, is that access point completes the resource allocation and scheduling within the network.

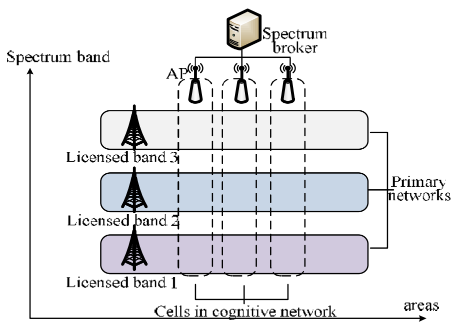

Figure 3. The application scene of dynamic spectrum allocation mechanism

The study about dynamic spectrum allocation mechanism between multiple networks or cells in cognitive system is focus more on avoiding interference among multiple cells; based on this motivation, graph coloring theory has been widely used in dynamic spectrum allocation mechanism used to avoid interference among multiple cells.

2.2. Spectrum resource allocation matrix

Assume that there are M secondary users, the number of available spectrum bands that perceived by cognitive radio networks is R and the bands are mutually orthogonal. Each matrix is defined as follows:

Definition 1 available spectrum matrix S

Available spectrum matrix refers to the spectrum resource that is not occupied by the primary users in a space and in a moment. The available spectrum matrix is used to show whether a spectrum is available to secondary user, recorded as

$$S\left\{y_{w,e} \middle| k_{j,l} \in [1,2]\right\}$$

In the formula, $y_{w,e} = 2$ represents the spectrum m(1<m<M)that can be used by secondary user $j(2 \le s \le l)$; $k_{j,l} = 1$ represents the spectrum m that the secondary user l can not use.

Definition 2 benefit matrix X

Different secondary user may obtain different benefit in an effective idle spectrum because the environment and the transmitting power and other technologies vares. The benefit obtained by users is shown by the benefit matrix X .

$X = \{i_{r,e}\}_{o \times p}$ represents the benefit obtained by user $j(2 \le s \le l)$ after using the spectrum $e(2 \le o \le p)$.

Obviously, when $i_{r,e} = 0$,then $k_{j,l} = 0$,to guarantee the benefit matrix is got only when the effective spectrum is available.

Definition 3 interference matrix O

For an available spectrum, different secondary users are likely to use this spectrum, so the secondary users may interference with each other. The interference between secondary users is represented by interference matrix O :

$$O = \left\{o_{s,d,f} \middle| o_{s,d,f} \in [0,1]\right\}_{s \times f}$$

In the formula, $o_{s,d,f} = 1$ represents the secondary user s and $f(1 \le n \le f)$ will interfere with each other when using the spectrum $d(1 \le s \le f)$,on the contrary, $o_{s,d,f} = 0$ represents there is no interference.

In the moment $y_s(d,f) + u_i(d,f) \le d(s,f)$ the interference is produced, that is $o_{s,d,f} = 1$. Interference matrix is decided by available spectrum matrix. When $s = f$, $o_{s,d,f} = 1 - y_{d,f}$ and the matrix factor satisfy $o_{s,d,f} \le y_{d,f} \times y_{d,f}$ that is ,only when spectrum m is available to secondary user n and k may it produce interference.

Definition 4 non-interference allocation matrix p

To assign the available and non-interference spectrum to users to get the non-interference allocation matrix.

$$p = \left\{l_{d,f} \middle| l_{d,f} \in \{0,1\}\right\}_{s \times f}$$

In the formula $l_{d,f} = 1$ represents to assign the spectrum m to secondary user, $l_{d,f} = 0$ represents not to assign the spectrum band m to secondary user n .Non-interference allocation matrix must satisfy the non-interference constraint condition of definition of interference matrix as follows:

$$l_{d,f} \times l_{s,f} = 1, if\ l_{s,d,f} = 0, \wedge s \ \mathbf{p}\ d, d \ \mathbf{p}\ f$$

As the above definition and analysis show, the allocation matrix p that satisfy allocation constraint condition is more than one. $\wedge s$, l is used to represent the set of all the allocation matrix p that satisfy the condition. If a non-interference spectrum allocation A is given, the total benefit that the secondary user n obtains is represented benefit vector E:

$$E = \left\{ l_n = \sum_{d=1}^{s} e_{s,d} \times l_{s,f} \right\}$$

The goal of cognitive radio network spectrum allocation is to maximize the network benefit $l(d)$, so the optimization of spectrum allocation can be:

$$p^* = \arg\max_{s \in \vee(s,d) f} l(d)$$

In the formula, $\arg\max l(d)$ represents the corresponding spectrum allocation matrix l in solving the maximization of network benefit. Therefore, $s \in \vee(s,d) f$ is the optimal non-interference spectrum allocation matrix.

3. Weight Solving Process based on Immune Optimization Algorithm

3.1. Immune optimization algorithm

Immune Optimization is an intelligent optimization method inspired by the biological immune principles and it has been widely used in the field of engineering application such as control, image processing, network security and so on. In immune algorithm, the antibody is candidate solutions of the optimization problem, immune algorithm optimize the candidate set through cloning, mutation, selection, etc.

3.2. Specific achievement of algorithm

1) Coding

Coding is one of the key technologies for immune algorithm solving. As the optimum weight setting is required, initial weight coding of antibody uses the fragment coding and the specific number of sub-space is decided by the attribute norm of spectrum resource. The size of each sub-space is decided by initial subjective and objective weight.

Assuming that there are three attribute norm of spectrum resource, the subjective weight is $P_i = [0.11, 0.39, 0.53]$ and the objective weight is $P_i = [0.23, 0.34, 0.49]$, then three sub-space produced initially are:[0.11,0.23],[0.34,0.39],[0.49,0.53].

2) Affinity functions

In immune algorithm, the problem is mapped to be the antigen, the solution of the problem is mapped to be antibodies, the merits of solution is measured by the affinity function. As the weight value that meet the minimum deviation is to be got, so the formula (1) is directly used as an affinity function.

(Step1-Step6) (Note: S indicates antibody population, S represents an antibody):

Step 1 Initialization

Assuming that the evolutionary algebra $o = 0$, stochastic initialization population s, the size is $m(m = |s|)$. Then the initialization population is recorded as: $s(o) = \{s_1(o), s_2(o) \ldots s_n(o)\}$.Meanwhile setting memory population $s(m)$, the size is $m(m = o * n)$,setting reserved population $o(m)$,the size is $m = o - s$, so there is: Antibody $o(m) = o(s) \cup s_o$ apply the binary to encode. The length of each antibody is $m = \sum_{0=1}^{M} \sum_{s=1}^{M} s_{o,m}$, that is ,1 is the number of element that the element value is not 0 in spectrum matrix; Each antibody represents a possible spectrum allocation scheme. Meanwhile, to record separately the element n and m that corresponds to the element whose value is 1in the matrix Land reserve it in m_1 according to the way that increasing in n firstly and then in m, namely $m_1 = \{(s,o) | m_1|\}$. Obviously, the number of element in m_1 is 1.

Step 2 Affinity judgment of immune cloning.

According to the target function to be optimized(definition 5), to separately calculate the population affinity of antibody and sort the antibody according to the descending order of affinity level, then the first s antibody is chosen to update memory population $s(y)$;when the antibody concentration achieve the minimum and the size of cloning achieve the maximum, the affinity function of antibody requires higher, which is good for maintaining the diversity of population and avoiding premature convergence.

The first u_{th} antibody with higher affinity is cloned in this paper. To define the cloning operation m_i^i as:

$$y(h) = m_i^i(y(h)) = \{m_i^i(y_1(h)), m_i^i(y_2(h)) \ldots m_i^i(y_n(h))\}^m$$

Specific cloning method is shown as follows: assuming that the selected t antibodies are sorted according to the affinity descending order as:

$y_1(h), y_2(h) \ldots y_n(h)$ then the antibody number produced by the cloning of the t_{th} antibody $t_y(h)(1 \mathbf{p}\ y\ \mathbf{p}\ t)$ is :

$$y_1 = Int\left(h_y \times \frac{S(t_y(h))}{\sum_{y=1}^{t} y(h_{ij}(h))} \times \frac{1}{b_{t_y}} \right)$$

In the formula $Int(.)$ represents round-off upward, $s(.)$ represents the affinity of antibody, $y_1\ \mathbf{f}\ (h)$ is controlling parameter, $y(h_{ij}(h))$ represents the concentration of antibody $y_1(h)$.

Step 3 Stop condition judgment

If the maximal iterations $h_{\max}$ is achieved, the algorithm is stopped. To map the antibody reserved in memory population with highest affinity to the form of B, then the optimal spectrum allocation is got; otherwise, turn to step 5.

Step 4 Cloning mutation h_r^t

To make mutation operation h_r^t to the cloned population $f(h)$ according to the probability u_x, the antibody population $s(y)$ is got. The definition is $f(h)=h_r^t s(y)$. The mutation applies the primary mutation.

The population after mutation is $f(h)=\{f_1(h), f_2(h)..., f_w(h)\}$.

Step 5 Cloning selection h_p^t

The definition is $f(h+1)=h_r^t(s(y))$. To keep the stability of population size, the affinity function judgment is made to $s(y)$ again and the first s antibody with higher affinity is chosen to constitute memory population $s(h+1)$.Meanwhile, to keep the population diversity, the reserved population $y(h+1)$ is generated by chance; $s(h+1)$ and $y(h+1)$ constitute the population of the next generation $s(h+1)$; recorded as: $s(h+1)=\{s_1(h+1), s_2(h+1)...s_n(h+1)\}$;turn to step3;

Step 6 $s=s+1$;turn to Step2;

4. Feature of Spectrum Resource

This section will get the statistics of available spectrum resource of cognitive system through analyzing the authorization system's using of spectrum resources. Spectrum resources used in the cognitive system come from the idle spectrum of the authorization system and the authorization system has the highest priority for the access to the spectrum resources; and the cognitive system is the secondary system, its use of the spectrum resources is under the unconditional constraint of authorization system. Therefore, the spectrum resources in cognitive system resource has temporarily stability.

Whether the authorization system is the communication system of frequency division or code division multiple access, each channel in the authorization system have two states of idle and occupied. When a channel is idle, the channel bandwidth occupied by the channel can be used as available spectrum resources of cognitive system. For example, channel bandwidth of WCDMA system is SMHZ, while the channel bandwidth of GSM system is 220KHz.Two parameter is used to represents the system characteristic feature description of each channel in a certain statistical time $<T$:

a) During the inspection time $<T$, the spectrum occupancy;

b) During the inspection time, the update times "idle-occupying" is used to check the situation of "occupying and idle' of the individual channel .There are four typical situations as it shows in Figure 4.

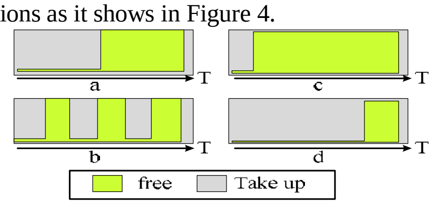

Figure 4. The idle spectrum occupancy of single channel of authorization system

In the same inspection time, the channel (a) and (B) share the same spectral occupancy, but in the situation, the frequency of authorization users' appearance is more. So, for the cognitive system, channel (a) has a better stability. Therefore, in the inspection time $<T$, the spectral statistical occupancy represents the availability of spectrum. The higher occupancy of the cognitive system, the worse the availability of the spectrum; the frequency that authorized user appears represents the stability of detected spectrum. The frequency that the authorized users appear is fewer, for cognitive system, the stability of the spectrum is higher. Therefore, to fully and accurately characterize the characteristics of the detected spectrum, two factors, including spectrum occupancy and the frequency that authorized user appears, is considered jointly

The use of the i_{th} channel of authorized system in examination time is shown in the following Figure5:

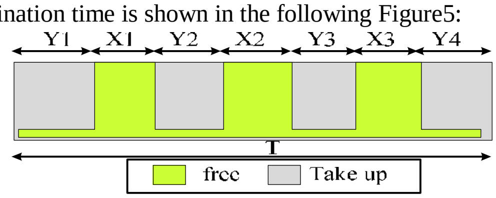

Figure 5. The idle spectrum occupancy of single channel of authorization system within a certain time

In the examination time $<T$, the long-term statistic occupancy of channel m is:

$$\bar{R}_m = W\left[\frac{\sum_{s-1} y_{mk}}{<T}\right]$$

In the examination time $<T$, the long-term statistic result of the frequency that authorized user appears in channel m is:

$$\bar{P}_m = W[P_i]$$

In the formula P_i is the frequency that authorized user achieves in a census.

5. Stimulation Experiment and the Result Analysis

5.1. Service idle spectrum simulation

First of all, using MATLAB to make simulation test on the service idle spectrum resource allocation of Internet of things to further, verify the effectiveness of the algorithm. Assume that the achievement probability of cognitive users and authorized users obeys the poisson distribution, and the existing idle spectrum resources are divided into two categories: one is that the idle spectrum {A, B, C} is open defined free frequency bands resources; Another is that the idle spectrum (D and F) is cellular network communication frequency bands spectrum resources. In simulation experiment, A-F coding sequence is made to spectrum resource number. The bandwidth, delay, jitter and packet loss rate data results of each idle spectrum is shown in Table 1.

Table 1. The characteristic value of each attribute of idle spectrum

The spectrum resource number	Bandwidth(*Kbps)*	Delay (ms)	Jitter (ms)	Packet loss rate **(%)**
A	4230	162-500	10	<6
B	4500	131-500	15	<6
C	5120	136-500	23	<6
D	1500	39-53	3	<1
E	100	36-53	4.3	<1
F	1230	39-53	3	<1

Three kinds of service is generated in the simulation: voice, video and file transfer. And the quality of voice service requires: delay<52ms, jitter<6ms,packet loss rate<4.3% and bandwidth occupies 9.8Kbps;the video service requires: delay<53ms,the packet loss rate<6% and bandwidth occupies100Kbps;and the file transfer have no special requirement for delay, jitter and packet loss rate, the maximum transmission rate of which is 120Kbps.

In immune optimization algorithm, after the experiment adjustment, to set the maximum evolutionary algebra $K_{\max} = 1230$; the population size $n = 23$, memory unit size $s = 0.41 \times n$;the cloning control parameter $n_t = 21$,mutation probability $p_{m=0.11}$.

During the experiment process, the subjective weight assigned by decision-makers to evaluate scheme according to their own preferences. Specific reference [6], through the analytic hierarchy process (ahp), get the comprehensive weight of each attribute index for the total goal, and then seek subjective weight vector. Objective weight is assigned through entropy technique. That is, to use information entropy, to calculate the weight of each evaluation index, providing basis for comprehensive evaluation of multiple evaluation index. Entropy technology method reflects the degree of difference between each index. The greater the difference, the larger the weight. On the contrary, the smaller will the weight. After subjective and objective weight is determined, to establish the optimization model for comprehensive weight solving, the fusion weight is derived from the immune optimization algorithm.

Figure 6 shows the idle spectrum resource allocation of different types of service by using the proposed scheme in this paper. For voice service, this scheme will assign it to idle spectrum 5 to transfer firstly, which is because that the spectrum resources in the frequency band can well meet the service quality requirement of voice service. For video and file transfer, when the delay<53ms,the scheme will assign it to idle spectrum to transfer firstly, which is because that idle spectrum resource can provide high transmission bandwidth.

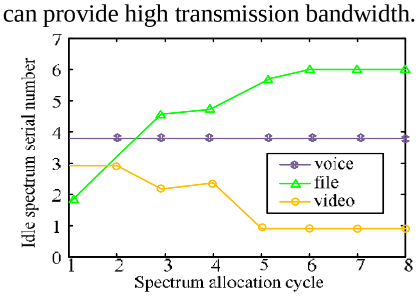

Figure 6. The period of spectrum allocation

In the simulation content, assuming that there are two kinds of service: the voice service and the data service in the cognitive system, and there are also two spectrum resource blocks that can be accessed to. And assuming that these two spectrum blocks share the same characteristic, both meeting the real-time demand of voice service, and satisfying the requirement that the SNR of data service is high; But the spectrum resource bands have different bandwidth, however, they can meet the minimum bandwidth requirements of voice and data service. In this simulation, assuming that the voice and data service within an hour is uninterrupted, so the voice traffic is 1 Ireland; and assuming that the rate of data service is $103 Mbit / Hz / h$; the simulation result is shown in Figure 7.

In the simulation figure 7, the abscissa is the ratio of the bandwidth of two spectrum resource blocks s / r, and $s \geq r$; the ordinate is the degree that spectrum efficiency provide. It can be obviously seen from the simulation figure that the scheme in this paper can achieve the reasonable matching of service type and spectrum bandwidth, greatly improving the spectrum efficiency; and the increasing degree of spectrum bandwidth is more obvious when the ratio of the bandwidth of spectrum resource bands.

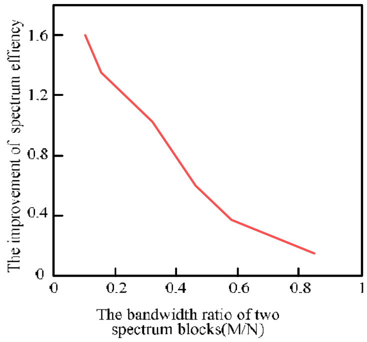

Figure 7. The increasing degree of spectrum efficiency

5.2. Optimal Accessible Throughput of Internet of Things

For the power allocation simulation base on optimal accessible throughput proposed in this section, the parameter setting is as follows:

$$s_0 = 1, t = 1, m_{x_1x_2} = m_{x_2x_3} = 1, m_{ux_2} = 0.02, P_{fu} = 5, \beta = 5$$

$$f_{x_1}^{Max} = f_{x_2}^{Max} = 12,\ f_x = 6, \lambda = 0.6, \alpha_1 = \alpha_2 = 0.3\ f_1 \le 0.8$$

Figure 8 shows the relationship that network effective throughput (the throughput that satisfy the service quality demand of users) changes with the amount of cognitive users. Compared with document[9], the solution in this paper apply more spectrum resource attribute to describe idle spectrum resource (including delay, jitter and packet loss rate), which is able to meet the service quality demand of service transmission of cognitive users, improve the effective throughput of network, and meet the demand of data transmission of node of Internet of things.

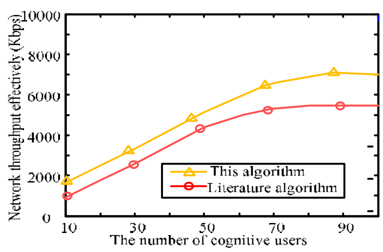

Figure 8. The presentation of relationship between network effective throughput and the amount of cognitive user

Figure 9 reveals the cognitive network throughput performance of primary user under different access probability. In the figure, when the access probability of main user is small, the power allocation algorithm performance in Oveday, underlay and hybrid access strategy is nearly the same; But when p increases, the performance of algorithm proposed in this paper is superior to overlay strategy, but inferior to Underlay strategy. Considering that the Underlay strategy would bring about more cumulative interference to primary users, so power allocation algorithm under hybrid access strategy can better protect the main users from interference to improve the network throughput, so as to improve the rate of transmission of network node and the quality of network transmission.

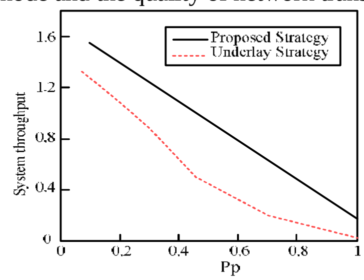

Figure 9. The cognitive network throughput of primary user under different access probability

6. Conclusions

For the spectrum demand issue of Internet of things, based on the spectrum allocation of cognitive radio technology, the allocation scheme and immune achievement of Internet of things with a new model of subjective and objective weight fusion is proposed, combining the advantage of the subjective and objective assignment, analyzing the idle spectrum characteristic and giving the solving process and algorithm realization of immune optimalization algorithm weight. Finally, the MATLAB is used to make simulation experiment. The experimental result shows that this scheme can achieve effective allocation of spectrum resources and meet the transmission quality demand of node of Internet of things. It guarantees the high mobility and massive data transmission of node of Internet of things, having high network throughput. And it improves the spectrum utilization and achieves the optimalization of idle spectrum resource utilization. It has significant meaning for the security and development of cognitive network.

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