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The Cognitive Ad-hoc Network Spectrum - Routing Selection Method

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Abstract

Based on cognitive self-organizing network transmission delay larger and larger interference to primary user receiver problem, put forward a method of spectrum joint routing selection, this method is effective to consider the transmission delay and the main user interference at the receiving end, mainly from < 1 > bandwidth available probability; < 2 > sent via link the number of bits of variance; < 3 > spread spectrum characteristic; < 4 > primary user receiver protection; < 5 > spectrum sensing five aspects to consider. Cognitive users of the information interaction with on-demand routing discovery process started, and to establish collaborative perception nodes along the route cluster, using the routing maintenance message to maintain the nodes in the cluster. At the same time on the cognitive network capacity maximization as the goal, put forward to jointly design spectrum collaborative perception and channel allocation. The simulation results prove the effectiveness of the method.

Keywords: *cognitive wireless networks cooperative sensing control channel channel allocation route discovery*

1. Introduction

Cognitive Radio (CR) technology is to improve the spectrum efficiency of a new intelligent wireless communication technology, it is the earliest by Joseph Mitola on the basis of the concept of software Radio. The technology can intelligently perception surrounding environment characteristics, and adaptive to learn, through wireless knowledge description language and intelligent communication between wireless communication system, at the same time, it also can adjust the transmission parameters, the real-time system of wireless transmission strategy adapted to the environment and the change of the wireless communication system, to ensure that no matter when and where to make wireless communication system with high reliability and frequency spectrum utilization efficiency. Cognitive radio has authorized users (*i.e.*, primary user) is not affected under the premise of the ability of intelligent use of spare time spectrum, and has provided whenever and wherever, the potential of intelligence, high reliable communication. Academics have proposed cognitive radio technology will become a key technology in wireless communication system in the future. About cognitive radio technology most recent study about spectrum detection, spectrum transmission scheme, etc., these studies are conducted in the physical aspects, plan design to the signal processing and transmission scheme of power allocation, etc., and its topology structure is mostly the structure of single jump, it is a central control node; In most application scenario, however, need more to complete, so the research of cognitive radio network layer under multiple dance scene design, practical is an urgent need to solve the

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problem. In existing research, a typical end-to-end multiple hops network are all the time delay, jump in the number of research, but these studies are not suitable for cognitive radio environment applications, so it is based on the above research foundation, the object of this study is a cognitive radio environment more jump self-organizing network, the physical layer and network layer of the combined optimization problem.

In the existing studies of CRN, are generally choose the ISM band or dedicated channels as public control channel, mesh ISM frequency band is becoming very crowded, however, inevitably affected by all kinds of interference, choose a dedicated channel will add frost on the network to the already spectrum shortage, so design reliable and efficient public control channel is imminent. Collaborative spectrum sensing, spectrum access and routing technology between not exist independently. In the detection time, detection cycle of collaborative perception and false-alarm probability will influence the quality and quantity of the idle channel, so as to affect the cognitive spectrum access opportunities for many users, which affect the network throughput of cognitive network [2, 3]. Channel allocation is reasonable not only affect the idle spectrum use efficiency, can also affect the connectivity between nodes, which affects the choice of the routing path. Found in this paper, all of these technologies are business transmission services for cognitive users, only business occurs, the only meaningful when it these operations.

This paper studies focus on cognitive radio self-organizing network, don't assume any specific topology, each user perception on the surrounding environment is limited, consider the main user receiver, cognitive radio service classification and scalar routing methods to distinguish primary user for cognitive radio network. Proposed scheme USES the perception of the frequency spectrum of the physical and MAC layer protocols combination optimization method, the application of the physical loop stability testing and coverage cooperation way, consider the final error probability factors such as perception, but these methods still cannot guarantee the main user reliable protection at the receiving end, so this paper USES the network layer to protect the main user measures at the receiving end, to ensure the main user communications functions.

2. Related Works

In multiple hops a single originated in the cognitive radio routing protocol, boils down to is a typical self-organization demand distance vector (AODV, Ad hoc on demand short vector) question [1], routing requests sent forward through all possible channels to reach the destination node. And then decide the choice of frequency spectrum; Spectrum selection based on the shortest path method, according to the analysis of the estimated time for spectrum of switching and channel connection, finally complete the data transmission. Similarly, the optimal path is first to find, and then according to find the first routing, in turn, keep looking. In the next path selection and spectrum allocation cannot guarantee spectrum can be used, along the path optimization for the typical matrix, such as delay or hop. In addition, send routing requests in all use the frequency spectrum of the channel or separate specific channel routing request will cause widespread attention. Protocol is proposed in the literature [2], with the routing and scheduling to reduce the interference between the cognitive network switching cost and reduce spectrum. More than a branch of learning way put forward by literature [3]. Cognitive users periodically to exchange each other channels of information, but also

provide different business class information (such as time delay sensitivity, *etc.*). The algorithm is studied the adjacent channel decision strategies of cognitive users, to unified by the adjacent channel of cognitive users.

Some existing research hypothesis know the topology structure, and that any given node to the edge of the proportion. This approach in the literature [4] we can see, the edge density, on behalf of channel capacity, and can according to the channel capacity to estimate the interference from the main users, received signal strength and so on. A path to the center of spectrum allocation structure is put forward by literature, the method for multilayer network diagram to represent the degree of available spectrum between nodes. Another case, a Dijsktra algorithm through this diagram to get the optimal path. This approach makes communication network edge of proportion of each node overload, causing the network paralysis, reason this kind of method is not suitable for adhoc routing method. Other documents mentioned mesh network distribution tree routing [5-6].

According to the above literature research, this article proposed solutions are based on the following conditions. This paper studies the cognitive radio technology of AD hoc self-organizing Mesh network, don't assume a certain fixed topology structure, and each user know only limited knowledge of the environment. In addition, considering the main user receiver, cognitive business classification and scalar routing method can only distinguish between cognitive users, this is different from other studies. In this research goal is to provide support for multiple network layers jump cognitive radio network, so you can use any of the underlying MAC protocols or the physical spectrum detection technology. Some studies have been put forward about a certain perception error probability is derived under the transmission duration, using advanced digital processing technology such as smooth circulation feature detection. However, these methods often put forward some theoretical assumptions such as simplified the user model, and testing the main users of the sender is not only testing the main users of the receiver, and there is no guarantee that perfect detection. These methods used in the lower MAC layer and physical layer, this paper mainly adopts independent measures to protect the main users in the network layer at the receiving end.

3. System Model

Suppose U primary user, exist in the cognitive wireless network W cognitive users, the frequency spectrum of the authorization to the primary user can be divided into F a non-overlapping channels. Because it mainly discuss the efficient use of public control channel, therefore, assume that there is a public control channel, don't discuss the establishing process of public control channel. Consider using a simple diagram $G=(V,E)$ to show cognitive wireless networks, including a collection of said SU, E for link set. Assume the transport layer uses the IEEE 802.11 standard, each node $u \in V$ there is a cognitive communication distance d_{tr} and an interference distance d_{ir}, in general $d_{ir} > 2d_{tr}$, here for easy take the node's interference distance is more than twice the distance communication, and the interference range off for two jump distance range. This paper mainly studies the collaborative perception, channel allocation and routing discovery process control information merging, efficient use of public control channel, at the same time for reasonable use of idle channel, channel allocation principles should be cognitive users access to the main user network and

cognitive network interference small as far as possible, at the same time maximize access to the channel capacity of its own.

Routing selection of beginning in the cognitive radio users agreement includes two steps, first step, spectrum selection stage, the second step, hop selection stage. Source node through broadcast routing request control and the packet is transmitted to the destination node. Every intermediate node forward to find the best possible spectrum, and find a better in frequency selective channels. In order to be able to do this, put forward some cognitive radio unified matrix, the matrix can be according to certain proportion to select the frequency spectrum. In addition, the cognitive network end-to-end duration is the key problem, in the spectrum of a given choice forward node selection must support the highest transmission distance, maximum allowable transmission time (the perception of a given adjacent nodes strategy).

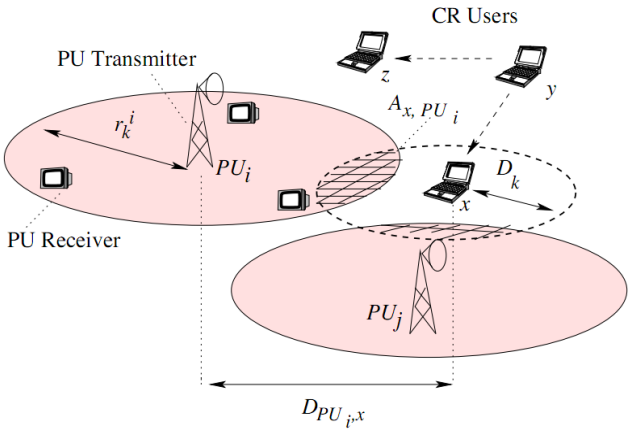

Figure 1. System Model

The next step is the next-hop selection stage, cognitive radio users to choose according to the spectrum of the selected and local networks, and physical environmental conditions for each sort of adjacent nodes, these sorting determines which as a follow-up next routing. As shown in Figure 1, the main users of the sender i and j are divided by distance $d_{PUi}x$. Shadow circle represents, they covered the receiving end of the main users in this range, although second users x y z location, the user are not known. Note that users x have greater transmission radius D_k , given the main users to send the transmission range, here imply the possibility of a greater interference to primary user receiver. As a result, its initiative to transfer the following packages than z . Suppose routing request have cognitive radio users z , x and z are received, as a cognitive users than to have a higher initiative, and have a lower time delay. So he sent routing requests to be earlier than the cognitive users x . Routing request arrival time is independent of transmission time, so the early arrival of routing request on behalf of its path is more conducive to cognitive user operation. This method reduce the cost of different spectrum of channel as a fixed routing. So the computational complexity is also relatively small.

This paper assume that the sender network by fixed main user i and j know its location and maximum coverage, its form is similar to TV towers, as shown in figure 1, which contains the main users and main users are known, its scope f_k^i is also fixed.

Cognitive users is moving, the position is known, but there is no primary user location information at the receiving end. In addition, the assumption is available channel statistical properties to know.

4. Routing Selection and Spectrum Optimization

Routing initiation stage coefficient of cognitive radio consider five factors: < 1 > bandwidth available probability; < 2 > sent via link the number of bits of variance; < 3 > spread spectrum characteristic; < 4 > primary user receiver protection; < 5 > spectrum perception of consideration. For the above consideration, this paper start points of discussion. The first is the probability of the bandwidth available. In a fixed period, a new road by its need for a fixed φ_D source node is expressed as the average bandwidth. Assumes that the channel bandwidth for different N_s spectral bandwidth, different definition. For optional cognitive user estimates that if choose spectrum bandwidth can guarantee availability.

A given spectrum bandwidth k consists of n_k channel bandwidth for each have φ_k, At the same time the minimum channel number $\left\lceil \frac{\varphi_D}{\varphi_k} \right\rceil$ is available. $\lceil \bullet \rceil$ is on behalf of the whole down among them. Make $\frac{1}{\alpha_i^k}$ and $\frac{1}{\beta_i^k}$ represent the i -th channel the average spectrum k -th of start and stop time. Open time primary users take the time to channel perception of the Lord. Only free time on behalf of the channel as a user transmission time. This information can be gained through statistics. Can be found in the i -thchannel can be for some time.

$$p_i^k = \frac{\alpha_i^k}{\alpha_i^k + \beta_i^k} \tag{1}$$

According to the hardware limitations, assume that the sender can only a user with an aim of authorized users, for the k th spectrum, the collection C^k is on behalf of the selected channel is used to forward transmission channel requirements. With (1) set of choices C^k

$$p_i^k > p_j^k, \forall i \in C^k, j \notin C^k, 0 < i, j < n_k \tag{2}$$

Spectrum bandwidth available probability with M_B^k denoted, want to choose $\left|C^k\right|$ channels to meet the demand of the forward transmission, it can be expressed as

$$M_B^k = \prod_{i \in C^k} p_i^k \tag{3}$$

For through the link to send the number of bits of variance, a recent study time users according to different adjustment difficulty, the bandwidth can be adjusted for large structures, so it makes the choice of channel may not available, and to cause a decline in the end-to-end performance. The general link to send the number of bits of variance is a cumulative function, is available for user.

The frequency spectrum k used for the i -the channel, ξ_i^k representative statistics and observation time $\bar{t}_{soff}$, stop time average for its definition

$$\xi_i^k = \frac{1}{N_v}\sum_{s=1}^{N_v}\left[\frac{1}{\beta_i^k} - \left(t_{soff}^{-}\right)\right]^2 \quad (4)$$

Here, s is on behalf of N_v's the maximum value, can be seen from the intuitively, can use more authorized channel availability is not a cognitive network. Therefore, according to the standard parameter ξ_i^k is not a simple represents the significance of variance, it also represents the available bandwidth of time under a given channel. Assumes that the primary user in a channel activity is independent of other users, its on the spectrum to the number of bits variance can be expressed as

$$V_B^k = \varphi_k \sum_{i \in C^k} \xi_i^k \quad (5)$$

For the spread characteristic of the frequency spectrum, frequency in the range below the MHz good transmission characteristics, can spread farther distance, this feature can help reduce the hop, thus easier to reach the destination node, improve the end-to-end delay. But the delay time as a factor, cognitive network choose good spectrum transmission characteristics. Assume that a simple transmission model, β is the attenuation constant. P_t^{CR} is the maximum send power of the cognitive users, P_r^{CR} is the receive threshold. c as the speed of light, f_k is to select the frequency spectrum, the transmission distance D_k can be expressed as

$$D_k = \left[\left(\frac{c}{4\pi f_k}\right)^2 \cdot \frac{P_t^{CR}}{P_r^{CR}}\right]^{\frac{1}{\beta}} \quad (6)$$

In regard to the protection of primary user receiver, the user decides the available spectrum is mainly to the main users to send end signal perception, it is bound to interference to primary user receiver, in addition, combined with the existence of the error detection probability, so the main user interference at the receiving end will increase, this requires selecting a route to choose less overlapping coverage, cognitive radio users y to nodes x and z forward, the scope of the user x to calculate transmission according to the principle of geometry, the coverage of the area $A_{x,PU}$ can be given

$$A_{x,PU} = D_k^2 \cos^{-1}\left\{\frac{D_{PU,x}^2 + D_k^2 - r_k^{i^2}}{2D_{PU,x}}\right\} + r_k^{i^2} \cos^{-1}\left\{\frac{D_{PU,x}^2 + r_k^{i^2} - D_k^2}{2D_{PU,x}}\right\} \quad (7)$$

Awareness for the users, found in the routing process before starting, the cognitive node can periodically to local state of primary user spectrum estimation, in order to supply some spectrum prediction algorithm data; When, after the establishment cooperative perceive node clusters with routing discovery in the routing node is using the frequency spectrum of the collaborative perception nodes within the cluster member awareness information to estimate the frequency spectrum of the primary user condition. Collaborative perception of many data fusion method, based on the literature [2, 9], the performance good based on Neyman - Pearson theorem of soft decision fusion. Because of this paper is not specific data fusion algorithm is derived, and the two important indicators of performance of spectrum sensing is the detection probability P_d and false alarm probability P_f. Among them, the detection probability P_d is when the primary user

activity and the probability of detection results of H1, and false alarm probability P_f is when the primary user activity but the probability of detection results of H1. When using the energy method, based on the principle of binary hypothesis test, can get and expression is as follows:

$$P_f = Q\left(\left(\frac{\xi}{\sigma_n^2} - 1\right)\sqrt{\tau f_s}\right) \quad (8)$$

$$P_d = Q\left(\left(\frac{\xi}{\sigma_n^2} - \gamma - 1\right)\sqrt{\frac{\tau f_s}{2\gamma + 1}}\right) \quad (9)$$

Routing node periodically broadcast Hello message, in addition to the traditional connection of adjacent nodes confirmed, in this paper, giving it additional maintenance function of collaborative perception nodes of cluster. Because CRN road by the node and the routing node mobility as well as the change of the surrounding environment, to keep jump range of cognitive activity routing node is often choose to update, to work in collaborative perception nodes within the cluster to maintain a certain number of working nodes. Hello message in addition to the traditional content, bring C_local and C_two which by the node. Receive Hello message cognitive nodes need to reply a Hello message response frame, its content includes the cognitive nodes C_one, switch channel when using for routing node. In addition, received the Hello message routing upstream of adjacent nodes need to update the node and the downstream adjacent nodes C_inte communication link. Routing nodes when a channel is not available, need to switch from the channel, channel allocation is completed by a Hello, radio channel will this routing node changes the results of the surrounding adjacent nodes via the Hello message. If a cooperative perceive time node in the cluster nodes, have not received any routing node sends to the center of information, is considered the center routing node has failed, the members of the collaborative perception nodes within the cluster automatically dissolved. At the same time the centre upstream of the routing node routing use this link to verify whether there is activity, to decide whether to try routing local repair. Visible, the spectrum information transfer mainly includes the following stages: first launched by routing request process, perception of spectrum information carried in a RREQ news, in the exchange of information within the entire network spectrum; And then reply the routing phase, spectrum information carried in a RREP messages, in the best form for the center with various routing node along the routing path of collaborative perception node clusters; Finally in the routing maintenance phase, to maintain the cooperative perceive node cluster Hello message.

5. Simulation Results

In order to validate the presented on-demand collaborative perception and the effectiveness of the channel allocation method, using normalized control overhead and cognitive users system throughput as the evaluating performance indicators. Network environment Settings are as follows: a (1 500 m x 1 500 m) in wireless network, cognitive users 50 random distribution in the region, a total of eight non-overlapping main user channel, each channel bandwidth is 1 mbit/s. Set the node transmission distance is 250 m, interference distance is 550 m. Assuming random 2 ~ 10 CBR stream, rate of 256 kbit/s. System false-alarm probability to 0.1, for each frame duration

T = 40 ms, tau = 3 ms spectrum detection time, PU on each channel to a certain probability random, so each node of a certain channel available probability as (40%, 60%, 80%). Suppose every cognitive user receiver of the instantaneous signal to noise ratio are - 10 db. The simulation time of 1000 s, all data from the simulation results of average 10 times. Because of this paper is not in the specific algorithm of data fusion, thus simplifies the complexity of the part of data fusion simulation. Set the channel available probability is 80%, in the simulation time normalized control overhead compared as shown in Figure 4. Traditional AODV and frequency spectrum of the collaborative perception control overhead is below the paper proposed algorithm (SA - AODV) brought about by the control overhead. Spectrum information from multiple distributed spectrum allocation algorithm because of the need to exchange, to achieve the optimal allocation and necessary to introduce a large amount of overhead, here is no comparison, therefore, omit this section. However only AODV and cooperative perceive spectrum curve and already with SA - AODV, such as when the source points for 6, both added 3.4% and + 4.4% = 7.8% have more than 5.4% of SA - AODV.

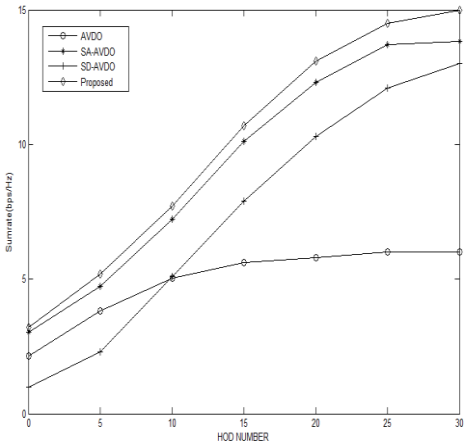

Figure 2. Maxinum Rates Comparison of 4 Schemes

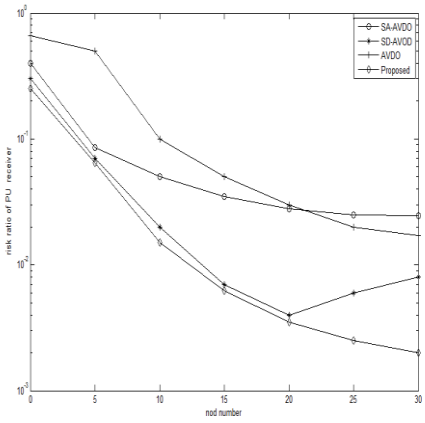

Figure 3. PU Receivers Risk Comparison of 4 Schemes

6. Conclusion

This paper proposes a cognitive multiple hops of routing and spectrum selection optimization scheme, this scheme is not restricted to specific topology structure, namely, strong applicability and give full consideration to the other literature did not consider the protection of the primary user receiver this factor, the simulation results proved that this scheme in the transmission delay and the effectiveness of the interference to primary user receiver.

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