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Data Rate Control and its Effects on Working of Cognitive Radio Adhoc Networks

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Abstract

In cognitive radio adhoc networks the utilization of spectrum without spectrum sensing is a difficult task because of the fluctuations of the availability of spectrum holes. Hence the location awareness is must for concurrent transmission area where both primary users and secondary users can exists. In this paper we examine the data rate control effects on the working of cognitive radio adhoc networks. The planned algorithm sufficiently increases the secondary user data transfer rate as much as possible without restraint the attainable primary data rate. As per result found the data rate control algorithm increases the concurrent transmission area with increasing data rate of secondary user without disturbing the primary user. The result shows that It is possible to increase the data rate and concurrent transmission region of the cognitive radio adhoc networks and hence increase in the spectrum utilization efficiency.

Keywords: Cognitive Radio, Adhoc Networks, Data Rate Control.

INTRODUCTION

Joseph Mitola used the term for the first time in 1999. It is network that senses the parameters and makes some real-time parameter changes to utilize the spectrum efficiently and making it a dependable network. It does not cause interference to other wireless system. CR analyses the spectrum usage along with the radio channel. Then it makes the decision to select the band for transmission. A Cognitive Radio is a perfect example of an intelligent wireless communication system. CR allows us to allocate the available spectrum dynamically to the unlicensed users and the licensed band is used when primary users are not doing any transmission in the frequency band. It allows us to re-adjust various parameters at different layers of protocol stack so that various spectrum access methodologies can be supported, and the quality of service can be maintained for terminals. Cognitive radio intelligently controls the various communication factors like transfer speed, modulation schemes, power, bands etc. by sensing the state of the network and its surrounding users. Cognitive radio technique is going to be newer generation technique that is going to be revolutionary in wireless services. The secondary networks are using cognitive radio technique and adapt to the available spectrum. A cognitive radio ad hoc network (CRAHN) is usually made of two networks in which one is the primary network and the other is the secondary network which is also called CR Network. While in the case of low mobility, CRAHN may be made of CR node and a central access point which can control the functionality of the node. This type of cognitive radio network may be referred as a centralized CRAHN. Cognitive radio ad hoc networks make good employment of cognitive radio, but the complexity become higher in this case. The main issue is how the network adjusts itself when topologies change dynamically, and the change occurs in vacant frequencies. Reinforcement learning is very useful in CRAHN [1][14][15].

LITERATURE SURVEY

To maximize the performance of cognitive radio ad-hoc network by adjusting the secondary user rate without affecting the achievable primary rate so that the primary and secondary user can co-exist [6].

The same channel used by multiple users using dynamic spectrum sharing method and uses it concurrently for maximum spectrum use along with the protection from interference to the primary user [7].

The data rate and efficient control of power of primary network using unidirectional antenna for communication to enhance the data rate and power efficiency of secondary network with unidirectional antenna. These strategies are proposed to increase the spectrum utilization by secondary user without affecting the achievable primary rate. This will increase the probability of concurrent transmission with the lower cost [8].

The concept of efficiently utilization of scarce spectrum by dynamic spectrum access in cognitive radio network. This paper suggested an algorithm for resource distribution for efficient use of resources in dynamic access ad-hoc network. In these networks active cognitive radio network links fulfil their own quality requirements along with no effect on primary user transmission. As cognitive radio (CR) system will operate in heterogeneous network, it requires control of transmission power and data rate for the active cognitive radio. So the algorithm will provide control of transmission power and data rate to maximize the cognitive radio user's link surplus function [9].

A location awareness engine architecture to give actualization to the concept of location awareness in cognitive networks which comprises location estimation, mobility management, security, statistical learning and tracking seamless positioning and location based application. This paper mainly focus on location based application in which location information is used in cognitive radio network by using some applications of location aware network optimization such as network planning, handover etc along with optimization of network performance [10].

A dynamic programming based algorithm which will increase average rate for cognitive radio (CR) link considering total energy budget and cognitive radio(CR)-to-primary radio(PR) disturbance. The suggested algorithm models the primary radio as two-state Markov chain. This model derived the optimal rate and power control scheme for each time slot. Results of the suggested algorithm shows a good performance improvement in average rate along with keeping cognitive receiver to primary receiver disturbance less than a given level [11].

An adaptive transmission technique for cognitive radio scheme which will first find the distance between cognitive radio user and use of the interference temperature information then by using cognitive radio adaptive power control, CR user find maximum transmission power which will not affect the user using interference temperature information. Then by using cognitive radio adaptive coding and modulation, the proposed scheme selects the order of modulation that will maximize throughput to the CR user. Finally using the proposed scheme data can be transmitted without any interference to the user utilizing interference temperature information [12].

The characteristic of cognitive radio ad-hoc networks called routing is discussed. As previous routing protocol presume the imaginary path between the source and the destination but this pre-assumption seems to be wrong sometimes due to the features of cognitive network ad-hoc network. This paper proposed a novel routing algorithm for multi-hop cognitive radio networks. By using this routing algorithm a maximum data rate and minimum delay is provided between the communication of source and destination [13].

An algorithm of power control of the cognitive radio adhoc networks for fixed and mobile stations, achieves quality of communication with maximum throughput of power without causing interference to primary and other secondary users [14].

SYTEM MODELING

Let us assume that stations are so close to believe limited interference during spectrum sharing in which cognitive radio adhoc network works in the primary user signal area. The model having Primary mobile station(PMS) / Primary transmitter(P_{TX}), cognitive radio transmitter(C_{TX}), Base station for primary receiver(PBS). The primary receiver(base station) lies at the origin of coordinates and the locations of mobile stations at their coordinates as (R_i , Φ_i): i=1,2,3,4……. represented primary mobile station. Cognitive radio transmitter and receiver are lies in the coverage area of primary transmitter/Base station.

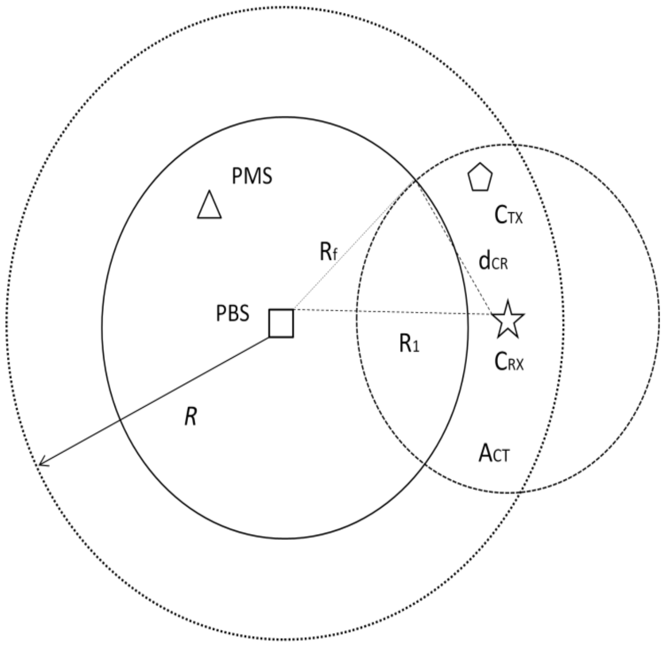

Figure 1: Layout of primary and secondary networks with concurrent transmission region

We must consider the path loss of long distance so the received power is σ_{sec}

$$W_R = \frac{KW_T}{D_{RT}^{\gamma}} \tag{1}$$

Where W_T represents the transmitted power, D_{RT} is the transmitter and receiver distance, and γ is path loss. K is constant and considers other factors like antenna gain and carrier frequency. We consider that both primary and secondary transmitter transmits equal powers. We are using two values of signal to interference ratio for quality of service for primary network capacity.

$$C_{prim} = B\log_2\left(1+SIRP\right) \tag{2}$$

And for secondary network capacity

$$C_{sec} = B\log_2\left(1+SIRS\right) \tag{3}$$

Where B is bandwidth of spectrum. For ideal conditions we consider that bandwidth B=1Hz. However for primary and secondary networks, the minimum capacity requirement is σ_{prim} and σ_{sec}. The area where the both capacity exceed the minimum value is called concurrent transmission area is

$$P_{conrt} = P\left\lfloor\left(C_{prim} > \sigma_{prim}\right)\cap\left(C_{sec} > \sigma_{sec}\right)\right\rfloor \tag{4}$$

A_{CT} is the area of concurrent transmission lies within the base station coverage area between the effective cognitive area and forbidden area. Forbidden area having radius R_f. Cognitive transmission operates outside the forbidden area. Hence the interference with the primary is very low to fulfill the condition

$$C_{prim} > \sigma_{prim}$$

The cognitive area is a circle having radius R_{cog} centered at cognitive radio receiver. If cognitive radio transmitter operates within this circle then

$$C_{sec} > \sigma_{sec}$$

Concurrent transmission probability is

$$P_{conrt} = \frac{A_{ct}}{\pi R^2} \tag{5}$$

Where R is radius of circle. However transmission probability value is very low when both primary and secondary networks are at higher capacity. When we consider the minimum signal to interference ratio for primary link then this technique becomes impractical because that is equivalent to capacity of 1.58 bits per seconds.

DATA RATE CONTROL TECHNIQUE

Now a technique for rate control is proposed for secondary transmission connection. The system already has capacity of dynamic spectrum allocation and re configurability. This method enhances the co-existence probability of secondary and primary networks in concurrent transmission area.

The capacity of secondary channel considers as per the location area of the user and then the data rate fix as much as close to the data rate capacity of channel with maximum possible time. The proposed work having two possibilities [2]:

1. If the capacity of secondary link is larger than minimum capacity (σ_{sec}). Then maximum possibility to achieve larger data rates and reduced time interval to transfer data.
2. If the capacity of secondary link is less than minimum capacity (σ_{sec}). Then data rate can be reduced without wasting time for extra concurrent transmissions.

For better understanding the possibility of data rate control, we examine the effects of minimum data rate capacity (σ_{sec}) for secondary link on cognitive transmission area. Let us consider the long distance path loss model with limited interference.

$$SIRS = \left[\frac{d_{21}}{d_{31}}\right]^{\gamma} \tag{6}$$

Where d_{21} is distance between Primary mobile station and d_{31} is distance between C_{RX} and C_{TX}. The radius of cognitive region is d_{CR} becomes (Maximum allowable d_{31})

$$d_{CR} = \frac{d_{21}}{\left(2^{\sigma_{sec}}-1\right)^{\frac{1}{\gamma}}} \tag{7}$$

d_{CR} increases with the decreasing of (σ_{sec}) secondary data rate capacity this means that all the region of cognitive radio area and hence the concurrent transmission probability is

$$P_{conrt}\left\{\left(C_{prim} > \sigma_{prim}\right)\right\} \tag{8}$$

In this case quality of the signal is not covered for secondary link so it is not useful for real time applications. This is useful for applications where main aim is to establish the connections and no need for a high data rate. Same analysis for primary user is

$$SIRP = \left[\frac{d_{34}}{d_{24}}\right]^{\gamma} \tag{9}$$

Where d_{34} is distance between C_{TX} and PBS, and d_{24} is distance between PMS and PBS. The radius R_f with minimum allowed distance between C_{TX} and PBS is

$$R_f = d_{24}\left(2^{\sigma_{prim}} - 1\right)^{\frac{1}{\gamma}} \quad (10)$$

Now the expended concurrent transmission area (A_{ECT}) can be find out as

$$A_{ECT} = \pi\left(R - R_f^2\right) \quad (11)$$

Where d_{14} is distance between PBS and C_{RX} then P_{Econt} (Expended concurrent transmission probability) is

$$P_{Econt} = 1 - \left(\frac{d_{24}}{R}\right)^2 \sqrt{2^{\sigma_{prim}} - 1} \quad (12)$$

Now when the distance d_{34} (Between PBS and C_{TX}) is greater than R_f then there is maximum probability for coexistence of both primary and secondary networks. At this stage the capacity of secondary network is

$$C_{sec} = \log_2\left\{1 + \left(\frac{d_{21}}{d_{31}}\right)^{\gamma}\right\} \quad (13)$$

Now there is maximum probability for secondary link to choose the data transfer rate close to its capacity (σ_{sec}).

RESULTS AND DISCUSSIONS

Table I: Parameters

Parameter Name	Values
R	102m
Γ	3
Possible locations for C_{TX} is N	10^5 points

Case 1: With limitation on secondary transmission but

σ_{prim} = σ_{sec} =1.58bps

Case 2: Without limitation on secondary transmission but

σ_{prim} = 1.58bps

Case 3: σ_{prim} = 4bps and σ_{sec} =1bps

Case 4: Without limitation on secondary link but σ_{prim} =4bps

Fig 2 shows that how channel data rate effects the concurrent transmission probability when distance between PBS and C_{RX} is 52m. In our proposed model the results found for case 1 and case 3 having minimum data capacity limitation on secondary user network. But for case 2 and case 4 which does not have any minimum data capacity limitation for secondary user. Note that the case 2 and case 4 having higher concurrent transmission probability because they don't have minimum data rate capacity. If we not apply minimum data rate capacity on secondary network the connection established very easily and oftenly. The expended concurrent transmission probability increased when distance between PMS and PBS decreased and concurrent transmission probability and expended concurrent transmission probability both are equal to zero when R_f equal to R, d_{24}=84m and 61m for σ_{prim} = 1.58bps and 4bps.

The next experiment based on case 4 only. Our aim is to find out the maximum data rate that can achieved when there is no condition of minimum capacity of 4bps, we consider four different conditions:

1. $d_{24} = d_{14}$ = 51m
2. d_{24} =51m and d_{14} = 92m
3. d_{24} =11m and d_{14} = 51m
4. d_{24} =11m and d_{14} = 92m

The graph shows that low data rate percentage increases when distance between C_{RX} and PBS (d_{24}) equal to 11m having data rates below 0.3bps because of the interference on secondary link by PMS and when distance between C_{RX} and PBS (d_{14}) equal to 92m we got the high percentage value for more than 5bps data rate.

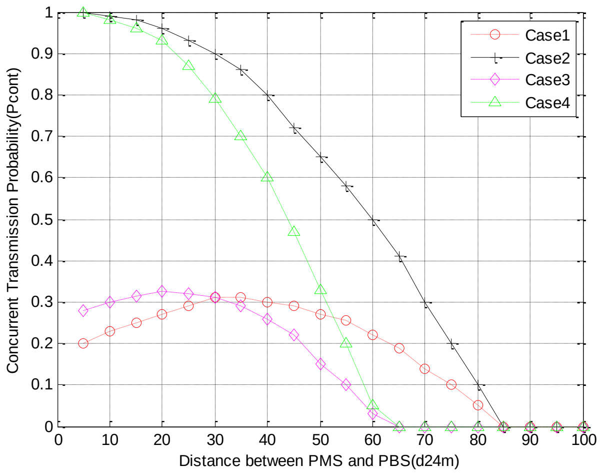

Figure 2: Concurrent transmission probability (P_{cont}) changing with change in distance primary mobile station primary base station.(By assuming d_{14} = 52m).

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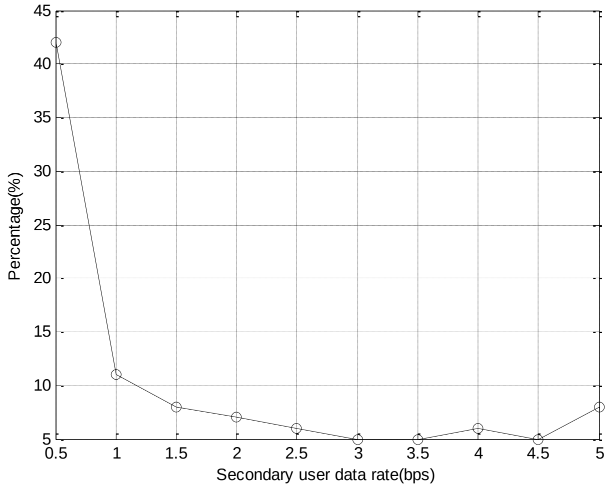

Figure 3: Percentage change of data rate for secondary user when $d_{24} = d_{14} = 52$m. $\sigma_{prim} = 4$bps

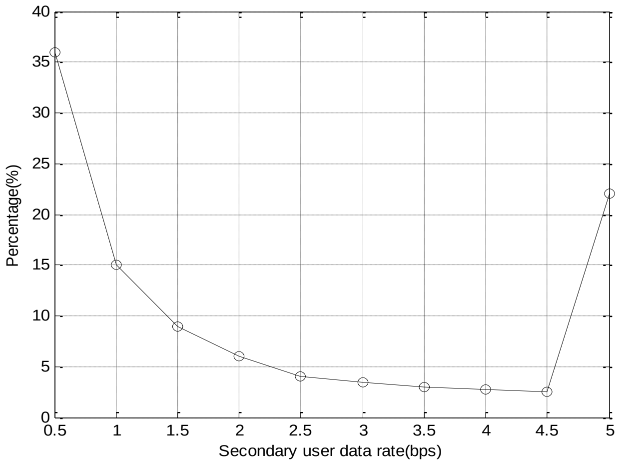

Figure 4: Percentage change of data rate for secondary user when $d_{24} = 52$m and $d_{14} = 92$m. $\sigma_{prim} = 4$bps.

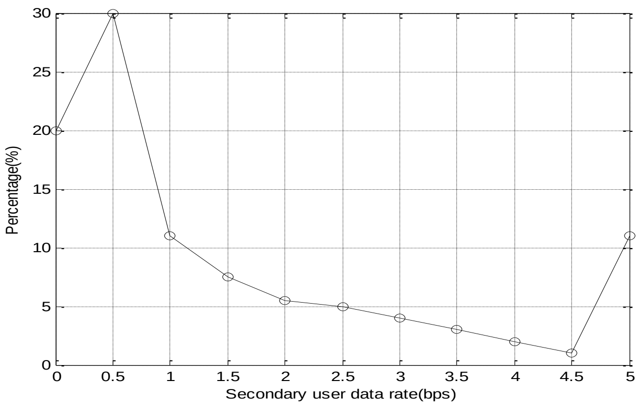

Figure 5: Percentage change of data rate for secondary user when $d_{24} = 11$m and $d_{14} = 52$m. $\sigma_{prim} = 4$bps.

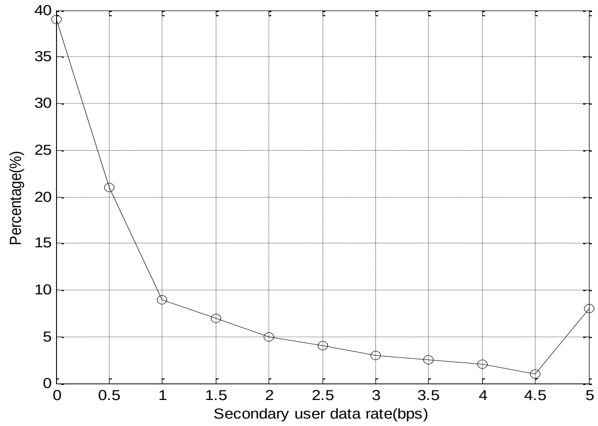

Figure 6: Percentage change of data rate for secondary user when $d_{24} = 11$m and $d_{14} = 92$m. $\sigma_{prim} = 4$bps.

Table II: Average minimum data rate capacity for secondary.

Condition	$C_{sec} < 1$	$1 \leq C_{sec} \leq 4$	$C_{sec} > 4$	Average C_{sec}
1	51.52%	25.21%	22.12%	1.7 bps
2	44.10%	24.11%	30.90%	3.4 bps
3	66.91%	19.10%	14.05%	1.4 bps
4	56.2%	23.00%	20.50%	2.0 bps

The table II as per results given by fig 3,4,5 and 6. The data shows in this table are conformed with previous papers. It is found that when we use data rate less than 1bps is more focused when d_{24} =11m (condition 3 and 4) than d_{24} =51m (condition 1 and 2) and when d_{24} =92m (condition 2 and 4) then mean data transfer capacity increases than d_{14} = 51m (condition 1 and 3).

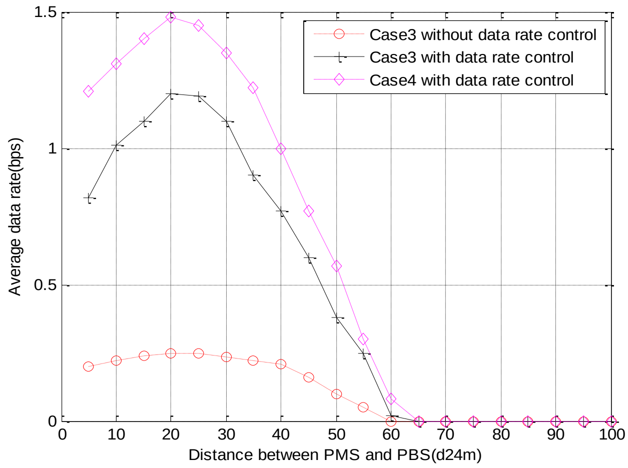

Figure 7: Average data rate for cognitive radio network with variation of distance between PMS and PBS.

As per previous results [2] our proposed data rate control scheme can consider that it will increase the concurrent transmission probability with acceptable data rates when minimum data rate capacity is not applied on secondary network. Now the compression of data rates attain by secondary network with different conditions. **i)** As per case 3 when σ_{prim} = 4bps and σ_{sec} =1bps. **ii)** As per case 3 if the channel situation allows then the secondary user for limited period of time communicate with higher data rate than σ_{sec} . But It will never communicate less than minimum capacity. **iii)** As per case 4 Data rate control applied with a condition that minimum capacity of primary network σ_{prim} = 4bps, and the secondary network can communicate with any achievable data rate.

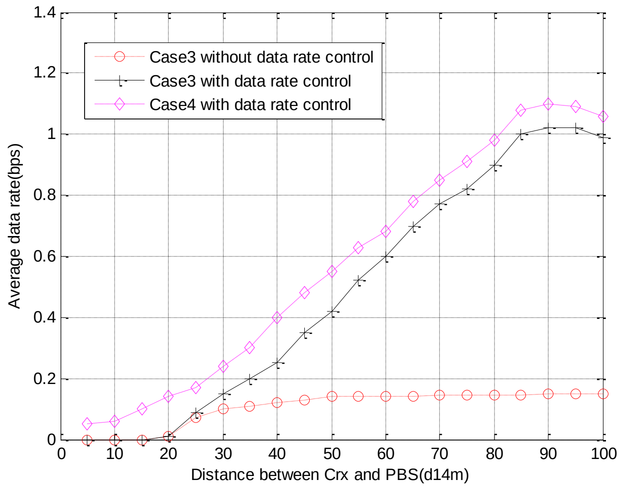

Figure 8: Average data rate for cognitive radio network with variation of distance between C_{TX} and PBS.

Fig 7 and 8 shows that the mean data rate of secondary user on variation of the distance between PBS and PMS (d_{24}) and PBS and C_{RX} (cognitive radio receiver) (d_{14}). The graph shows that the proposed scheme of rate control has much advantage over without rate control.

CONCLUSION

This paper propose the secondary user's data rate control and enhances concurrent transmission area in the presence of primary and secondary user with location awareness of cognitive radio adhoc network. As per results we found that the efficiency of secondary user increased without interfering the primary network and the performance of secondary user also increased. We have considered both cases in which minimum data rate capacity is applied or not. The performance of secondary is achieved at its maximum level when there is no limitation of minimum data rate applied to it. So the concurrent transmission area increased. For the future work we can consider the shadowing effects also for making results suitable for practical applications.

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