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Notification Algorithm for TV White Space based Cognitive RadioNetwork

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Abstract

Cognitive Radio (CR) devices are using polling (request and response) based method to get listof unused channels in both VHF and UHF frequencies from TV White Space Database (WSDB).Traffic of the Cognitive Radio network increased due to the request and response method, we proposed a new Notification Algorithm to reduce the load on TV WSDB. We analysed the Total Network Traffic and Sensing Cost of existing polling model and proposed Notification Algorithm, compared theresults.Notification Algorithm sends the list of available channels to the both fixed and portable CR devices at real timedecreases the latency and increases the Quality of Service (QOS) of Cognitive Radio.

Keywords: Cognitive radio, TV white space database, ultra high frequency, very high frequency, sensing cost and total network traffic.

1. Introduction

Standard IEEE 802.22 allows the use of T.V White Spaces in both Very High Frequency (VHF) and Ultra High Frequency (UHF) bands by Cognitive Radio (CR) users in ruralareas [1].The unused TV channels in VHF and UHF bands are referred toas TV White Space(TVWS) and they have been allocated for TV but not using in particular areas as shown in below Fig.1,The availability of TVWS varies based on the area and on time.

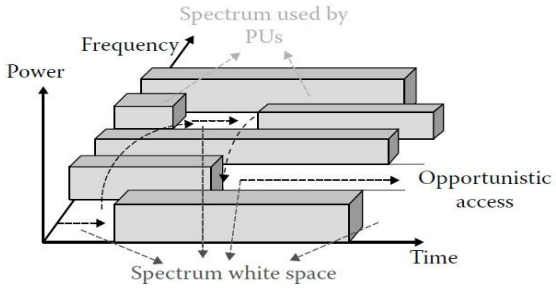

Figure 1: White SPACES in TV Bands

The advantages of using TV White Spaces for Cognitive Radio are:

- A large portion of VHF and UHF TV bands are available between 50MHZ and 700MHz after the switch over from analog to digital.
- Both VHF and UHF bands operate below 1GHz frequency hence they are more reliable than Scientific and Medical (ISM) bands.
- Minimal interference from other users that are operating on TV white spaces.

There are two types of users in Cognitive Radio Network,Primary Users (PU) and Secondary Users (SU). Primary Users havethe license to use the spectrum and Secondary Users use the spectrum opportunistically when Primary Users are not using. Secondary Users are referred to as Cognitive Radio (CR) users and they are able to access both licensed and unlicensed TV White Spaces in VHF and UHF bands.

2. Review of Literature

The Federal Communications Commission (FCC) allowed the TV WSDBaccess to CRusers (devices) to know the unused channels information on VHF and UHF bands [2,3-7]. CR devices have to register their Geo location information in the TV WSDBto get access to PU information.TV WSDBcontains the frequency of the channels, transmission signal power and location of all the Primary Users.Based on the release notes by The Federal Communications Commission (FCC) inNovember 2008,Cognitive Radio (CR) devices can be classified into the fixed CR device and portable CR device [8].Portable CR

devices further classified into two types Mode I and Mode II. Both fixed CR device and portable CR Mode II have the ability to access the TV WSDB directly, as they don't have Geo-location sensing capability Portable CR Mode I device cannot access WSDB and work under the control of either Portable CR Mode I device or fixed CR device as shown below *Fig.*2

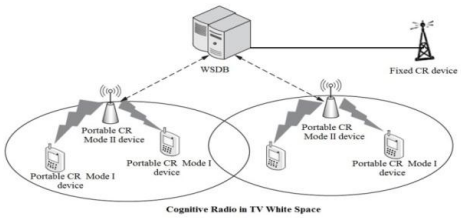

Figure 2: Cognitive Radio Network and TV WSDB

As shown in above figure, CR fixed and CR portable devices will query the WSDB for available channels in a location. The WSDB returns the list of available channels for a given location id.Industry Canada published specifications and technical rules for TV WSDB in 2015[9-10].They are summarized in below Table. 1

Table 1: Specification for CR devices

	Fixed CR devices	*Portable CR Mode-I device*	*Portable CR Mode-II device*
Allowed TV Channels	2, 5–36, 38–51	21–36, 38–51	21–36, 38–51
Geo-location accuracy of CR device	± 50 m	Not applicable	± 50 m
Available free channels information	Through TV WSDB access	From Fixed CR device/ Portable CRModeI device	Through TV WSDB access
WSDB access duration	At least once a day	Not applicable	When it is power on/changes location more than 100m / at least once a day

The main limitation in existing model is CR devices(Fixed CR device and Portable CR Mode II)query the TV WSDBand get the response with available channels information periodically or when changes the location or powered on as shown in Fig.3,it causes the load on WSDB and increases the network traffic due to database request and response.

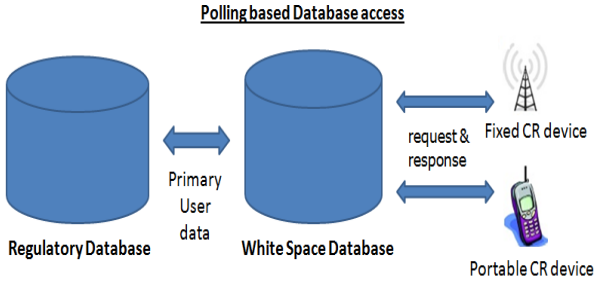

Figure 3: Existing Polling (request and response) Method

3. Proposed Notification Algorithm

Instead of relying on polling based method, sending requests to TV WSDB and waiting for the response to discover the available free channels in TV WSDB.In this paper, we propose a new*Notification Algorithm* for Cognitive Radio Network operating on TV White Spaces (TVWS) with main objective to reduce the load on TV WSDB and reduce network traffic in CR Network.The *Notification Algorithm*is based on the notification service of the TV WSDB. It sends the notifications automaticallywhen free channels available or periodically after specified time to the registered CR devices.*NotificationAlgorithm* is implemented in the TV White Space Database as shownin below *Fig.4*

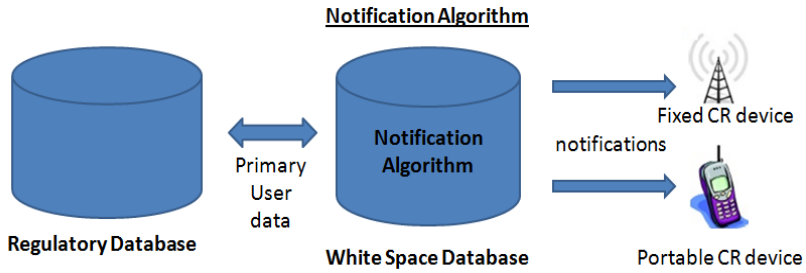

Figure 4: Notification Algorithm for TV WS based CR Networks

As shown in above Fig.4, *NotificationAlgorithm*gets the Primary Users data from Regulatory Database and pushesthe available channel information to both Fixed CR devices and portable CR devicesperiodically without affecting the primary licensed users. The main functions of *NotificationAlgorithm* are

1. It gets the last accessed DateTimeof Regulatory database from TV WSDB.
2. Based on the last accessed DateTime, it query the Regulatory database if datetime is greater than 24 hrs else it searches the available free channels in WSDB only.
3. It collects up to date information such as frequency of the channels, transmitted signal power and geo location of all Primary Users from Regulatory Database at least once a day.
4. Calculate the Tmax value of all channels once the received data is updated on WSDB. Where Tmax is the maximum available time of each channel for CR users and this value is more of the channels which are reserved for new TV channels or currently not used.
5. It searches for the free channels and arranges them on descending order based on Tmax value.
6. If number of channels available greater thanzero, then notification service of WSDB triggers the notification to send the list of available

channels to registered fixed and portable CR devices based on their Geo-location.

7. CR devices (Fixed and Mode II)receives the available channels list based on their Geo-location, They select the first channel in the list as the operating channel and next two channels in the list as backup channels to reduce the sensing activity. The flow char of the Notification Algorithm is shown in Fig.5.

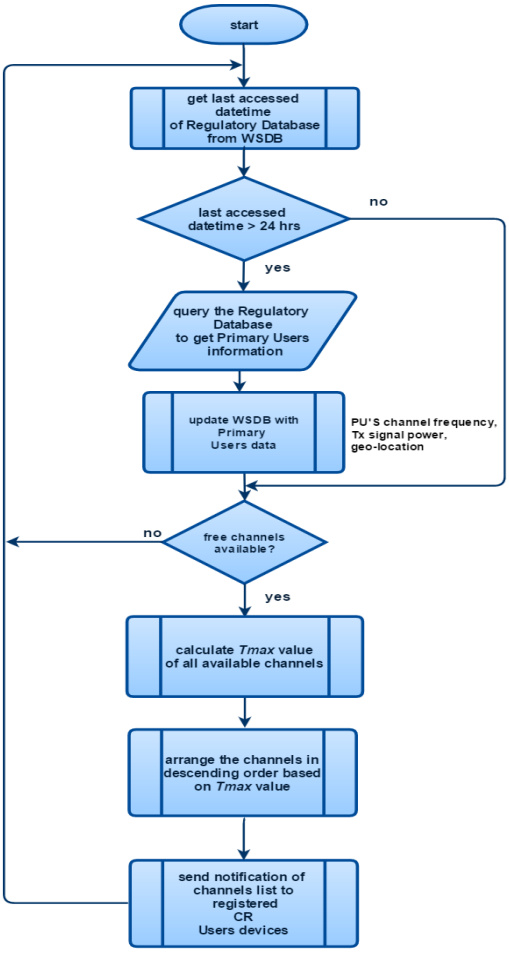

Figure 5:Shows Flow Chat of NotificationAlgorithm

4.Analysis and Simulation

In this paper, we analysed two parameters Total Network Traffic and Sensing Cost (Number of Sensing Activities) ofa Cognitive Radio Network operating on TV white Space Database byproposed Notification Algorithm.

Total Network Traffic of Cognitive Radio: In the polling based method, both fixed CR devices and portable CR mode II devices must query the TV WSDB and get the list of available channels as a response from TV WSDB. Assume that amount of traffic to or from TV WSDB for each request and response is G, N_{fix}, N_{mob} are the number of fixed CR devices and portable CR devices respectively in the simulation model. The fixed CR and portable CR devices access the TV White Space Database (WSDB) once per T_{fix} duration and C_i is the number of times that portable CR device i changed its Geo-location more than 100m during T_{mob}.The total traffic due to request and response between CR devices and TV WSDB over a unit of time given by below equation [11].

$$F= G\left(\frac{\text{Nfix}}{Tfix} + \frac{Nmob}{Tmob}\sum_{i=1}^{Nmob} Ci\right) \quad (1)$$

Based on the *NotificationAlgorithm*, both fixed CR devices and portable CR devices no need to access the TV WSDB for the list of available channels because the TV WSDB automatically send the list of available free channels information to fixed CR devices at once per T_{fix} duration and portable CR devices every T_{mob} duration. As per proposed*NotificationAlgorithm,*TV WSDB directly sending notification of free channels information instead of round trip (request and response)hence it reduces the amount of traffic and also the traffic of the mobile(portable)CR devices are very high when compared to fixed CR devices so the equation (1) can be written as equation (2)

$$F=\frac{G}{2}\left(\frac{\text{Nmob}}{Tmob}\sum_{i=1}^{Nmob} Ci\right) \quad (2)$$

G/2 for direct notification and the total traffic (F) is inversely proportional toT_{mob}anddirectly proportional to$N_{mob,}C_i$wherethe value of C_i is depends on the speed of the CR portable devices. We assume that all the portable CR devices move randomly over some area, stay in one geo-location for some time and then move to new location randomly at the selected speed. To simulate this scenario we consider Random Way Point Mobility Model proposed by Johnson and Maltz [12].Parameters in *Table 2* are used in the simulation of Random Waypoint mobility model for total Network Traffic calculation.

Table 2: Parameter Values used in Network Traffic Simulation

Parameter	*Value*
CR Fixed users	10
Portable CR devices	10-200
Speed of CR device II	1-2 m/s
Simulation time	1800 s
Available channels for CR users	10
Operating channels	1
Back up channels	4
Operating channel sensing duration	2 s
Backup channel sensing duration	6 s

Sensing Cost (Number of Sensing Activities): In order to reduce the interruption to the primary users, CR devices have to sense both operating

channel and the backup channels regularly. Assume that CR network consists of *N*number of cognitive devices ,*B* as the number of backup channels, operating channel and backup channels are sensing at T_{op}andT_{bk}seconds respectively. The sensing cost (number of sensing activities per unit time) is denoted by below equation (3)[13].

$$Sensing\ Cost = N\left(\frac{1}{Top} + \frac{B}{Tbk}\right) (3)$$

As per the proposed *Notification*algorithm,all free channels are arranged in the descending order based on theirT_{max}value in TV WSDB before sending the notification to CR devices and CR devices must select the first channel as operating channel and next channels in the list as backup channels based on their location id. The operating channel and backup channels are selected based on the higher value of T_{max}, increases the channel probability of available time for CR devices hence it reduces the need for number of backup channels. We assume that one operating channel and minimum two backup channels are enough for *NotificationAlgorithm*where as polling based method require one operating channel and four backup channels. The values of equation (1) and equation (2) are tabulated based on number of backup channels in below table 3.

Table 3: Values Used in Sensing Cost Simulation

No. of CR devices	*Polling Method (No. back up channels =4)*	*Notification Algorithm (No. Of back up channels =2)*
1	1.16	0.83
2	2.32	1.66
3	3.48	2.49
4	4.64	3.32
5	5.8	4.15
6	6.96	4.98
7	8.12	5.81
8	9.28	6.64
9	10.44	7.47
10	11.6	8.3
11	12.76	9.13
12	13.92	9.96
13	15.08	10.79
14	16.24	11.62
15	17.4	12.45
16	18.56	13.28
17	19.72	14.11
18	20.88	14.94
19	22.04	15.77
20	23.2	16.6

5. Result

Total Network Traffic of Cognitive Radio: Total Network Traffic of PortableCognitive radio network is simulated in MATLAB with the help of

*Random Way Point Mobility Model*and used parameters are described in Table 2,Fig .6 and Fig. 7 illustrates the total traffic rate of polling method and proposed *Notificationalgorithm*. It clearly shows that 50% of Total Network Traffic rate is reduced by *NotificationAlgorithm*compared to Polling based method at number of CR devices N_{mob} =10 and N_{mob}=200 and as shown in Fig .6 and Fig.7 the Total Network Traffic rate of polling based method is 0.95 at N_{mob}=10 and 1.0 at N_{mob}=200 but the Total Network Traffic rate of *Notificationalgorithm*is same i.e. 0.45 for N_{mob}=10 and 1.0 at N_{mob}=200.

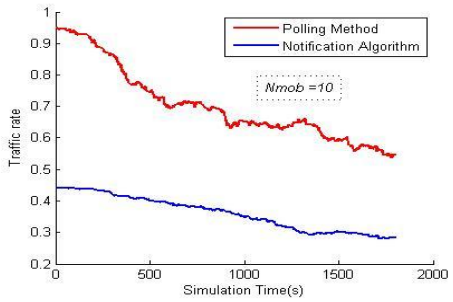

Figure 6: Traffic Rate of Polling Vs Notification Algorithm at Nmob =10

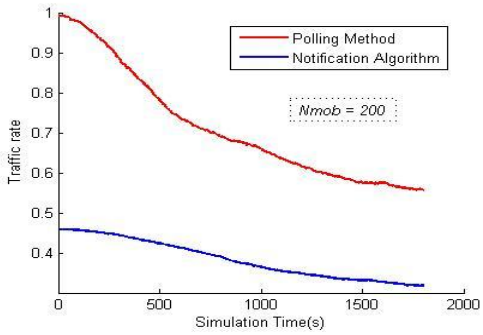

Figure 7: Traffic Rate of Polling Vs Notification Algorithm at Nmob =200

SensingCost (Number of Sensing Activities): SensingCost (number of Sensing activates) depends on the number of channels required to be sensed before an unoccupied one is found. Portable CR devices Sensing Cost results are simulated in MATLAB by using equation (3) and the values in Table.2 and Table.3,Fig. 8 illustrates the Sensing Cost of polling method and *NotificationAlgorithm*. We considered 20 Cognitive Radio devices in simulation, Sensing Cost increased linearly with number of Cognitive Radio devices for both the methods.As seen from the Fig. 8,*NotificationAlgorithm* gives better performance than polling based method from Sensing Cost prospective. The *NotificationAlgorithm* can reduce the number of sensing activities for both operating channel and backup channels per unit time.

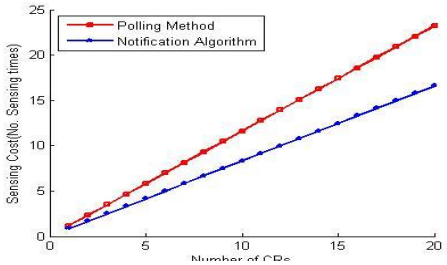

Figure 8: Sensing Cost Vs Number of CRs

6. Conclusion

Standard IEEE 802.22 allows the use of T.V White Spaces in VHF and UHF bands by Cognitive Radio (CR) users in rural areas. Cognitive Radio users access the TV White Space Database to get up to date information of Primary Users (PU).In this paper, we proposed *NotificationAlgorithm* to send notification of available channels directly to CR devices instead of polling method. We considered two parameters*Total Network Traffic* and *Sensing Cost*to compare the performance of polling method and proposed *NotificationAlgorithm*. MATLAB software is used for simulation of Total Network Traffic and Sensing cost by increasing number of CR devices. From the observation of results, it is found that the proposed *NotificationAlgorithm* increased the performance of Cognitive Radio Network by reducing both the Total Network Traffic and Sensing Cost.

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