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SURVEY ARTICLE

Effective Deployment of TV White Space for Enhancing Rural Broadband in India

Jai Sachith Paul[1], Akhil P Sivan[2], Kumar Raushan Ratnesh[3], Sreekala K[4]

Christ University Faculty of Engineering, Bangalore, Karnataka

[1] jai.paul@cse.christuniversity.in, [2] akhil.sivan@cse.christuniversity.in,

[3] kumar.ratnesh@cse.christuniversity.in, [4] sreekala.k@christuniversity.in

***Abstract*—The Radio spectrum has always been a scarce resource right from its initial deployment in 1920s. The television spectrum band is poorly utilized in Indian scenario. Also more efficient spectrum usage is possible with the migration from analogue to digital broadcasting. The use of Cognitive Radios allows an efficient use of the available resources so as to solve the problem of spectrum scarcity. An overview of the current T.V spectrum allocation in India along with the challenges and opportunities in the deployment of White Space using Cognitive Radio technology to enhance rural broadband is discussed in this paper.**

***Index Terms*—White Space Devices; digital dividend; spectrum sensing; RF propagation models; cognitive radio; SDR; opportunistic spectrum access; bootstrap; DSO**

I. INTRODUCTION

The rapid growth of wireless communication is directly linked with desire of fast data rate and reliable connectivity. Radio frequency spectrum is being utilized by mobile phones, government, security agencies and many other private organizations. This extensive use has brought a sort of drought in the field of band spectrum since use of all radio frequency device needs an authenticated license.

This demand has initiated many research programs to improvise on the spectrum sharing and allocation techniques. In practical scenario the radio waves are the actual medium and are not limited by any sort of spectrum[15]. It's just the efficient use of spectrum that can help with the minimum interference. The spectrum scarcity is basically the result of inadequate advanced radio technologies and the government policies. The technologies have been far improved and the government policies have been much more relaxed regarding the spectrum usage. A new standard has been brought to allow the usage of spectrum by the secondary users if it causes minimum interference to the primary user.

Beyond that there is a large amount of spectrum that is being made available with the migration from the analogue to digital transmission throughout the country through effective planning. Digital Dividend refers to the 'leftover frequencies' that results from the change of broadcasting from analogue to digital domain. The TV white space considers the white space as a part of the

spectrum that is available for the radio transmission at a given time in a particular geographical area with minimum interference to the primary user. Cognitive Radios make use of the spectrum sensing techniques and the radio propagation models for exploring the available spectrum in a given area. In India a lot of researches are being carried out to find out the effective way of exploiting the white spaces.

There is a rapid uncompensated need for wireless broadband services exist in the country. Between 2008 and 2010 the data traffic grew by 280%.With the emergent technologies like Wi-Fi, Wi-Fi enabled smart phones and man to machine interface, this rate is again going to increase. The unique solution for meeting such a huge requirement in the data traffic is to use the cognitive radios in the TV White spaces to explore the unused or underutilized spectrum.

II. Current Spectrum Usage In India

The television spectrum of the country is largely unutilized. Over 90% of the sub-gigahertz spectrum is under utilized in India. As per the Microsoft Research, India uses only 16MHz out 566 MHz of the spectrum [14].

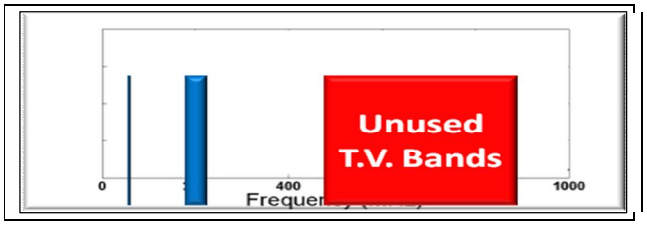

Fig 1: Spectrum usage in India

'Doordarshan' is the only national carrier for the television broadcasting in India. Though Satellite channels are also being watched through DTH and cable television Doordarshan is the only broadcast channel that is watched widely. The T.V spectrum from 470 to 806 MHz is distributed on a primary basis to fixed, mobile and the broadcasting services.

Frequency bands for TV broadcasting

INDIA	REMARKS
47-68 MHz (Fixed mobile broadcasting)	
87-100 MHz (Fixed mobile broadcasting)	IND-13, IND-14, IND-17
87-100 MHz (Broadcasting)	IND-15
174-223 MHz (Fixed mobile broadcasting)	IND-23
223-230 MHz (Fixed mobile broadcasting, Aeronautical radio navigation)	IND-23
470-585 MHz (Fixed mobile broadcasting)	IND-37
585-610 MHz (Fixed mobile broadcasting)	IND-38
610-890 MHz (Fixed mobile broadcasting, Radio astronomy)	IND-37

For terrestrial broadcasting services, the spectrum allocation is as follows [2]:

*UHF Band IV(470-582 MHz):*In this band we can accommodate 14 T.V channels with a bandwidth of 8 MHz each. About 330 transmitters of Doordarshan is operational in this band. On experimental basis, 3 digital transmitters of Doordarshan is also operating in this band.

UHF Band V(582-806 MHz): In this band we can accommodate 28 T.V channels with a bandwidth of 8 MHz each. This band is not primarily allocated for Doordarshan for analogue transmission. But, Doordarshan shares this band with fixed and mobile services for digital transmission of data, voice and video. A fast migration from analogue to digital transmission is not practical in Indian Scenario. Still there are a lot of rural population who depend only on the analogue broadcasting. Hopefully by 2020, India would be able to consolidate the available digital dividend.

India, being a country with more than 1.2 billion people and more than 500 million people with cell phones, has only a nominal 0.75% users having high speed internet access.

III. RECLAIMING THE UNUSED TV SPECTRUM

The TV white space is occasionally referred to as "Swiss cheese spectrum" because a channel that might be vacant locally need not be so regionally or nationally. Also, to avoid both co-channel and adjacent-channel interference with local TV stations, white space devices should operate at very low power.

If a white space device operates at frequency adjacent to the TV transmitters' operating frequency, they are in principle allowed to transmit within the coverage area. But they have to adjust the transmitter power so that the interference they generate should stay below the limit television receivers can tolerate. Therefore the white space devices at the edge of the nearby channel television transmitter's coverage area should have a much lower transmit power limit than the ones' located at the centre of television transmitters' coverage area.

Not only that, TV white space would meet the needs of broadband providers and the consumers who currently rely on unlicensed spectrum. Today, only a small portion of spectrum
is accessible on unlicensed basis in the "prime" frequencies below 1 GHz. Allocating a portion of the TV band for the unlicensed use would make more prime spectrum freely accessible , triggering the ability of both wireless ISPs and device makers to deploy much more cost-effective broadband solutions, particularly in rural areas where wired connections are unavailable or unaffordable.

There are mainly three options available for reclaiming the unused spectrum. First option is to auction away the unutilized or the underutilized television bands to commercial providers. The inherent disadvantage which we experience from the recent spectrum auctions is that these bands available in the rural areas are of not much interest for the commercial providers. Second option that we have in our hand is to utilize this band as a free band like the ISM band. Indeed this is a good option for the government to ponder over. Availing of a large band as free band for the user can actually spur tremendous growth in communication. The government might not be so interested in this option as they might lose the opportunity to monopolize the band and there will be significant reduction in their revenue.

Third and the most preferable option for utilizing the television spectrum is to have Opportunistic Spectrum Access (OSA) schemes by using Cognitive Radio

IV. OPPORTUNISTIC SPECTRUM ACCESS SCHEMES

The ultimate aim of any opportunistic spectrum access schemes is to utilize the white space without causing any interference to the primary user. Successful operation of cognitive radios depends on two parameters[3]:

(i) *Safety*: ensuring that the secondary users do not interfere with the primary users.

(ii) *Efficiency:* optimum utilization of available white spaces.

This opportunistic usage an be implemented in two ways. Either to keep the unused spectrum as a license exempt one like in U.S.A or as a lightly licensed one as in the case of Canada. In the first case, the low start up cost results in the rapid deployment without technology bias whereas the latter results in the rapid market deployment only if appropriate technology is developed. Unlike the lightly licensed approach, service and spectrum is not guaranteed in the license exempt approach even though innovative approaches can fuel the research and development and can eventually fill this gap.

Mainly three methods are proposed by FCC for optimum opportunistic usage: The use of spectrum sensing techniques, geolocation databases and beacons

A. SPECTRUM SENSING TECHNIQUES:

The spectrum sensing techniques[4]will have constant monitoring of the channel so as to detect the presence of the primary users and white spaces. Primary user detection can be done by techniques such as matched filters, energy detectors or feature detectors.

The main advantage of using the energy detection schemes is that there is no need of much information about the primary user. The feature extraction technique utilizes a priori probabilities which increases the performances at low Signal to Noise Ratio(SNR). Matched filter approach has got a filter bank in which if the signal frequency matches with any of the filters, the presence of primary user is being recorded.

B. USE OF GEOLOCATION DATABASES

In the geo-location database scheme the primary user will register to a valid database. The secondary user will notify its determined position at first and then inquire the base station in that particular area to know about the free space channel availability in the particular area[3]. In this approach the position and the location of the CR device should be known within a given threshold level of accuracy. This accuracy is fixed by the regulator. The data which is to be send from a CR device to the base station includes the type of the device, its model number and the expected area of operation. The data base will in return send the available set of frequencies, the maximum power of signal with which it is transmitted and whether the CR device can use the available spectrum or not.

This device works upon the data available from the database created by the regulators or operators. When a new CR device arrives, it cannot start packet transmission as it does not know the availability of white spaces in the location. This bootstrapping problem can be eliminated if the BS always transmits the white space availability. Here the client just has to find out the base station corresponding to the associate with it.

C. BEACON TECHNIQUE

Beacons are the indicative signals which informs about a particular channel's availability. A beacon signal is being broadcasted by every base station on a periodic basis, which consists of the information about the availability of channel in all regions of its coverage area[5].In reply for the beacon from the base station the client broadcasts its home location to this channel. So for the client, the beacon is considered as a look up table at the time of bootstrapping. Here the secondary user is permitted to transmit only if a beacon signal is received from a base station.

By the method of increased likelihood of detection at higher threshold values, the efficiency of spectrum sensing devices can be raised by a significant amount.

The various beacon setups which can be incorporated are:

-Enable beacon: The considered channel is ready for use if the beacon is detected along. With enabled beacons, a network of beacon transmitters ranging an entire region in which white space devices are permitted to operate would be required. The white space devices would only operate on the authorization from any one of these beacons. Each device would be incorporated with a beacon receiver.

-Disable beacon: If the beacon is detected for a particular channel, the considered channel cannot be used by the white space devices.

-Beacon as pilot channel: it identifies the local used TV broadcasting channels.

All the above three techniques have their own advantages and disadvantages. The current trend is to have both the geo-location data base approach and spectrum sensing approach to be clubbed together.

V. STANDARDIZATION EFFORTS IN A GLOBAL LEVEL

The research and development works for the effective spectrum utilization were initially concentrated in US. The main motive behind this is the intention of giant players like Microsoft and Google to get access to the TVWS[6]. The formulation of the IEEE 802.22 Working Group (W.G) is the first advanced wireless air interface standard. The IEEE 802.22 W.G is responsible for the development of cognitive radio based wireless regional area network operating on the physical and Medium Access Control (MAC) layers. This WG is basically intended for the rural areas where favourable propagation characteristics are extended by the television frequencies. The CR standardization effort includes IEEE 802.19 [7], IEEE 802.11af and the Cognitive Networking Alliance (CogNea) [8]. The IEEE 802.19 standard aims at enabling effective use of TVWS with the IEEE 802 wireless standards. IEEE 802.11af working group is set up to define a standard for implementing Wi-Fi technology within the TVWS.

VI. THE DEPLOYMENT OF WHITE SPACE DEVICES IN INDIAN SCENARIO

There are many debates are being carried out , there are on major legislations made in India for effective utilization of T.V white spaces .

Some of the initiatives that has been taken are as follows[4]:

a) To identify additional frequency bands periodically for exempting them from licensing requirement for the usage of low power devices

b)To promote the use of white space with low power devices without causing harmful interference to the licensed applications in the specified frequency bands by deploying SDR, Cognitive radio etc.

c) To promote the use of In Building Solutions[IBS] and Distributed Antenna systems[DAS]

d) To promote the use of energy efficient equipments including the low power wireless devices in telecommunication networks and adopt measures for the reduction of the coverage footprint in the telecom sector.

An Indian Joint Task Group (JTG – India) has been set up for studying the compatibility between services and applications in 700 MHz band. NFAP includes aspects related to the utilization of digital dividend. There had been several proposals in this aspect. The cellular operators and TV broadcasters recommend the sticking on to WRC-07 guidelines for using this spectrum for mobile applications

VII. CHALLENGES IN THE DEPLOYMENT OF WHITE SPACE DEVICES IN INDIA

The major technical challenges involved in the deployment of TVWS devices in the country are as follows

(a)The major concern of using cognitive devices for the deployment of white space devices in the country is obviously the spectrum sensing. The Cognitive Radios should be able to sense the signal having power which is as low as the noise power. Embedding such a component in the modern portable devices operating in RF frequencies needs complex algorithm. The power requirement for running such an algorithm is high. The modern technology is insufficient to handle this much power requirement.

(b)As far as India is concerned, the country does not have a proper geolocation database. Even the data provided by the country regarding the frequency allocation through RTI is significantly different from the actually measured values.

(c)Cochannel and adjacent channel interference poses an important constraint for the primary and secondary users.

(d) Reconfigurable TV white space transceivers should be developed.

(e) The Quality of Service (QoS) is another major concern. The government should be able to guarantee required quality of service for the primary and secondary users.

(f)Challenges involved in developing cost effective equipment in order to meet strict regulatory specifications

(g)Security is the major concern of the primary and secondary users while providing cognitive access to the white space network. Measure should be made to address the concern of those who invest in the white space network.

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VIII. RECOMMENDATIONS FOR INDIA

The frequency 470 – 685 MHz should be considered for lightly licensed operations as per the proposal outlined in the following section. In our view, such a move will create an environment of the efficient use of TV white Space spectrum in India. In addition it offers tremendous benefits to the Indian industry and end users in the same manner. More specifically it will provide ample opportunity to Indian academia field. It will be home grown technical innovations and will be India's own intellectual property for TV White Space spectrum access and usage. It will provide Telecom Indian Standard Organization to develop its own platform specific industry. It will be a start of new era of Indian wireless technology similar to the standards of US , European.[13] We can also deploy the secondary users in the areas where the spectral activity is low, the location of the base stations are known and the receivers are interference tolerant. Even though the satellite bands and the high activity bands might not be available for the white space devices, the low frequency bands amateur radios and RADARs could be good candidates for Cognitive radios.

The free IMT band can also be used as white spaces (698-806 MHz). A part of this band is allocated long back. There are practical difficulties in shifting the services from these bands. But, we can actually improve the overall spectrum efficiency and increase the flexibility by using the IMT band.

It will an opportunity for new rural and urban entrepreneurs in investing in wireless industry to provide low cost services and devices to comply with the unique scenario of India where the per capita income of major Indians are very low. It will facilitate research and development in field of wireless industry in India. So it ensures to provide every citizen of India a bunch of unique benefits, it should be lightly licensed

IX. PROPOSALS FOR THE EFFECTIVE UTILIZATION OF WHITE SPACES

As per the discussions above we would like to propose to start with a phased approach in introducing new technologies in TV white space band. We should consider a geo-location based database approach in the short term. However the sensing and beacon propagation techniques have the potential to significantly improve spatial reuse of frequencies and bandwidth, we propose to follow international developments relevant to these techniques and develop homemade technology and specifications. Also we should precisely adopt advanced techniques developed by other SDOs whenever it is available. We are expecting white space devices to be operating under the variant of OFDM technology, the proposed power limits should be similar to authorized 2.4 - 2.4835 GHz. To ensure the interference protected service white space devices should implement features such as adaptive power control which will minimize the possibility of out-of-band and in-band leakage to primary users. Limits should be fixed in terms of power spectral density to avoid the possibility of multiple WSD to share a common TV channel. The technique involved is using narrow band operation when operated at higher power levels.

X. OPPORTUNITIES AND CHALLENGES IN WHITE SPACES FOR RURAL BROADBAND

There is a major shift in intended applications from "peer to peer" to "network based" with the devices under control of the base station that then provides the connection back to the database. This might be broadband especially for the rural areas or the machine to machine interface. The reason for change in the potential application is because of the shift from the sensing approach to the database based approach.

The scope and feasibility of circular cell concept for enhancing rural broadband is very limited.[12] It is because of changing terrain conditions in any particular area.

In order to exploit the white space opportunities, the database should be initially created by using RF propagation models. Periodic updates should be provided by the base stations to the CR devices. There should be constant monitoring of spectrum with the help of spectrum sensing techniques. Once a data base is being created there are immense of opportunities.

Doordarshan is the primary licensed user for almost the entire television frequency band. Government regulations have to be made in order to avail this spectrum for the secondary users. Also, the secondary users should be able to guarantee the primary user that there will not be interference of any sort while using the spectrum.

Another challenge in this respect is that the secondary users providing rural broadband would be reluctant to invest billions for a temporary solution for the spectrum. The secondary users will be happy only if they get the spectrum for the entire lifespan of their service[7]. Also there is a migration of channels from digital broadcasting to the transmission through optical fibres. Thus the service providers are waiting for better opportunity for the so called digital dividend.

XI. TV WHITE SPACE- A GOOD CANDIDATE FOR RURAL BROADBAND IN INDIAN SCENARIO

TV white space is often considered to be a good candidate for rural broadband in India while it is considered as a bad option for the Europe. It is never the matter of the availability of spectrum, but a matter of cost when it comes to rural broadband. We have achieved pretty good mobile broadband in Scandinavia which has got population density very similar to that of rural India. In fact there is no much need of very large spectrum for broadband in rural areas as the density is very low. Spectrum scarcity is always the problem of an urban area.

An obvious reason for using the TV white space in the UHF spectrum is that the propagation conditions are far better at 450 MHz than at 900 MHz or 2 GHz. We will have better range and hence we need to deploy only fewer base stations. This is theoretically supported by the free space path loss which says that the distance that can be covered by a single omnidirectional antenna is inversely proportional to the square of frequency.

XII. CONCLUSIONS AND FUTURE SCOPE

The availability of TV White Spaces presents a great opportunity for a better coverage and substantial bandwidth for the broadband communications. With the SO, there will be even more white spaces available for wireless communications. This study serves as a starting point towards the development of fully operational white space networks for rural broadband connectivity and better utilization of white spaces in India. . A study on combining both spectrum sensing and geolocation databases for TVWS access will be the major agenda of our future work.

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