Research Paper on White Space for Digital India

By

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In association with

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Introduction:

This paper discusseshow opportunistic access of TV Band WhiteSpaces in the VHF/ UHF spectrum canbe used to provide pervasive rural broadband connectivity.This document provides an overview of the published and emerging regulations in various countries. It also provides an insight into how this technology can benefit India, to meet the Digital India vision and to connect 640,000 villages to broadband internet connectivity.

Rural Broadband Internet Connectivity

I. Current Rules

Today, two out of three people in the world do not have access to internet[1]. More than half the population in the world lives in rural areas with hardly any access to broadband. It is expensive to lay fiber / cable in rural and remote areas with low population density. Except for direct coverage by satellite where cost-effective and low latency solutions are still developing, wireless is the only practical solution. Backhaul/backbone internet access for rural areas is also very expensive (typically 50% of the cost). Traditional wireless carriers have focused on urban areas with high population density which typically results in faster Return on Investment using licensed spectrum. Traditional technologies have been unable to provide large area wireless coverage under non-line-of-sight (NLoS) conditions present in rural area to build successful and viable business models. This has resulted in a digital divide and this situation tends to be worse in developing and under-developed countries.WhiteSpace Alliance[2] was recently formed to address this issue of turning Digital Divide into a Digital Opportunity by leveraging un-used or under-utilized spectrum to provide broadband wireless access.

Analog to digital TV transition has provided an opportunity to bridge this digital divide. This is because one traditional analog TV channel typically allows up to 5 standard definition digital television (DTV) signals to be transmitted. Excess spectrum is often called the “digital dividend” and it can be used to provide broadband access as long as no interference is caused to primary users of the bands. While moderate number of TV stations are deployed in urban areas of developed economies such as the United States, in the rural areas of the developed economies as well as, the urban and the rural areas of the developing economies, a large number of TV channels are lying fallow, which can potentially be accessed opportunistically. In addition, TV

[1] Internet World Stats (Accessed October 2014)
[2] WhiteSpace Alliance - www.WhiteSpaceAlliance.org

Channels in VHF/UHF bands have highly favorable propagation characteristics for long-distance reach. Many administrations including the United States are moving towards establishing regulations that allow opportunistic license-exempt usage of the spectrum on a non-interfering basis with the TV receivers using cognitive radio techniques. TV Band WhiteSpaces can provide more than ten times the reach of the wireless access solutions in other bands that are above 1 GHz.

In 2004, the Federal Communication Commission (FCC) in the United States issued the first Notice of Proposed Rule Making in view of allowing unlicensed wireless networks to utilize vacant TV channels, referred to as TV "white space."In 2012, FCC issued the Third Memorandum Opinion and Order proposing the WhiteSpace device operation rules in the TV Band White Spaces[3]. In 2011, the FCC adopted an order conditionally approving several companies as TV bands device database administrators.[4] The role of these administrators is to manage databases identifying unused channels (or white spaces) in the TV bands that could be accessed by fixed and portable personal unlicensed devices. Thirteen companies received conditional approval; of those companies, five have completed the required 45-day testing phase, one is currently conducting that testing, and four have been approved to begin operation of their databases. FCC rules require approved database managers to synchronize their databases, which are used by fixed and personal portable unlicensed devices to identify unused channels (hereafter referred to as "white spaces") that are available at the devices' geographic location.

Personal unlicensed devices are allowed to operate in the white spaces subject to their ability to mitigate interference by either sensing spectrum or determining spectrum availability by accessing a database that informs the device on spectrum availability based on its geo-location.[5]

Device manufacturers may use either spectrum-sensing technology or a geo-location database to avoid bands where TV stations operate. To date, seven geolocation radio models have been certified by the FCC for nationwide operation. Those devices, under the FCC's rules, must have secure communications with the database and must query the database daily to obtain knowledge of their operational and geographic environment, established policies, and internal state. Devices, by querying the database, can dynamically and autonomously adjust their operational parameters and protocols according to their obtained knowledge in order to achieve predefined objectives and to learn from the results obtained.

Apart from FCC, Singapore[6] has recently completed and released their TV Band WhiteSpace rules that allow license-exempt devices to opportunistically access this spectrum to provide

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[3] United States Federal Communications Commission - Third Memorandum Opinion and Order – TV Band White Space Rules : Link

[4] See Unlicensed Operation in the TV Broadcast Bands; Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band, Order, ET Docket Nos. 04-186, 02-380 (Jan. 26, 2011) ("Database Managers Order").

[5] *See Unlicensed Operation in the TV Broadcast Bands; Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band*,Second Memorandum Opinion and Order, ET Docket Nos. 04-186, 02-380 (Sept. 23, 2010) ("*Second Memorandum Opinion and Order*"). The 2010 Order confirmed most technical requirements from the 2008 TV white spaces Order for devices, after which some entities received and participated in experimental licenses to field cognitive networks. *Seeinfra* at n. 4. *Id*. at ¶¶ 69-70, 77-80.

[6] Singapore Rules on Opportunistic Access of TV Band White Spaces by License-Exempt Devices http://www.ida.gov.sg/Policies-and-Regulations/Consultation-Papers-and-Decisions/Store/Proposed-Regulatory-Framework-for-TV-White-Space--Operations-in-the-VHF-UHF-Bands

broadband services. United Kingdom OfCom is likely to issue their rules in early 2015 time frame. Canada is working on its own regulations and it is likely to issue them in 2015 time frame.

II. Protection of Broadcast Services

Unlicensed devices may not cause interference to authorized, protected services and must accept any interference received. Protected services are broadcast television stations (full power, TV, low power TV, and Class A stations); fixed broadcast auxiliary service (BAS) links; receive sites for TVtransmitters, low power, and Class A stations, and for multichannel video programming distributors (MVPDs); public safety and private land mobile operations; offshore radio telephone service operations; radio astronomy service operations at specific sites; and low power auxiliary service operations. Except for MVPD receive sites and licensed and approved wireless microphones, all data on protected services areextracted by the database operators from the FCC's databases or arespecified in the rules. MVPDs obtain protection by registering with the database administrators (and those registrations are shared among the databases).

The FCC rules protect broadcasting services through several technical rules applying to the devices and the operation of approved databases. For unlicensed fixed TV bands devices, the Commission adopted a maximum antenna height limit of 30 meters above ground.[7] To address concerns regarding elevated terrain, the Commission also restricted the devices from operating at locations where the height above average terrain off the ground is greater than 75 meters.Unlicensed fixed TV bands devices are not permitted to operate in excess of the equivalent of 4 watts EIRP. Personal/portable devices are not allowed to operate in excess of the equivalent of 100 mW EIRP. For personal/portable devices that are operating adjacent to an occupied TV channel, however, the maximum permitted EIRP is 40 mW. Personal/portable devices that rely on spectrum sensing without use of geo-location and a database may not operate in excess of a power level of 50 mW EIRP.

To ensure that the geolocation database protects authorized services, the FCC requires that applicants, to operate a TV white space database, undergo a public trial of at least 45 days to enable broadcasters and other members of the public to test its ability to protect against interference, including accurate selection of channel availability. Approved managers must operate a database system that include records for all licensed facilities and certain additional facilities (including registered venues where licensed and unlicensed wireless microphones are operated) in the TV bands that are to be protected from interference. As noted above, managers of approved various databases are required to regularly synchronize their databases to keep information on channel availability accurate. These rules are likely to be further optimized for better efficiencies in further revisions to the rules.

III. Broadcast Incentive Auction

The FCC is currently preparing to conduct an auction that will repurpose some television broadcast spectrum above the 585 MHz for mobile wireless broadband use. That auction is planned for 2015. Broadcasters that do not relinquish their spectrum will be relocated ("repacked") to provide the necessary contiguous spectrum required for mobile wireless

7 *Second Memorandum Opinion and Order*.at ¶¶ 63, 65-66.

broadband use. The FCC has proposed that it will retain its white spaces policy in the repacked broadcast bands, so that white spaces devices will continue to be able to operate where unused broadcast spectrum remains. The incentive auctions may reduce the amount of white spaces available, particularly in mid to large markets. The expectation is that there will be plenty of TV Band white spaces available in suburban and rural areas.[8]

IV. Nationwide Wireless Microphone Registry

In addition, the FCC established a national unlicensed wireless microphone registration system, to allow wireless microphone operators to reserve channels for their use in the white spaces databases. Registration is available for certain events—"major sporting events," "live theatrical productions/shows" and other "major events where large numbers of wireless microphones will be used and cannot be accommodated in the available channels." This registration will allow microphone access to channels in addition to the two TV band channels that are already reserved for wireless microphone use. Registration requires a showing to the FCC that those two channels are not sufficient for the needs of the venue and event.

V. Deployments, Pilots and Field Trials

In March 2013, the FCC authorized the approved white space database systems to provide service on a nationwide basis.[9] That authorization was intended to allow the nationwide roll-out of TV white space devices. The FCC noted that nationwide authorization was expected to fuel innovation and investment in new unlicensed wireless technologies.[10]

Prior to that announcement, several regional networks had been launched:

- In late 2009, a white space-based wireless broadband network was established in an insular mountain town. There, a private company established a central white space link that transmits a signal to Wi-Firouters at a local school and community center, bringing broadband to a previously unserved population.[11]
- In 2010, private companies deployed the first white space broadband network for healthcare providers in a rural hospital.[12] That network enables and supports healthcare providers' ability to utilize affordable broadband, while also providing data transmission for telemedicine applications.
- Also in 2010, in a rural mountainous community with a high percentage of part-time residents, private companies deployed the first smart grid over white space. There, companies configured a white space network for a rural electrical utility, enabling the

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8 http://www.whitespacealliance.org/documents/20131204_WSA_Brattle_ Webinar_TVWS_Availability.pdf.

9 *Office of Engineering and Technology Authorizes TV White Space Database Administrators to Provide Service to Unlicensed Devices Operating on Unused TV Spectrum Nationwide*, Public Notice, DA 13-324, ET Docket No. 04-186 (Mar. 1, 2013) ("*OET Nationwide TVWS Roll-Out Notice*").

10 *OET Nationwide TVWS Roll-Out Notice* at 1.

11 *See supra* n.4; *see also*Nate Anderson, *First white space broadband deployment in small Virginiatown*, ARTS TECHNICA, Oct. 21, 2009, www.arstechnica.com/tech-policy/news/2009/10/first-white-space-broadband-deployment-in-small-virginia-town.ars.

12 *See* Brian Dolan, *Google eyes white space for wireless health*, MOBI HEALTH NEWS,Sept. 15, 2010, www.mobihealthnews.com/8913/google-eyes-white-space-for-wireless-health/.

utility to automate substations and initiate a smart meter-style network using white space.[13]

- A coastal city with environmentally-protected wetlands established in 2010 a SmartCity white space network to support municipal applications including water quality monitoring, traffic monitoring and management, and lighting management. The SmartCity also includes a "middle mile" wireless network that connects its fiber network with Wi-Fi™ access points in parks and other areas under-served by Internet service providers to provide affordable broadband access services to city residents.[14]In April 2012, broadband white space access trials were conducted in Cambridge, UK[15]. Many companies and some broadcasters were involved in these trials to understand the feasibility of using white spaces for broadband deployment, as well as the coverage that they can provide. The measurements were made at a number of test points at 10m and 1.5m height, in order to simulate fixed customer premises equipment (CPE) and mobile user equipment (UE) applications. TVWS spectrum is of variable quality and the measurements were repeated on CH59 and CH61 to explore how the coverage might vary as a function of DTT interference present from distant parts of the TV network. The test and development licenses were chosen to avoid interference to TV services.
- In addition to the operational white space networks, one of the selected managers operates a database to create a marketplace for spectrum in which a user can search for white space spectrum in a particular market. The service allows searches for available spectrum by geography, as well as by specific features such as frequency, part number, and market boundaries.

Since the 2013 announcement, additional TV White Space networks have launched.

- A public university in a mountainous region launched a campus network in July 2013.[16] Students and faculty at the university now have WiFi connectivity on campus and at rapid transit platforms that use white spaces. The network links three main campus locations, ranging from a mile to a mile and half from each other, over the hills and mountains of the city in which the university is located. Because of the highly mountainous topography, broadband connectivity has presented numerous challenges. Because of the propagation characteristics of white space spectrum, the new network is better able to serve a wider area covering challenging terrain. The launch of that network was aided by a consortium of over 500 colleges and universities, technology companies and public interest groups dedicated to bringing improved wireless broadband connectivity to college campuses.[17]
- A public interest library group announced a white spaces trial for a library consortium to

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13 *See supra* n.4; *see alsoNation's First Smart Grid White Spaces Network Trial*, THE SMART GRID OBSERVER, June 25, 2010, www.smartgridobserver.com/n6-25-10-2.htm.

14 *See supra* n.4; *see also*City of Wilmington, North Carolina, Port City WiFi, www.ci.wilmington.nc.us/information_technology/port_city_wifi.aspx; EsmeVos, *Wilmington, NC uses white spaces for smart city, eco-friendly wireless applications*,MUNI WIRELESS, Feb. 24, 2010, www.muniwireless.com/2010/02/24/wilmington-uses-white-spaces-for-smart-city-ecofriendly-wireless-applications/.

15 http://www.adaptrum.com/docs/WP_228.pdf

16 http://www.tvtechnology.com/article/west-virginia-university-launches-first-super-wifi-campus-white-space-network/220307

17 *See http://www.airu.net/about/*

enable public library hotspots.[18] More than fifty library systems submitted proposals to deploy white space devices to better serve their communities and patrons, and six were accepted. Those six received equipment for use during the trial. The accepted proposals were from library systems in Kansas, New Hampshire[19], Mississippi, Illinois, California, and Colorado. The library group has also expanded its pilot to three other countries.

- A rural Wireless Internet Service Provider (WISP)[20] launched a TV White Spaces pilot in a rural western county in mid-2013 under Special Temporary Authority from the FCC. The WISP hopes to show that TV White Spaces can be effective at bringing wireless broadband to areas with challenging topography such as deep valleys and thick forests and where wireline broadband is unavailable. Commercial deployment is scheduled to begin in early 2014.
- As of the end of 2013, rural and tribal communities in western and eastern states have begun testing high-speed broadband to households in areas unserved by digital subscriber line and cable broadband access networks.
- Some companies in Japan have conducted field experiments using their IEEE 802.22 and IEEE 802.11AF prototypes[21]. Using their IEEE 802.22 prototype, they observed successful downstream and upstream data transmission at a distance of 12.7 km between the base station (BS) and the subscriber station (SS) with a speed of 5.2 Mb/s and 4.5 Mb/s respectively. In addition, a multi-hop network was implemented using IEEE 802.22 as a backbone link for IEEE 802.11AF to expand the coverage area. Applications such as video monitoring or roads and cliffs and video telephony in mountainous areas was demonstrated, These achievements showed feasibility of providing broadband services in rural areas and supporting radio communications during disaster relief activities using TV Band white spaces.

World-wide Trials to Provide Broadband Access Using TV Band WhiteSpaces

As of today, more than 30 trials have been conducted all over the world on TV Band WhiteSpaces. Out of this, three trials have been proposed to be conducted in India. It would be difficult to cover all these more than 30 trials in this Paper. However, here are some examples–

- Indigo Telecom/Microsoft and the Kenyan government is reportedly delivering bandwidth speeds of up to 16 Mbit/s to three rural communities which lack electricity. TV White Space technology operates in the unused portions of the broadcasting band (470-862 MHz) to provide internet connectivity in rural (underserved) areas[22].
- In Namibia "Citizen Connect" project, a collaboration between the Microsoft 4Afrika Initiative, the MyDigitalBridge Foundation, and the MCA-N (Millennium Challenge Account Namibia), has been started to deliver broadband Internet to "twenty-seven schools and seven circuit offices of the Ministry of Education using "TV White Space technology"[23, 24, 25].

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[18] http://giglibraries.net/Default.aspx?pageId=1628969; see also e.g., http://www.skokienet.org/whitespace,

[19] http://unhbcoe.org/technology/tv-white-space/new-tv-white-space-ready-prime-time

[20] http://www.whitespacealliance.org/documents/Cal-Net%20TVWS%20Deployment%20Review%20140222a.pdf

[21] http://www.whitespacealliance.org/documents/hitachikokusai_nict_802dot22_802dot11af_trials.pdf

[22] Mohamed A. Haji: Licensing of TV White Space Networks in Kenya (ITU –R SG1/WP 1B Workshop: Spectrum Management Issues on Using White Spaces by Cognitive Radio Systems , Geneva, Switzerland , January 20, 2014)

[23] 4Afrika TV White Space (http://www.microsoft.com/africa/4afrika/TV-Whitespace-PR-Nambia.aspx last accessed 14 October 2014)

- In South Africa, Google, in a partnership with the Independent Communications Authority of South Africa, the Council for Scientific and Industrial Research (CSIR), the Wireless Access Providers Association (WAPA) and Carlson wireless delivers wireless access to 10 schools through 3 base stations at the campus of Stellenbosch University's Faculty of Medicine and Health Sciences in Tygerberg, Cape Town[26].
- WhiteSpace Alliance, IIT-Bombayand Tata Teleservices pilot trials in Palghar District of India. More information can be found later in Section VIII of this report.

Rural areas are often inhibited from wireless access because they are inaccessible and off the local power grid. Cell towers are difficult to install and cannot connect, either. Fortunately, White Space power stations can be charged with solar panels, and the excess electricity generated can also power other institutions in the area such as schools[27].

VI. Standards for Use of TV Band WhiteSpaces

Many international Standards Development Organizations are working on creating a wide variety of inter-operable standards and specifications for the use of TV Band white spaces.

- Institute of Electronics and Electrical Engineers (IEEE) 802 LAN MAN Standards Committee[28] is a leading consensus-based industry standards body, and it produces standards for wireless networking devices, including wireless local area networks ("WLANs"), wireless personal area networks ("WPANs"), wireless metropolitan area networks ("Wireless MANs"), and wireless regional area networks ("WRANs"). Included in the IEEE 802 standards development activity is an emphasis on coexistence, which is the focus of theWireless Coexistence working group.
- Some of the IEEE 802 standards that are relevant to TV Broadcast Bands include IEEE 802.11 AF[29] (WLAN), IEEE 802.15.4m[30] (WPAN), IEEE Std. 802.22-2011[31] (WRAN), and IEEE 802.19.1[32] (Coexistence). More information on these standards for Television Band White Spaces and Spectrum Sharing can be found here[33].
- WhiteSpace Alliance has created inter-operability tests and certification procedures for the IEEE 802.22 systems which is called Wi-FAR™. The Wi-Fi Alliance has given the inter-operable IEEE 802.11 systems a commercial name of Wi-Fi®.

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[24] 'White space' internet developed to reach rural communities (August 28, 2014, BBC : http://www.bbc.com/news/technology-28962232)

[25] Jim Beveridge: Dynamic Spectrum Access: Linking Africa and Scotland (ITU –R SG1/WP 1B Workshop: Spectrum Management Issues on Using White Spaces by Cognitive Radio Systems , Geneva, Switzerland , January 20, 2013

[26] The Cape Town TV White Spaces Trial (http://www.tenet.ac.za/tvws accessed: October 14, 2014)

[27] Lyndsey Gilpin : White Space, the next internet disruption: 10 things to know (http://www.techrepublic.com/article/white-space-the-next-internet-disruption-10-things-to-know/ March 12, 2014, accessed 25 September, 2014)

[28] www.ieee802.org

[29] http://www.ieee802.org/11/Reports/tgaf_update.htm

[30] http://www.ieee802.org/15/pub/TG4m.html

[31] http://www.ieee802.org/22/

[32] http://ieee802.org/19/pub/TG1.html

[33] https://mentor.ieee.org/802.22/dcn/13/22-13-0114-00-0000-ieee-itu-joint-meeting-spectrum-sharing-and-white-space-standardization-to-bridge-the-digital-divide.pptx

- The Internet Engineering Task Force (IETF) Protocol to Access White Spaces (PAWS)[34] Working Group is working on creating a standard for interfaces and access to the White Space Database by a White Space device operating in the Television Broadcast Band.
- WhiteSpace Alliance has also created inter-operability tests and certification procedures for the IETF PAWS protocol which is called as the WSAConnect™ Specification.

VII. Pervasive Rural Broadband Wireless Access in India Using TV Band WhiteSpaces

VII.a Differences between USA, UK and India

In US, terrestrial TV broadcasting has been and is being operated by many private service providers in the VHF and the UHF bands. When analog TV channels switched to digital or when some broadcasters stopped their transmission, spectrum bands became available in various channels at different geographic locations. These spectrum holes are called as white spaces. In UK and Japan also, the situation is similar. The amount of white spaces available in countries such as US, UK, and Japan varies depending on the geographical locations. It may also be fragmented. It must be noted that several studies on quantitative assessment of these white spaces have shown that the amount of spectrum available as white spaces in these countries is limited.

In the US and the UK, regulators (FCC and Ofcom, respectively) have permitted devices to make use of “white spaces” as a “secondary user” without causing interference to the “primary”, i.e., the TV broadcasting on a “license-exempt” basis.Low power license exempt operation on a “secondary basis” was followed by FCC where the regulators would like to optimally utilize the spectrum which was otherwise utilized fully earlier for analog transmission, but now is part of “white spaces” due to the Digital Dividend.

How is the TV Band utilization in India?

There are a few salient points in this regard. They are listed as follows:

1. Unlike in the US and the UK, there is only ONE terrestrial TV broadcaster in India—the Doordarshan.
2. Doordarshan transmits only two channels (namely, DD1 and DD2) at any given location in the country. These channels occupy either a bandwidth of 7MHz in the VHF band or a bandwidth of 8MHz in the UHF band.
3. Doordarshan has 1415 TV transmitters operating in India. Out of these, 8 transmitters operate in the VHF Band-I, 1034 transmitters operate in the VHF Band-III and the remaining 373 transmitters operate in the UHF Band-IV. Figure VII.1 shows the IIT Bombay research to map the 373 TV transmitters operating in the UHF TV band in India.

[34] https://datatracker.ietf.org/wg/paws/charter/

4. Thus, a majority of the TV transmitters in India operate in the VHF band. A detailed quantitative assessment of spectrum in 470-585 MHz has revealed that, unlike in the developed countries, major portion of the UHF TV band is unutilized in India.
5. Digitization of broadcasting services in India by Doordarshan is under progress. The frequency band 585-698 MHz, has been exclusively earmarked for digital TV broadcasting in India. This will free up even the full spectrum of 470-585 MHz for other applications**.**

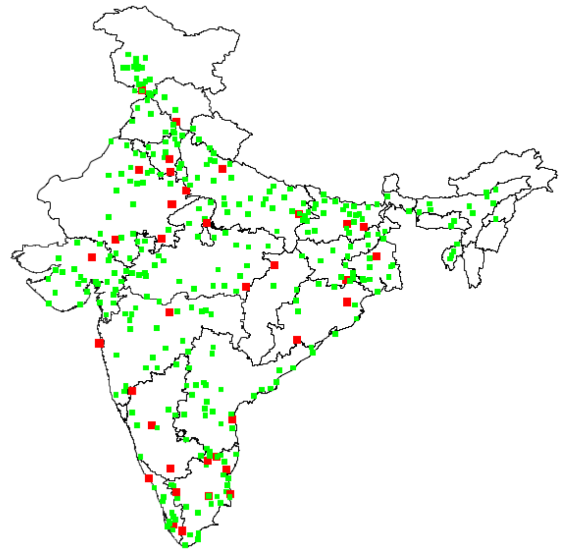

Figure VII.1 IIT-Bombay research to Map all of the 1415 TV Transmitters in India.

How is the Indian situation different?

In 470-585MHz, white spaces (or spectrum holes) have not been created in India in a manner similar to the way they will be dynamically created in the US, the UK, and other countries by digital TV switchover of terrestrial broadcasting. In India, practically about 100MHz spectrum is available in the 470-585MHz band, which has been lying unutilized even by analog transmission.

In India, a "spectrum sensing" based approach is not required due to the following important reasons: (a) there is a single broadcaster—Doordarshan—which is using the spectrum; (b) the usage of spectrum by Doordarshan is (nearly) static and has not changed for decades; (c) at any given location, minimum 96 MHz will be available as unutilized frequency band in 470-585MHz; and, (d) information about free channels at any given location is also known and a geo-location database can be created to ascertain these free channels (in fact, IIT Bombay has already created such a database).

What are the ITU frequency allocations?

As per the International Table of Frequency Allocations of the Radio Regulations Articles (Edition 2012), the allocation of various radio services is done region-wise. For the purpose of allocation of frequencies, the world has been divided into three regions—1, 2, and 3. India falls in Region 3.

In Region 1, the band 470-790 MHz is *only for Broadcasting*.

In Region 2, the band 470-512 MHz is *for Broadcasting as Primary service and Mobile and Fixed Services can be Secondary.*

*In Region 3 —where India belongs— 470-585 MHz allows Fixed, Mobile, and Broadcasting as Primary Services.*Thus in Region 3, apart from Broadcasting, even Fixed and Mobile services allocation for "Primary Services" is possible.

What technologies and services are deployed in the US and the UK in the white spaces?

In these countries, only low power secondary operation is permitted. Technologies based on standards such as IEEE 802.22 and IEEE 802.11af have been deployed. These technologies also support wide area network including multi-cell architecture and mobility.For end consumers, 802.11 based Wi-Fi devices form cost effective way of accessing broadband and it may be used as a last mile access solution. IEEE 802.22 Wi-FAR™ systems may be used for middle-mile which remains a major issue in delivering cost-effective broadband access.

Then what is the use case scenario for India?

In order to understand the TV band scenario, first consider the Indian National Frequency Allocation Plan (NFAP) 2011. As per NFAP 2011, the spectrum in the frequency band 470-890 MHz is earmarked for fixed, mobile, and broadcasting services:

Frequency Band	**Services**	**NFAP Remarks**
470-585	FIXED,MOBILE, BROADCASTING	Requirements of fixed and mobile services will be considered in the frequency band 470-520 MHz and 520-585 MHz on case-by-case basis
585-610	FIXED,MOBILE, BROADCASTING, RADIO NAVIGATION, RADIO ASTRONOMY	1. The requirement of Digital Broadcasting Services including Mobile TV may be considered in the frequency band 585-698 MHz subject to coordination on case by case basis. 2. The requirement for IMT and Broadband Wireless Access may be considered in the frequency band 698-806 MHz subject to coordination on a case-by-case basis.
610-890	FIXED,MOBILE, BROADCASTING, RADIO ASTRONOMY	610-646 MHz has been earmarked for Broadcasting services on case-to-case basis. Beyond that primarily for MOBILE services

After the completion of digitization, Doordarshan will operate within the frequency band 585-698 MHz, which has been exclusively earmarked for digital TV broadcasting in India.

Once again, it must be noted that 470-585 MHz band can be considered for providing Fixed Services as Primary Service (and not secondary service) in India. This is permitted under NFAP.

Why 470-585MHz band should be considered for Fixed Services?

One of the major impediments to providing broadband connectivity in semi-urban and rural India is the lack of robust cost-effective backhaul. Even in urban areas, one of the major impediments for widespread deployment of Wi-Fi Hotspots is the lack of connectivity to WiFi access points.

Fiber connectivity in terms of backhaul that is being planned (or provided) by the National Optical Fiber Network (NOFN) currently reaches only till the Block level. Even when NOFN would be complete, the optical-fiber connectivity would reach only till the Gram Panchayats in the country.

In such a scenario, the problem of connecting the backhaul link to the access network can be addressed using a mesh based last-mile or *middle-mile network*. A middle-mile backhaul network is a Point to Multi-Point (PMP) and/ or a multi-hop wireless mesh network that is capable of providing coverage within a radius of one to ten kilometres to enable seamless connectivity from the access network such as Wi-Fi Zones/Access points/clusters to a backhaul point such as an NOFN node. In order to reach these distances, sub-GHz spectrum provides excellent propagation characteristics, and at the same time will not require expensive infrastructure such as high towers and strict line-of-sight. This middle mile connectivity can be accomplished using IEEE 802.22 Wi-FAR™ systems or IEEE 802.11 systems using directional antennas.

What kind of Regulatory Approach should be adopted?

Since Indian scenario is different, we believe a different regulatory approach is required. We can consider developing an approach that is fundamentally a re-allocation of spectrum. However, it is different from the traditional re-allocation in that it provides access to spectrum for fixed services based on Doordarshan voluntarily relinquishing spectrum by geographic areas through an incentive method of dynamic allocation. Thus, parts of the spectrum and geographic areas would be used for broadcasting services and parts of the spectrum and geographic areas would be used for fixed services. The broadcasting services would share the same frequencies with the new fixed services based on the band plan that may also be established on geographic separation. The sharing conditions should be defined as was done to permit sharing during the transition of the 700MHz (698-806 MHz) band from broadcasting to fixed and mobile services, and to permit sharing in other parts of the spectrum allocated to TV broadcasting.

Once Doordarshan voluntarily relinquishes spectrum in a particular geographical area, fixed services could enter this spectrum based on geographical separation between services and specified technical criteria including coexistence with adjacent bands. The above approach is consistent with ITU Region 3 Frequency Allocation and our own NFAP 2011.

Do we have products for such Fixed Services?

Initially, 802.22 (Wi-FAR™) based products can be configured to work in point to point or point to multipoint links for backhauling to the Wi-Fi clusters. Since this cost is not born by each end customer, it gets amortized over all customers of Wi-Fi clusters connected to it and thus acts as a cost-effective solution. It can even turn out to be a cost-effective solution compared to fiber cables for connecting Wi-Fi access points and for extending the reach of Wi-Fi.

There are a couple of Indian companies which are developing technology based on 802.22 standards as OEM supplier for multi-nationals. These companies can develop products and technologies for deployment in India. Other multi-national companies are also interested in manufacturing solutions in India. These synergies may be leveraged. IIT Bombay, has also developed prototype which is being field tested on experimental trial.On a long term basis, several innovations can be harnessed to address the needs of India specific requirements.

Finally, what should be done?

Essentially we can unlock about 100MHz in 470-585MHz band for last mile and middle mile connectivity. In India, we have spectrum scarcity, and this vast amount of spectrum is completely unutilized and being wasted. The unutilized UHF band can be used for affordable backhaul. This Fixed Service backhaul can be used for connecting Wi-Fi clusters. It can eventually terminate into urban, sub-urban or village gram panchayat NOFN node. At other places, it can even provide alternative to fiber connectivity (for example, in remote locations, difficult terrain, and scenarios where right of way for fiber is not possible).This can accelerate the deployment of broadband services thus making "Digital India" goals to be achieved faster. Thus, middle-mile and last-mile network using UHF band system can be developed along with NOFN.

VIII. Proposed TV WhiteSpace Commercial Pilots in Palghar District, India

This section will describe the technological solutions envisaged for the successful deployment of affordable broadband in India. We also outline the technical challenges in the rest of this section.

The proposed test-bed and associated research experiments for rural broadband

In this project, the IIT-Bombay research group and Tata Teleservices in association with the WhiteSpace Alliance will implement test beds at several selected locations in various parts of India (the details of these locations will follow subsequently). The implementation schematic of this test bed is shown in Figure VIII.1.

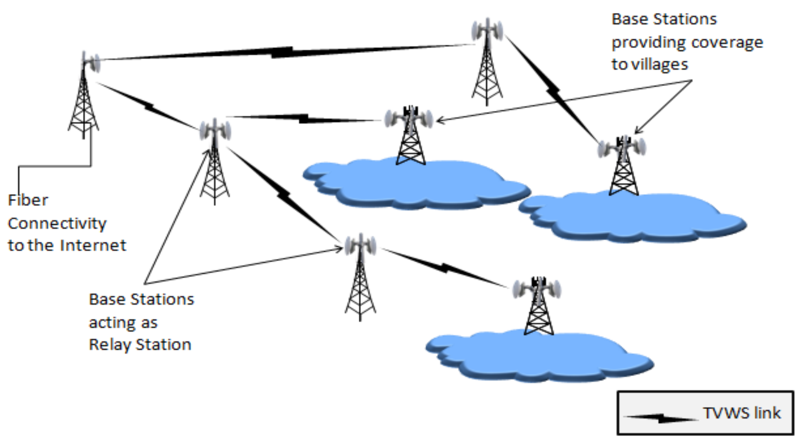

Figure VIII.1: *Proposed rural broadband wireless backhaul network is depicted. The blue clouds represent a village which is under coverage by the TV white space base station. The intermediate base stations act as relays. All the relays terminate at a base station with Fiber connectivity.*

In India, typically there is a town within 15-20 km from every village. The optical fiber network in India currently provides service to all such towns. Thus, it is this 30-40 km distance in which backhaul has to be provided using the TV band spectrum. In these 30-40 km distances, two typical scenarios are prevalent. In one scenario, the regions between the villages are covered by highways or connecting roads with very little or almost no population. Similar scenario exits when the region between two villages is separated by forests, desert areas or water bodies. In this case, point to point links can be established between the relay base stations.In the other scenario, the region between two base stations needs services. In this second scenario, the intermediate base station has to relay the signal to the next base station as well as provide services to its surrounding area. This gives rise to a mesh topology. Within a particular region, 2.4 GHz unlicensed band Wi-Fi can be used as the last mile connectivity option as shown in Figure VIII.2.

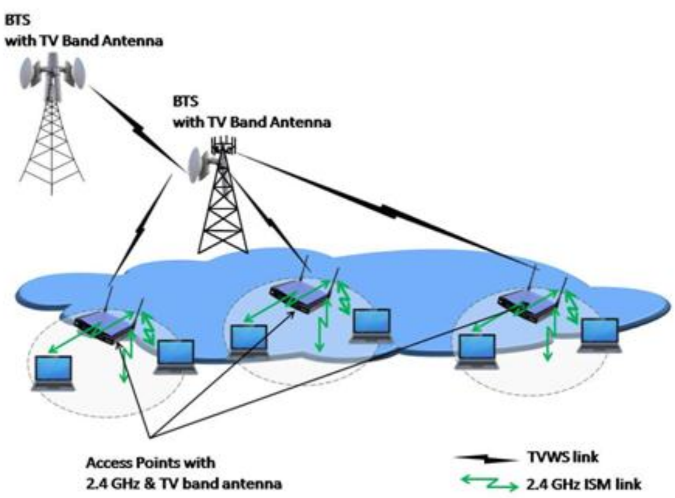

Figure VIII.2: *Rural area Wi-Fi connecting to TV band backhaul is depicted.*

The proposed plan for setting the test beds in Wagholi and Vasai are as shown in Figure VIII.3.*Vasaigaon has optical fiber connectivity and wireless backhaul can be used to reach the neighboring villages.*

1. Locations selected for the deployment of rural broadband test-beds

In order to conduct the experiments, IIT-Bombay research group and Tata Teleservices will set up experimental test beds in locations in Maharashtra, and a few other states. The choice of the locations depends on the ease of accessibility to these locations and the availability of resources needed for experiments. Currently IIT-B research group and Tata Teleservices have shortlisted seven locations for setting up the test beds, the details of which are given below.

Village	Tower Height	Latitude	Longitude
Khamloli	45 meter	19.6616	72.8642
Haloli	45 meter	19.6813	72.9108
Maswan	45 meter	19.7049	72.8563
Pargaon	45 meter	19.5939	72.8837
Ganje	45 meter	19.5917	72.9389

The proposed plan for setting the test bed in Palgharis as shown in Figure VIII.3.In each of the five villages shown in Figure VIII.3, Ground Based Towers (GBTs) of Tata Teleservices are available. At these locations, equipment are installed on these towers at a height of 45 meter. Beside these locations, equipment are also installed at lower masts at two other villages, Dhuktan and Bahadoli in the Palghar district.

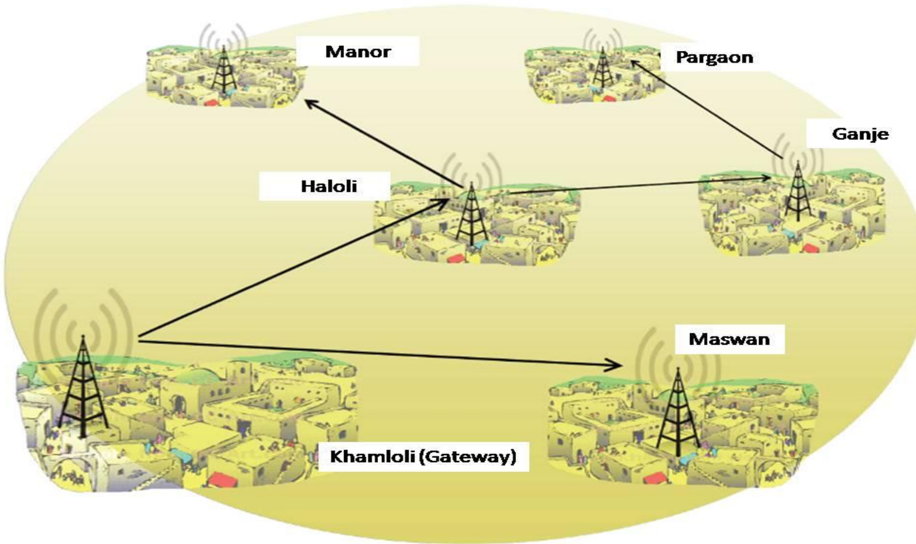

Figure VIII.3: *The detailed geographical layout ofPalghar test bed is depicted. Khamloli village has optical fiber connectivity and wireless backhaul can be used to reach the neighboring villages.*

For the testing of rural broadband in the areas where test-beds will be located, few services will be launched for the development of social community and broadband usage. These services will include (i) broadband access; (ii) e-Health initiative; (iii) e-Learning initiative; and (iv) e-Agriculture, (v) e-Governance (vi) e-Inclusion etc.

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