American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936

Volume-7, Issue-3, pp-36-45

www.ajer.org

Research Paper Open Access

TV White Space in Rural Broadband Connectivity in Case of Bangladesh toward “Vision 2021”.

Manjurul H. Khan[1], P.C. Barman[2]

[1] *ICT Department-System, Janata Bank Limited, Head Office, Dhaka, Bangladesh.*
[2] *Department of Information & Communication Engineering, Islamic University, Kushtia, Bangladesh.*
Corresponding author: Manjurul H. Khan

ABSTRACT: *Next generation wireless technology with converged voice and data applications can offer rural broadband connectivity for proper boost in Information and Communication Technology (ICT) to play all areas of human life. ‘White spaces’ in the UHF bands that have traditionally been used for television broadcasting but the opening of TV white space (TVWS) bands for cognitive access is one of the first tangible steps to solve spectrum scarcity problem in current wireless networks. We briefly try to cover the TV White Space technology, the global scenario for the use of TVWS, the pertinent standards to the TVWS system, the regulatory framework, cost Benefit analysis and other relevant points. In the target riverine country like Bangladesh, TVWS wireless connectivity model can play an important role to develop rural community. In this paper, our objectives are to Explore, assess and propose TV white space implementation rural broadband in Bangladesh to make digital Bangladesh.*

KEYWORDS *-Cognitive Radio, TVWS, BTRC Spectrum Band, TVWS Bangladesh and Rural Broadband.*

Date of Submission: 17-02-2018 Date of acceptance: 05-03-2018

I. INTRODUCTION

The 21st century has seen the dawn of the era of ICT (Information & Communication Technology). ICT continues to shape societies and its contribution to global development very much support every other input to economic growth and social development. Securing access to efficient and sustainable ICT infrastructure has become a major goal worldwide, especially considering the vital role that ICTs play across all areas of human life, such as education, health, science, financial markets, security and civil protection, media, entertainment and business development, amongst others. With the ongoing efforts to meet this goal, there has been a steep increase in the demand for bandwidth for communication systems and also the preferential shift from the usage of fixed wire-line technologies to mobile technologies. With the drastic increase in the demand for mobile connectivity, comes the inevitable pressure on the supply side of the resource, being the radio spectrum the necessary resource to enable wireless technologies to transmit and receive data. It has been felt worldwide to devise ways for efficiently managing the spectrum to serve the exponentially growing demands. This has led to the development of different techniques for addressing the spectrum crunch and also to optimize the use of the available spectrum. One alternative mode of spectrum utilization that is finding popularity world over is the use of TV White Spaces for communications systems. TV white spaces (TVWS) are “portions of spectrum left unused by broadcasting, also referred to as interleaved spectrum”. The TV White spaces have excellent propagation characteristics and hence are a huge attraction worldwide for wireless communications. Countries like US, UK, Canada & Singapore have already formulated regulations for the usage of TV White Spaces for wireless communications (fixed and mobile), and many others like Japan, Hong Kong etc. are actively considering to do the same. This study paper briefly tries to cover the TV White Space technology, the global scenario for the use of TVWS, the pertinent standards to the TVWS system, the regulatory framework and other relevant points. In this paper, we Explore, assess and propose TV white space implementation architecture in Bangladesh to provide internet connectivity in rural areas.

II. TV WHITE SPACE & TECHNICAL OVERVIEW

2.1 Cognitive Radio Technology

The TVWS technology based communication system is mainly based on the Cognitive radio based architecture. “Cognitive Radio System (CRs) is a radio system employing technology that allows the system to obtain knowledge of its operational and geographical environment, established policies and its internal state; to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives; and to learn from the results obtained” [9]. A brief description of a cognitive radio system is given. Chief enabling technologies for the Cognitive Radio Systems are Geolocation database, Spectrum Sensing and Combined Spectrum Sensing Geolocation Database. Geolocation database is an entity that controls the TV spectrum utilization by unlicensed white spaces devices within a determined geographical area. Its sole objective is to enable unlicensed access to white space spectrum while protecting incumbent broadcasting services. Spectrum Sensing can be detecting unused spectrum and sharing it, without harmful interference to other users; an important requirement of the cognitive-radio network is to sense empty spectrum. Detecting primary users is the most efficient way to detect empty spectrum. Combined Spectrum Sensing and Geolocation/Database is possible to use sensing in parallel with access to database.

2.2 What is TV White Space?

The sub-band 470–806 MHz in the Ultra High Frequency (“UHF”) band (i.e. Channel 21– 62) is allocated primarily for terrestrial TV broadcasting service on a worldwide basis. In traditional radio system planning, co-channel TV broadcasting stations and hence their coverage areas are geographically separated so as to avoid radio interference. As a result, some TV channels at certain locations are not used at all times. These TV channels are generally referred to as “TVWS” or “TVWS spectrum” [4] Radio spectrum is a scarce resource. With the continued growth in demand for spectrum for telecommunications services, some countries are/have been exploring ways to use the TVWS for low power telecommunications applications, such as wireless broadband Internet access [4]. In 1996, US Congress had set June 12, 2009 as the deadline for full power television stations to stop broadcasting analog signals [3].TV White space(TVWS) are unused gaps in TV broadcast spectrum (470-690MHz). In Figure 1 provides the basic concept of TVWS.

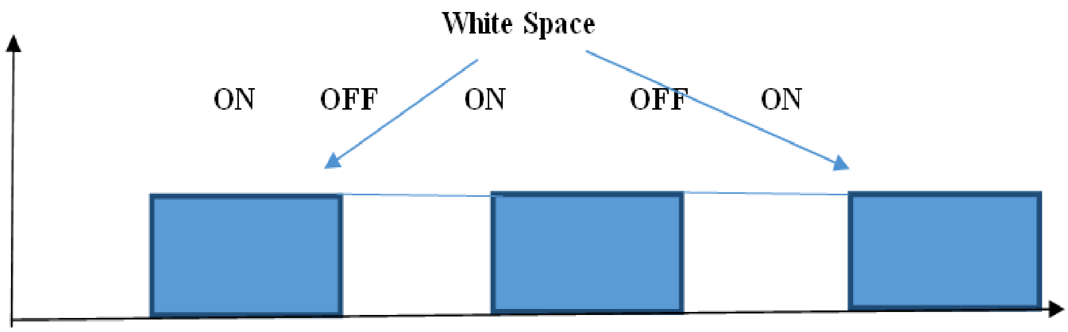


Figure 1: Basic concept of TVWS. [5]

TV white space rules by which unlicensed devices, called TV Broadband Devices (TVBDs), can make use of specific TV channels in the Very High Frequency (VHF), and Ultra High Frequency (UHF) bands in Table 1.

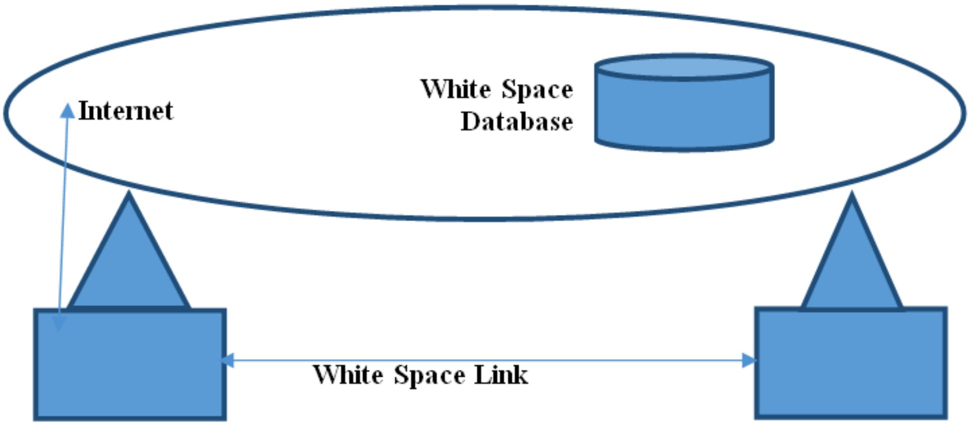
Table 1: TV White Space Spectrum Allocation [Source: Gartner 2011]

TV Channels	Spectrum	Band
2,3,4	54-72 MHz	VHF-Low Band
5,6	76-88 MHz	VHF-Low Band
7-13	174-216 MHz	VHF-High Band
14-51	470-698 MHz	UHF

2.3 Basic Mechanism of TVWS

Basic Mechanism of TVWS are given below [2]

i. Devices only use the TV White Spaces channels specified by the database.
ii. Devices are required to re-check the database for the list of available channels
iii. Databases are prohibited from providing devices access to the channels occupied by incumbent operators. Such as broadcasters.
iv. Databases are required to maintain up to date lists of protected operators.
v. Databases can block newly occupied channels to prevent further white spaces access. In Figure 2 shows basic mechanism of TVWS.



White space Base Station **White space Base Station**

Figure 2: Basic Mechanism of TVWS. [5]

2.4 TV White Space Trials around in the World

There has been increasing interest in telecommunications use of 'white spaces' in the UHF bands that have commonly been used for television broadcasting. In more and more countries this interest is fueled by the now inexorable move towards digital terrestrial television broadcasting, the consequential and looming end of analogue terrestrial television broadcasting, continuing growth in internet usage and increasing demand for wireless broadband access. USA already has a number of certified database administrators and is the front runner in the deployment of TVWS based networks. UK and Singapore are also hastening in the deployment process.UK has had a number of pilot deployments pertaining to the use cases of Smart City, Rural Broadband, Wi-Fi Hotspot coverage, M2M communications, sensor networks etc. Singapore has deployed many smart grid solutions based on TVWS and is undertaking many pilot deployments for a number of use case scenarios. Now, TV White Space Trials around the World is figure out in Table 2.

Table 2: TV White Space Trials around the World [8]

Completed or Ongoing Country	Planned Country	Expression of Interest Country
1.USA	1.Ireland	1.Mexico
2.Canada	2.Philippines	2.China
3.Brazil		3.Ecuador
4.UK		4.India
5.Finland		5.Peru
6.Germany		6.Thiland
7.Belgium		7.Nigeria
8.Japan		8.Souh Africa
9.Singapore		9.New Zealand
10.Kenya		10.Malaysia
11.Uruguay		
12.South Korea		

2.5 Rural Broadband

We are more dependent on the Internet for communication, information, health services, education, disaster management and business relations. Internet has to be seen as Basic Human Right in days to come out of 7.2 billion world population, only 3.3 billion populations is connected through internet Out of 3.9 billion unconnected internet population 07million population is from BANGLADESH – ideal case for make in BANGLADESH and for BANGLADESH “10% increase in internet penetration can boost GDP by 1.4%”: Source: ITU. Connectivity is a must for rural area to manage limited resources and utilize them in an efficient way like power, irrigation etc. Improves education and health services in rural area E-commerce platform to connect end buyers to farmer eliminating middle men. Comparison of different Existing Standard in rural broadband are figured out in table 3.

Table 3: Comparison of different Existing Standard for rural broadband [12]

Standard	Range (Kms)	Entry Cost	Frequency Band	Deployment Time	Maintenance Cost	Network Latency
ADSL/Cable/Fiber	1-2	High	NA	High	High	Low
Mobile Telephony	5	High	Licensed	Medium	Medium	Low
Wi-Fi	0.1	Low	Un- Licensed	Low	Low	Low
WiMAX	2-3	Medium	Licensed	Low	Low	Low
Satellite	>100	High	Licensed	High	Low	High

III. TVWS IN BANGLADESH SCENARIO

3.1 Country profile of Bangladesh

Bangladesh Television (BTV) is the only terrestrial broadcaster in Bangladesh, and once it completes the digitization of its broadcasting services then it will be limited to a small region of the UHF band and most part of the band will lie vacant. There has to be the assessment that whether the use of TVWS technology be allowed only in the white spaces between the occupied broadcasting channels or to the remaining part of the unused (which forms the major portion of the UHF band) or freed spectrum after digitization. Department of Broadcasting also needs to be consulted to gather data regarding the spectrum usage for terrestrial broadcasting over the entire geography of the country so that their services are protected if and when TVWS technology is deployed. The country profile of Bangladesh is figure out in Table 4.

Table 4: Country profile of Bangladesh

General Indicators	Frequency Indicators	ICT Indicators	Urbanization & Geography
Population: 162 million(year of 2016) **Area:**143,998 sq km (55,598 sqmiles) **ICT Regulator:**Ministry of Information and communication Technology (ICT) Division	**Regulator:**Bangladesh Telecommunication Regulatory Commission (BTRC) **Number of TV Stations:** 43 **Radio Stations:** 30	**Number Telecom Operators:** 6 **Internet Penetration:** 35% (May 2017,BTRC) **Mobile Penetration:**89% (June-2017,BTRC) **Domestic Bandwidth Capacity:**200gbps **Cost of Bandwidth:** 5USD(June-2017,BTRC) **Submarine Cables:**1(one, Bangladesh Submarine Cable Company Limited) **Internet Service Providers:**182(2016) **WiMAX service Providers:**3 **VSAT Data Providers:** 12(Source:BTRC) **Domain name:** .bd	**By Population:** -70% Rural -30% Urban **Mountainous and river landscape:** -Hill Tracts is about 13,184 km -Highest point in the country:986 meters Difficult terrain for fiber deployment and Expensive -Densely of rural population

In Bangladesh the total number of Internet Subscribers has reached 80.483 million at the end of December, 2017. The result of the Internet subscribers is shown in Table 5.

Table 5: The Internet subscribers are shown below [7]

S/N	Operator	Subscribers (Million)
1	Mobile Internet	75.050
2	WiMAX	0.089
3	ISP + PSTN	5.344
	Total	80.483

3.2 SWOT Analysis for TVWS in Bangladesh.

A SWOT analysis involves specifying the objectives of the TVWS implantation project and identifying the internal and external factors that are favorable and unfavorable to achieve that broadband internet connectivity in rural areas in Bangladesh. The Table 6 shows SWOT Analysis for TVWS in Bangladesh for rural connectivity. Table 6 represents SWOT Analysis for TVWS in Bangladesh.

Table-6: SWOT Analysis for TVWS in Bangladesh.

Strength	Weakness	Opportunities	Treat
-Digital Migration has already commenced -Extensive nationwide TV coverage - Government promotion of rural connectivity -Submarine cables deployed.	-Lack of Knowledge of TVWS among ISPs - Lack of regulatory framework on TVWS deployment. -lack of regulatory framework that covers TVWS	-Large part of the population resides in rural area -Availability of unlicensed TV Frequency - Platform for new wireless broadband entrance. -Low internet penetration in the rural Communities. -Enhance Educational services within the rural Communities.	-Rural-Urban migration - Rural market unattractive to telecom operators. - Strong competition from existing operators - resistance from broadcasting operators

3.3 TV White Space availability and Broadcasting Status in Bangladesh

Bangladesh Telecommunication Regulatory Commission(BTRC) is a regulatory authority to distribute spectrum Band. The table 7 shows of BTRC Frequency Band Allocation and Broadcasting Status in Bangladesh

Table 7: BTRC Frequency Band Allocation and Broadcasting Status in Bangladesh [6]

Band MHz	Up Link MHz	Down Link MHz	Total BW MHz	Broadcasting Status
450	450-457.5	460-467.5	7.5	*3 MHz is free *Allocated to private PSTN
UHF	698-806		108	
850	825-845	870-890	20	*Fully Allocated *Allocated to mobile & private PSTN
900	890-915	935-960	25	*Fully Allocated *Allocate to Mobile operator
1800	1710-1785	1805-1880	75	*15.6 MHz is free *Allocated to Mobile & One private PSTN
1900	1880-1910	1960-1990	30	*22.20 MHz is free *Allocated to 3 private PSTN but one operative
2100	1920-1960	2110-2170	40	*Free to allocate
2300	2300-2400		100	*Fully Allocate *Allocated to Broadband including WiMAX
2500	2500-2690		190	*FDD portion 70 MHz is free *TDD 35MHz is allocated to WiMAX.

3.4 TV White Space Standards

Several TV White Space standards have been developed such as IEEE 802.22, IEEE 802.11af, IEEE802.19.1, IEEE 802.15.4m, IEEE 1900.7 and ECMA 392 [21]. Of all these standards, the two most relevant standards in providing rural connectivity are IEEE 802.22 and IEEE 802.11af. IEEE 802.19.1 is relevant in terms of coexistence of IEEE 802 family operating in TV White Space.

1. IEEE 802.22(WRAN): IEEE 802.22 was the first standard based on Cognitive techniques that has been developed to access the TV White Spaces [10]. The most important application of this standard is to provide wireless broadband access in rural and remote areas. The standard specifies that a large range of 33 km can be achieved with only 4 W of effective Isotopically Radiated Power (EIRP). The standard uses both geo-location database and sensing based techniques to access the TV White Spaces. As, Bangladesh scenario is almost static, the use of geo-location database can suffice. This standard is capable of working in any regulatory regime (e.g. US, Japan, UK, Canada, etc.). The operational range of this band is 54-862 MHz and can work with various TV channel bandwidths i.e. 6, 7 and 8 MHz IEEE 802.22 follows a Point to Multi-Point (PMP) topology with a Base Station (BS) and its associated Customer Premise Equipment's (CPEs). To protect the incumbents, it follows a strict master-slave relation where BS is a master and the CPEs are its slaves. No CPE can transmit before receiving an authorization from the BS.

2. IEEE 802.11af: IEEE 802.11af standard or the White-Fi was formulated to adapt the existing IEEE 802.11 for TV band operation [11]. IEEE 802.11af systems operate on frequencies below 1 GHz and uses geo-location database to access the TV band. This standard was designed due to the congestion in unlicensed band i.e. 2.4 GHz and 5 GHz spectrum. There are two operating scenarios of IEEE 802.11af viz. indoor and outdoor. The indoor scenario has a range of up to 100 m similar to Wi-Fi. The outdoor scenario has a range of about few kilometers and is more suited for the rural setting. As TV channels may have varying bandwidths of 6, 7 or 8 MHz, it is required to aggregate the bandwidth. This standard works with the bandwidth of 5, 10, 20 and 40 MHz and hence depending on the availability of the channel, this bandwidth can be adapted.

IV. RECOMMENDATIONS FOR BANGLADESH

4.1 Proposed Recommendations to Implement TVWS in Bangladesh

1. Development of Regulations and licensing framework for Dynamic Spectrum Allocation
2. Need for a well-managed Geolocation Database
3. Monitoring the development of the technology to avoid interference with broadcasting operators
4. Regulators should consider allocation license exempt managed use of TVWS
5. Development of TVWS usage conditions for authorized
   - -Acquisition of trial authorization license
   - -Utilization of 470 MHz - 694 MHz frequency band
   - -Provision & use of spectrum on non-protected, utilization of spectrum on non-interference basis, & non-exclusivity license
   - -Type Approval of equipment used for TVWS to avoid interference
6. Universal Service Funds should support the deployment of this technology for rural broadband connectivity

4.2 Proposed Design of Rural Broadband using TV white space in Bangladesh

In Figure 3 proposed depicts how a TVWS based communication network can be deployed in the rural areas. Two main types of deployment options have been shown here. One depicts the master-slave kind of communication between the WSDs, mainly a point to multipoint type of deployment scenario. The slave WSD may then emulate Wi-Fi or any other communication technology compatible with the User Equipment. If the user equipment supports, TVWS communication standards like 802.11af then that can also be supported by the slave TVWSD. The other scenario in the figure depicts the TV band being used to provide middle mile connectivity to the Base stations and repeaters to reach the far flung rural areas which are then served by Wi-Fi in the last mile. There can be other deployment scenarios pertinent to the rural areas depending upon the requirement. 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. For example, 689 MHz frequency band can be used as a frequency band for transmitting and receiving at 31 m and 5.5 m heights (assumed) to provide internet connectivity in rural areas. In this case QPSK and QAM modulation techniques can be used here. Point to point Topology, IEEE 802.22 standard, link budget calculation and Hata model are consider to achieve coverage distance result in rural broadband. The results are showed in Table-7. In Bangladesh Average One thousand peoples live in one kilometer cycle. In figure 4 shows almost seven or eight times higher Number of user connected TVWS Technology compare than other wireless technology During Downlink and in figure 5 shows almost six or seven times higher Number of user connected TVWS Technology compare than other wireless technology during uplink in Rural Areas.

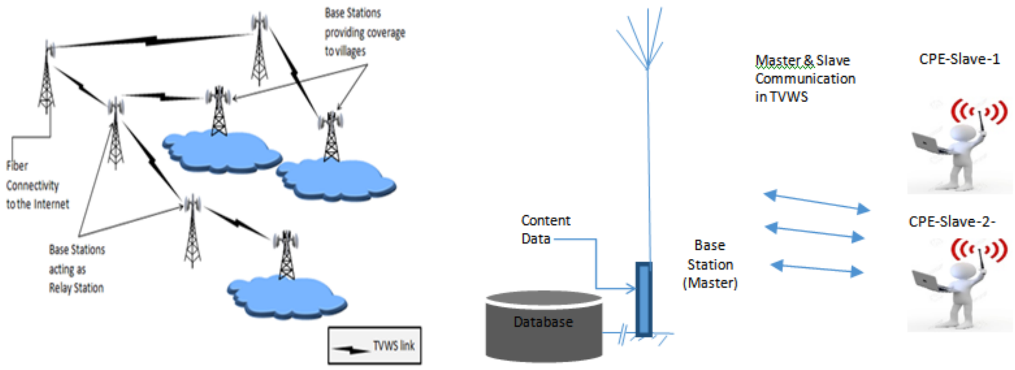


Figure 3: Proposed design of Rural Broadband using TV white space

Table 7: Comparison coverage range between TVWS & Other Wireless (WiMAX/Wi-Fi) in Rural Areas

Modulation Technique	DownlinkCoverage Area in rural Area		Uplink Coverage Area in rural Area	
	TVWS	Other Wireless (WiMAX/Wi-Fi)	TVWS	Other Wireless (WiMAX/Wi-Fi)
QPSK 1/2	59 km	7 km	61 km	9 km
QPSK 3/4	46 km	6 km	49 km	8 km
QPSK 7/8	42 km	5.5 km	45 km	7.5 km
16 QAM 1/2	40 km	5 km	41 km	7 km
16 QAM 3/4	29 km	4 km	31 km	6 km
16 QAM 7/8	23 km	3.5 km	27 km	5 km
64 QAM 3/4	21 km	3 km	19 km	3 km
64 QAM 7/8	18 km	2 km	17 km	2 km

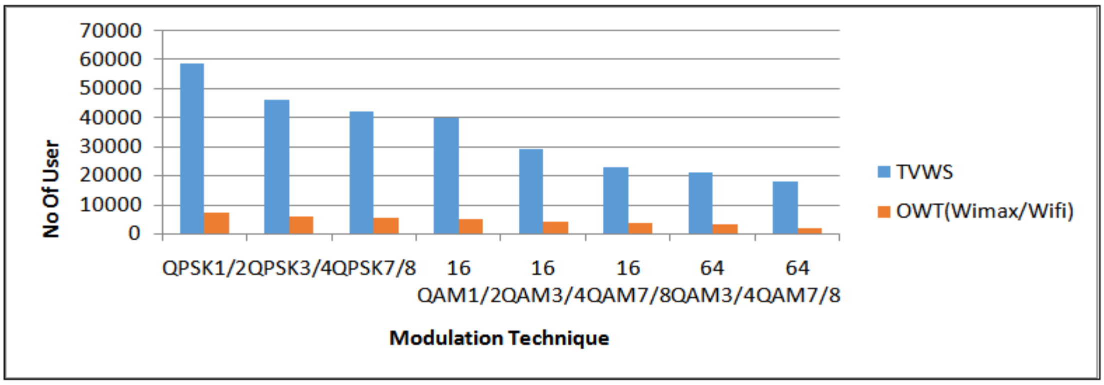


Figure 4: Comparison Number of user connected between TVWS & Other Wireless (WiMAX/Wi-Fi) Downlink in Rural Areas

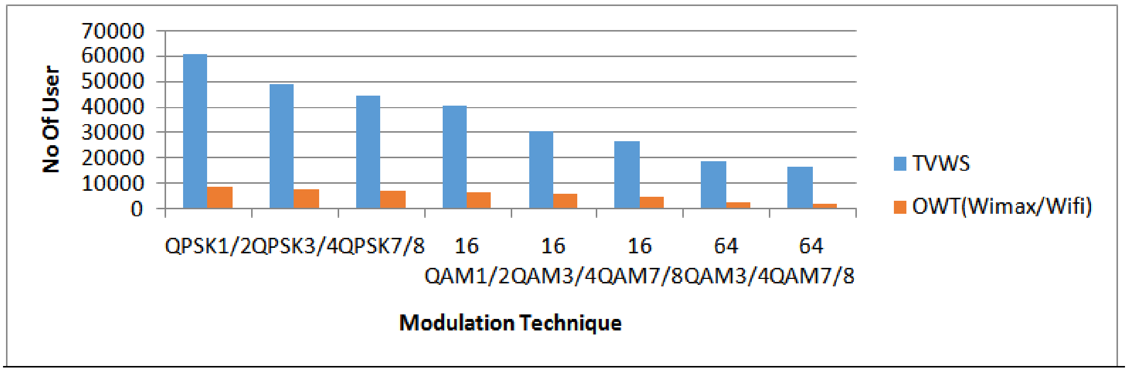


Figure 5: Comparison Number of user connected between TVWS & Other Wireless (WiMAX/Wi-Fi) Uplink in Rural Areas

4.3 Proposed Regularity Framework in TVWS usage in Bangladesh

Proposed Regularity Framework in TVWS usage in Bangladesh noted in figure 6.

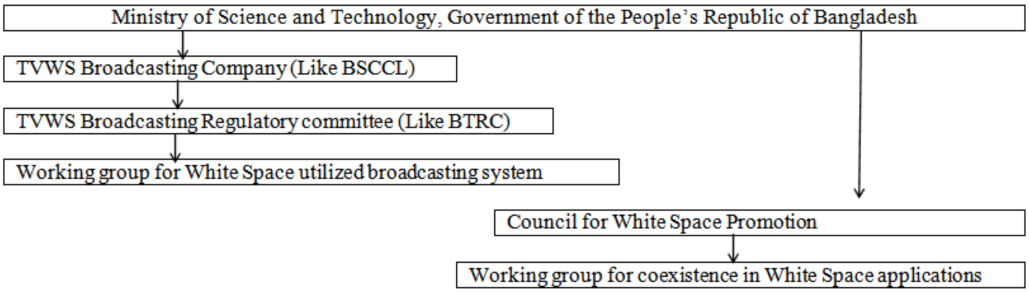


Figure 6: Proposed flowchart of Regularity Framework in TVWS usage in Bangladesh

4.4 Proposed Stakeholder position towards TVWS in Bangladesh

In Bangladesh TVWS in different Stakeholder, those Stakeholders are noted in Table8.

Table 8: Proposed Stakeholder position towards TVWS in Bangladesh

Public Institute	Telecom Operator	Manufacturer	Broadcaster	Svc/OTT Operator
-Free Public Wi-Fi -Remote Metering Monitoring & Control -Public safety Applications	-Negative on public Wi-Fi -BH Solution for rural Areas -M 2M Service Application -Active in regulation development & trials	-New Biz Opportunities in communication system market	-Additional DTV Channels in TVWS Band -Requires strict regulations for TVWS interference	-Monitoring on going technical /regulation development.

4.5 Proposed Financial Analysis

Proposed Financial estimations for one TVWS base-station deployment facilities, and one-year operation cost in Bangladesh are given in Table 9.

Table 9: Proposed Financial cost estimations for TVWS in Bangladesh.

Development Equipment item	Cost in BDT Taka*
Tower, Building & BU Power	12,00,000/-
Infrastructure equipment installation	2,00,000/-
Electronics — Client Unit & Antenna	2,80,000/-
Electronics — Back-office Systems	8,00,000/-
Internet Bandwidth Cost	2,50,000/-
HR Development & Training	10,00,000/-
TVWS Engineering & Other Services	6,00,000/-
Total	**43,03,000/-**

* This estimation is NOT final, and will vary for specific regions and the conditions of serving areas.

4.6 Cost Comparison of Rural Broadband Connectivity

Cost Comparison of Rural Broadband Connectivity compare than Other Wireless &Wired (Fiber optic) Connectivity is given in Table 10. As well as Comparison of TVWS with other wireless Technologies are also given Table 11.

Table 10: Cost Comparison of Rural Broadband Connectivity

Parameter	TVWS Broadband Wireless Connectivity Cost for Throughput 22 Mbps & 44 km Coverage Distance (approx.)		Other Wireless & Wired (Fiber optic) Connectivity Cost for Throughput 10Mbps & 11Km Coverage Distance (approx.)	
	BDT	**USD**	**BDT**	**USD**
Monthly Maintenance Costs	40,000/-	$ 490	4,00,000/-	$ 4400
Installation, per site	68,000/-	$ 850	3,30,000/-	$ 4100
External Wiring	3,30,000/-	$4000,persite	4,00,00,000/-	$44000
Equipment Cost, per site	4,40,000/-	$ 5500	4,00,000/-	$ 5000

Table 11: Comparison of TVWS with other wireless Technologies

Parameter	TVWS Connectivity	Wi-Fi or Other Wireless Connectivity
Distance Coverage	Can travel up to 50 km over various terrains	Can cover distance up to 4-6 km
Smooth Connecting of Coverage Area	Cover nearly 3,000 km2 with single base station	Hop for one hotspot to another
Internet Handoff	Universal internet Coverage.	loss of internet connectivity between hotspots
Number of supportable user	In TVWS can support 40-48user per Customer Premise Equipment (CPE) in a rural Configuration.	In Wi-Fi or Other Wireless connectivity can support 2-3user per CPE in a rural Configuration.

V. MARKET TRENDS AND OPPORTUNITIES OF TVWS

5.1 Advantage of TVWS [1]

The key advantages of long range and good penetration for TVWS translate into the following advantages:

- Lower cost of capital expenditure (CAPEX): with longer range and better penetration, a smaller number of devices are required to connect up an area. As such CAPEX can be significantly reduced. Savings of up to 90% can be expected.
- Lower cost of operating expenditure (OPEX): with license-exempt nature of TVWS as well as lesser installations (site access, rental, etc.), the cost of owning and operating a network is much lower than alternatives.
- Easier and faster deployment: TVWS can be deployed very easily and quickly. This also translates to lower cost of deployment besides the non-tangible savings it gives such as minimal disruption to people & businesses, faster replacement of existing technologies, etc.
- Better performance: TVWS is lesser affected by rain, haze and other natural disturbances. Therefore, TVWS network is much more stable compared to networks using higher frequencies such as 2.4 GHz or 5.8 GHz.
- Lower latencies: due to the larger available bandwidth, the latencies, especially for large networks are greatly reduced. Comparing to narrow-band IoT networks operating at 900 MHz bands, the latencies can be reduced by up to 100 times.
- Reduced security risk: networks with narrower bandwidth and thus smaller capacity are more susceptible to security attacks, e.g., when DDoS attacks happened, smaller capacity networks can be brought down easily. With larger capacity available for TVWS, DDoS attack is more difficult.

5.2 Disadvantage of TVWS [3]

- White space is variable and unlicensed. An assigned channel in one area may not be available in another. This could be a problem for some applications.
- Radios designed to use white spaces must be widely frequency agile. Wide band frequency synthesizers are available to make frequency assignment less of a problem, but power amplifiers are more difficult to make for such a wide band.
- When using unlicensed spectrum, you may at times be sharing space or adjacent channels. That means potential interference, such as from or to wireless microphones. For applications requiring good channel reliability, that may be a knockout factor.
- To be effective, any wireless device needs a good antenna. On the higher channels (500 MHz+), antennas are small. For example, a half wave antenna at 700 MHz is only about 8 inches. At 300 MHz, it would be 18 inches. At 54 MHz, that translates to almost 9 feet for a half wave. Long antennas are not a big problem for fixed applications but become a major obstacle in portable devices.
- The FCC requires radios to access certified databases in real time to find an open channel, ensuring minimum interference. These databases list TV stations and other licensed and unlicensed wireless devices such as wireless microphones that can potentially interfere with one another in a given area. Device data such as location, type (fixed or mobile), power level, and other factors are included. It has taken time for these databases to come on line, and the FCC is just now in the process of certifying them for use.
- There are no radio/network standards in place. Numerous proprietary standards have been tested but none has emerged as a clear favorite. Two are now available: the IEEE's recently approved 802.22 standard and the forthcoming 802.11af Wi-Fi variation.

5.3 Potential Applications of TVWS [1]

The potential applications of TVWS can be broadly classified into 2 categories:

1. For broadband connectivity
- ✓ Rural Internet/Broadband
- ✓ Cable replacement (e.g., cable-less roll out of Wireless@SG)
- ✓ Private networks
- ✓ Fast deployment (e.g., during disaster, ad-hoc events)

2. For IoT connectivity
- ✓ Smart grid
- ✓ Smart street lighting
- ✓ Smart buildings
- ✓ Industry 4.0
- ✓ Precision agriculture

VI. CONCLUSION

The availability of TV White Spaces presents a great opportunity for a better coverage and substantial bandwidth for the broadband communications. In this paper, we have proposed a wireless broadband network based on TV White Spaces along with a sustainable economic model which can not only provide connectivity but also enable successful operation of the network at the rural areas. 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 Bangladesh. A study on combining both spectrum sensing and geolocation databases for TVWS access will be the major agenda of our future work.

REFERENCES

[1]. http://www.ipi-singapore.org/technology-offers/tv-white-space-super-wi-fi

[2]. https://www.microsoft.com/en-us/research/wp-content/uploads/2016/02/spectrum-microsoft-super-wifi-overview.pdf

[3]. http://www.scriptmag.com/wp-content/uploads/tv-pilot.jpg

[4]. Telecommunications Regulatory Affairs Advisory Committee Development of TV White Space Technology, TRAAC Paper No. 6/2014.

[5]. http://www.slideshare.net/hellomariajoseph/tv-white-space.

[6]. Bangladesh spectrum present and future, Bangladesh perspective, Asia -pacific tele community, 1stmeeting of SATRC working group on spectrum in SAP-iv,10 – 11 October 2012, Dhaka, Bangladesh.

[7]. http://www.btrc.gov.bd/content/internet-subscribers-bangladesh-december-2017.

[8]. http://www.slideshare.net/meshingom/tv-white-space-for-rural-broadband-connectivity, Source: Beveridge, J & Webb, W., 2013

[9]. SATRC Report on challenges of future technologies in spectrum management: cognitive radio, developed by SATRC Working Group on Spectrum, 13th Meeting of the South Asian Telecommunications Regulator's Council 18 – 20 April 2012, Kathmandu, Nepal.

[10]. C. R. Stevenson, G. Chouinard, Z. Lei, W. Hu, S. J. Shell hammer and W. Caldwell, \IEEE802.22: The first cognitive radio wireless regional area network standard," in IEEE Communications Magazine, vol. 47, no. 1, pp. 130-138, January 2009.

[11]. A. B. Flores, R. E. Guerra, E. W. Knightly, P. Ecclesine and S. Pandey, IEEE 802.11af: a standard for TV white space spectrum sharing," in IEEE Communications Magazine, vol. 51, no. 10, pp. 92-100, October 2013.

[12]. G. B Padaki & R. V Hegde, "Connecting Next Billions: Rural Area Broadband Access Network using Saankhya Labs TVWS technology" Saankhya Labs Pvt Ltd, Bangalore.

Manjurul H. Khan." TV White Space in Rural Broadband Connectivity in Case of Bangladesh Toward "Vision 2021" American Journal of Engineering Research (AJER), vol. 7, no. 3, 2018, pp. 36-45.