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MakeDigital India in India using TV White Spaces

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Digital India: Vision

The vision of the Government of India for creating a "Digital India" has brought to fore-front, the issue of providing digital connectivity in our country. While Telecom players compete for the urban share of this digital connectivity pie, the major challenge is in reaching the large semi-urban and rural population.

One could define Digital India as ubiquitous data connectivity where people in every single village in India have internet access in each school, healthcare center, farmer, small business and eventually every home!

Benefits to Rural India

When other basic infrastructure is lacking in rural India a question would naturally come up: Why is Digital connectivity so important? The simple answer is that it can become the best leveler in today's digitally divided society. Lack of access to the internet is a big disadvantage today and affects all aspects of life. Let us look at how digital access can help improve the quality of life of rural population in the following ways:

- **Education**

  Lack of well-trained teachers and teaching materials is the single biggest disadvantage faced by children in rural government schools. While broadcast TV has been around for decades in India it is not suited for primary education where children need a lot of hand-holding which can only come from interactivity.

  IIM-Bangalore's unique interactive education program SAME, which is operational in 1000 schools of Karnataka plans to overcome this by introducing interaction with teachers. In this program a teacher conducts a live-session with well-thought-out education material in the student's mother tongue and this is broadcast over satellite. What makes this program unique is the element of interactivity which makes it possible to have question-and-answer sessions with the teacher. Teachers are also able to track students' understanding through discreet and casual quizzes answered on-line by every student and sent over interactive link to a central server. Effectiveness of students' learning is measured to fine tune the teaching material based on that. Today the main hurdle in this unique program is the lack of 100% broadband digital connectivity to every school that would make interactivity possible. While DSL broadband can connect about 30-50% of these rural schools today, the remaining schools are not reachable due to the difficulty in drawing up a copper line to reach a single school located 20-30Km away. Clearly bridging this digital divide can make a big difference to the lives of the most disadvantaged student.

- **Healthcare**

  Tele-medicine is an upcoming application of digital connectivity that allows benefits of expert healthcare professionals from urban areas to interactively diagnose and treat patients in far-flung rural areas.

  IISc (Indian Institute of Science), Bangalore is developing an infant health monitoring device that can automatically report vital health parameters (temperature, heartbeat, saturation) of neo-natal babies during the first 1-2 weeks at a primary health care center in rural areas. In case of any adverse changes in parameters the central monitoring system would trigger alerts for action. Such technology can clearly help in improving infant mortality rates in far-flung corners of the country. Similarly telemedicine could enable preliminary diagnosis of diseases for patients of all ages by expert healthcare professionals located in cities.

- **E-Governance**

  Many state governments run e-governance projects that cater to needs of the rural population within

accessible distances. Kiosks are set up at to deliver services from a single-window approach for variety of departments from land records, bill/tax payments, transport authority certificates, birth/death registration. Such reach is not available to all villages today and a major hurdle is lack of pan-India digital connectivity. With it these services could be extended to each Gram Panchayat level in every state.

- **Agriculture**

  Krishi Vikas Kendras in each and every gram Panchayat can provide agriculture related information and education to farmers for better productivity and crop planning. Digital connectivity can enable better pricing, demand forecasting and supply information for farmers. Portals like ITC's e-chaupal are examples of this.

- **E-commerce & E-banking**

  In today's world e-commerce is a big business enabler but it is dominated by consumer (buy-side) connectivity to markets. But a far more impactful trend is the sell-side market access. Portals like AliBaba now enable a small village business in China from putting up his goods for sale to any corner of the world. This aspect can revolutionize rural industry and businesses by eliminating intermediaries and providing direct market access. Similarly schemes like rural e-banking via Jan-DhanYojana require digital connectivity to be effective.

Digital Connectivity: Status

Today there is a reasonably good backbone infrastructure for digital connectivity extending up to District and Block/Taluka levels in rural areas of India. Every such telephone exchange has Optical Fiber connectivity of 1 Gbps data rate. The newly sanctioned NOFN (National Optical Fiber Network) program aims to extend the fiber connectivity through GPON technology to 2.5 Lakh Gram Panchayats (GP).

Hurdles to a *truly* Digital India

The Last-Mile Gap

NOFN program addresses the backbone infrastructure but it will only extend connectivity to GP. It does not solve the most crucial "Last Mile" connectivity to village households, schools and primary healthcare centres etc. So unless the rural user is connected to this vast infrastructure we will continue to encounter what is called the "dark fiber" issue – where fiber is laid but is not "lit-up" because there is no user traffic going through it! The NOFN initiative is an excellent launch pad, but a truly Digital India will only be fulfilled when connectivity bridges the last mile gap to every end user in every village!

A 'Typical' Gram Panchayat needs connectivity for

- 4 schools, 1 Public Health Center, 1 Krushi Vikas Kendra, 1 e-Governance center, 2 e-Kiosks and 500 households
- Spread over 10-20 square Km
- How do you reach these economically?

Rural Last-mile v/s Urban Last-mile

How do we bridge this "Last-Mile" gap in rural areas? What works in urban areas for last mile will not be cost-effective in rural areas. The main difference is the population density in rural areas is much lower compared to urban areas. Due to the sparse population density in villages the so-called Last-mile gap would actually turn out to be the "Last-10Km" gap. Cellular towers have a range of 2 to 4Km which would require a large number of towers to be installed to cover a smaller population. Terrain in rural areas also tends to have thick foliage or uneven terrain (hills etc.) which shrinks the area served by each tower.

Rural ARPU's (Average Revenue Per User) will be lower than urban ARPU. So while urban areas can be covered cost-effectively through 4G or 3G Cellular Broadband technologies, they will not be viable for rural areas.

Clearly bridging the Rural Last-mile requires a different approach.

Gaps in the Fiber

Laying fiber to 2.5 Lakh GP's is an onerous task and in many places it will encounter logistical difficulties such as Right-of-way issues through private land, thickly forested areas and hilly terrain. Such areas will need a solution that can help span such large areas through minimal installation.

Also the remaining 3.5 Lakh villages which will not be covered by NOFN also need to be reached through other means.

Digital Divide: A Global issue

The issue of rural connectivity is not peculiar to India. Even developed countries like US, UK have significant chunk of rural population that does not have digital connectivity. The FCC of US in a report last year said "An estimated 15 million Americans, primarily in rural communities, don't even have access to entry-level broadband in their homes. Forty-one percent of American's rural schools couldn't get a high-speed connection if they tried."

It is estimated that World-wide nearly half of the population is still not connected which means the problem is shared by 3 Billion people!

TV White Spaces: An introduction

Transition from Analog to Digital TV

Terrestrial TV transmission is carried out in designated bands VHF (30 to 300MHz) and UHF (300 to 900MHz) regions of the electromagnetic spectrum.Traditionally terrestrial TV signal is transmitted using Analog modulation schemes like PAL in India/Europe, NTSC in US and SECAM in France/Russia.The bandwidth for each TV channel is divided into 6, 7 or 8MHz bands depending on the country. Each band could carry one program (or TV channel) in analog transmission mode. Terrestrial TV is the "traditional" TV reception that was done using Roof-top Yagi antennas.

During the last decade most countries have decided to use, started using or testing Digital TV modulation standards like DVB-T2/DVB-T in India/Europe/Africa, ATSC in USA/South Korea, DTMB in China and ISDB-T in Japan/Brazil. Some countries have both analog and digital transmissions ongoing today and some countries (like USA) have switched-off analog TV transmission altogether or have announced dates for future analog switch-off.

The advantage of digital TV transmission is that it offers highly efficient usage of the spectrum because compression technology (MPEG2/4/H.264) which allows up to 20 TV programs to be packed in one 8MHz band which would fit only a single TV program with analog transmission. Digital TV now allows high-definition content (progressive scan 1080 lines x 1920 pixels) to be aired with up to 6 times better image resolution than analog TV (interlaced scan 576 lines x 720 pixels). Further it allows mobile-TV transmission (as in DVB-T2-Lite), advanced features like Electronic Program Guide and provision for interactivity.

What are TV White Spaces?

Digital TV requires fewer bands than analog TV even after accommodating larger number of programs and high-definition content. This frees up bands in the VHF and UHF range and these unused gaps in spectrum are called TV White Spaces. The exact bands that get freed-up vary from region to region as per usage and regulations. The illustration below shows TV White Space bands around Digital Terrestrial Transmission (DTT) bands and some Local usage bands.

India also has availability of unused terrestrial TV bands! IIT-Bombay has studied potential for TV White Spaces in India in its paper.

White Space policy regulation

As part of migration to Digital Terrestrial Transmission (DTT) world-wide it was recognized that the freed-up spectrum (also called "Digital Dividend") could be put to new use. While some of this spectrum was licensed to Telecom players, it was also recognized that some part of this freed-up spectrum should be reserved for unlicensed operation that could enable innovative consumer applications – these unused gaps of spectrum are called TV White Spaces.

The Economic potential of White Spaces

It was already evident that de-licensing of 2.4GHz spectrum for WiFi had produced a tremendous social impact that allowed creation of a large number of wireless connectivity applications. In astudy published by Professors at Stanford University they note that unlicensed spectrum led to WiFi and RFID applications that contribute to an economic value of 16 to 37 Billion US Dollars every yearin US alone!

In US, the Federal Communications Commission

(FCC) - which is their national regulator of communications – established a regulation to enable use of TV White Spaces for Wireless Rural Broadband. It also set up a database administration for the entire US that recorded usage of TV spectrum by geographical location and in real-time allowed users to query which bands could be used as TV White Space for unlicensed operation.

Earlier this year UK's regulator OFCOM has also established a TV White Space policy.Similarly regulators in Japan, Singapore, South Africa, Korea, China and Philippines have established or are in the process of establishing similar policies.

Co-existence with Terrestrial Transmission

Regulatory authorities like FCC and OFCOMhave specifications for TV White Space devices to avoid interference from White Space devices into terrestrial TV receivers or devices like wireless mikes.

Communication Standards& Industry

An important aspect of actualizing communication equipment is establishing industry-driven communication standards for TV White Spaces. This allows multiple vendors to provide equipment that while competing will also inter-operate. Industry body IEEE (Institute of Electrical and Electronics Engineers) has established two communication standards for TV White Spaces:

a) IEEE 802.22 standard for Wireless Regional Area Network (WRAN)

   This standard is created for Wireless Fixed Rural Broadband applications that can cover distances ranging from 1Km to 100Km.It is designed for efficient sharing of bandwidth among users.

b) IEEE 802.11af standard for Wireless Local Area Network (WLAN)

   It is for extending range beyond traditional WLAN technologies like WiFi and can work within a building or across short distances within 1Km.

There arealso two Global industry associations called White Space Alliance (WSA) and Dynamic Spectrum Alliance (DSA). WSApromotes development & deployment of broadband solutions using White Spaces. DSA advocates laws and regulations for efficient use of spectrum.

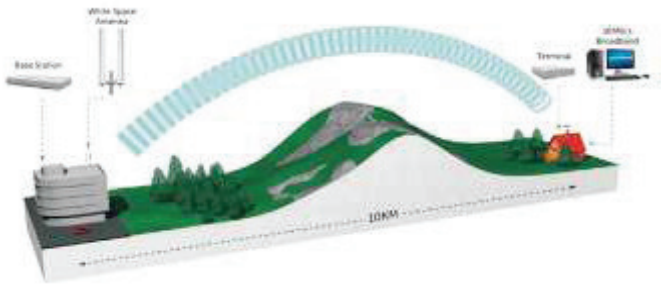


Figure TV White Space Non-LOS communication [image credit: Carlson Wireless Inc]

Advantages of Sub-Giga Hertz Signals

Long-distance Communication √

UHF and VHF signals in sub Giga-Hertz (frequency < 1GHz) spectrum have favorable properties that makes long-range (10 to 100Km) communication possible. At these wavelengths a signal transmitted at a given power-level suffers lower attenuation and hence can be received intelligibly at receivers further out from transmitter. As an example: a sub-GHz TV signal at 30dBm (=1W) radiated power (EIRP) can reach 10Km whereas a 2.4GHz WiFi at 30dBm can only reach 100m in outdoor conditions.

Non Line-of-Sight propagation √

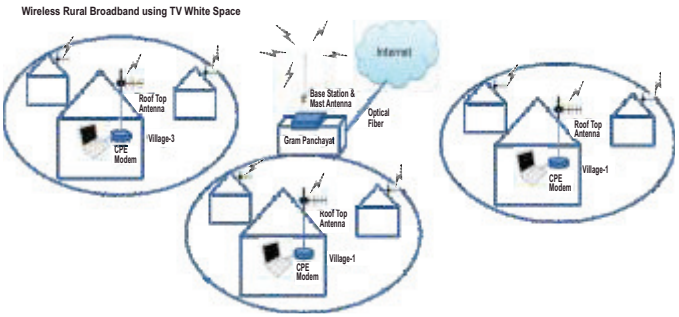
Sub Giga Hertz signals can also undergo diffraction (bending) around corners/edges of obstructing features such as buildings, trees and hilly terrain in the inner Fresnel zone. This allows Non-Line-of-Sight (N-LOS) communication, i.e. signal can be received even when there is no direct straight line path (i.e. it is obscured by objects of certain size) between transmitter and receiver.

TV White Space: the master-stroke needed for Digital India

White Space for Last-Mile Rural Broadband

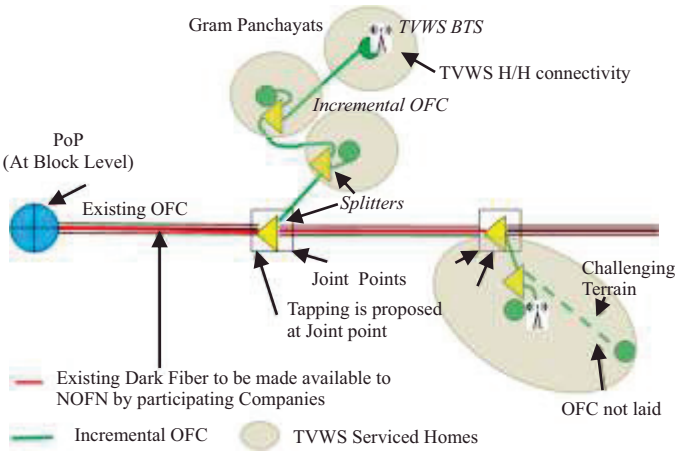
As per NOFN plan a GPON (Gigabit Passive Optical Network) will terminate at each Gram Panchayat (GP) building. The diagram below shows how a TV White Space (TVWS) solution can enable wireless broadband connectivity for individual user premises spread across the village. At the GP a TV White Space (TVWS) Base Station will be fed by the optical backhaul equipment Optical Line Terminal (OLT) which would give out a 100M/1G Ethernet to a TVWS Base Station. The Base

Station has a bi-directional RF interface (Up-link and Down-link) compliant to the IEEE 802.22 standard. This RF signal interfaces over a coaxial cable to a tower-mountedomni-directional antenna that will transmit the wireless broadband signal to multiple user equipmentwithin a range of 10 to 100Km depending on antenna height and transmitted power. User premises will have directional Yagi-type antennas mounted on roof-tops and which will feed the Customer Premise Equipment or Modem compliant to IEEE 802.22 standard. The Modem will then distribute the broadband within the user premises using standard LAN protocols such as Ethernet or WiFi.



White Space to fill gaps in Fiber to un-reached villages

TVWS technology can help reach broadband to villages that do not have an Optical Fiber reaching them. Here TVWS will operate as a wireless relay in Point-to-point (P2P) mode of operation. In this mode at each relay location there would be a TVWS Relay equipment that would communicate with the back-haul (towards optical network) and with the front-haul that would reach the remote village. Multiple TVWS Relays can operate in cascaded fashion to reach difficulties of terrain.



Benefit of White Space over alternatives

A Launchpad for Triple-play Services

Together with DTT, TV White Spaces offer an excellent mode to deliver triple-play services to rural areas. Broadcasting companies can now offer not only Broadcast TV or Mobile TV but also Broadband and Voice using VOIP technology.

Lower Capex costs

Rural areas are characterized by sparse population density, where small population is spread over a large area. Long distance reach of White Space technology allow a smaller number of Base Stations to cover such users, compared to shorter range technologies such as Cellular 3G/4G.Due to this it is estimated that White Space infrastructure would incur one-tenth the cost of deployment.

Lower Opex costs

Due to its lower power consumption TVWS broadband equipment could be solar-powered which would reduce its operating expenses as well.

Ease of installation/maintenance

Because it is a Wireless technology there are no issues with right-of-way or cost of digging, repair or replacement that would occur with Optical Fiber installation.

Why not WiFi for Last-mile?

WiFi standard was designed primarily for indoor LAN usage with short distance coverage (100 meter range). Some solutions attempt long range outdoor coverage by increasing radiated power which apart from creating health-hazards does not achieve the kind of range required for rural coverage. Due to its operation at 2.4GHz it is not capable of propagating well through walls, forests, hilly terrain. Another major drawback with WiFi is that it operates on the CSMA/CA protocol ("Listen-before-talk") due to which more than 5-10 users leads to fast degradation of service and poor data rate due to increased "collisions" between user traffic. This leads to poor end-user data rates.

Why not Cellular for last mile?

3G/4G Cellular technologies were designed for city

usage with high-density coverage. These base-stations have a short-range, so it would need a large number of base-stations to cover sparsely populated rural areas. This means larger investments are required to reach rural users. Even developed countries like US with good cellular network coverage in cities have rural populations that have zero coverage because telecom companies find it unviable!This is one reason for emergence of TV White Space technology to address their rural broadband coverage issue.

An umbrella of Drones, Balloons and Satellites…?

There are other futuristic options being investigated to address the Last-mile gap. Facebook is exploring use of an umbrella of Drones and Satellites. Google is looking to use high-altitude Balloons. However all of these are not near-term solutions and even if they succeed will take 10 years to mature and be available at affordable costs.

Make Digital India in India!

Perhaps for the first time in history India has a lead in developing a Telecom standard like TV White Space. Indian academia and industries have played an important role in development of TV White Space standards and have already developed products for the world market.

As the rural broadband gap is a world-wide issue India can not only cater to its domestic market but also export these products to countries like USA, UK, Korea, Nigeria, South Africa, Philippines, Singapore.

India leads in 802.22 & TV White Space!

- Indian academia and companies have been early adopters of IEEE 802.22 TVWS standard
- White Space Alliance has an active India Chapter
- IIT-Bombay, IIT-Delhi, IIT-Hyderabad, IIIT-Bangalore, IIT-Madras have done pioneering work and are collaborating on TV White Spaces for rural broadband
- IIM-Bangalore, and IISc have excellent rural initiatives in Education & Healthcarethat would benefit from TVWS technology
- Saankhya Labs has recently launched World's first TV White Space products based on IEEE 802.22 standard
- These products are entirely manufactured in India and will not only be made but also developed in India

Conclusions

- Digital India cannot be a reality without bridging the Last-Mile Gap in NOFN
- TV White Space Technology provides an excellent avenuetorealize a truly Digital India!
- Provides excellent reach for sparse rural populations in difficult terrains
- Huge economic benefits for Rural India
- Needs a fraction of the capex&opexof other technologies
- Made-in-India TVWS solutions can help in completing the Digital India Vision!

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About The Author

Mr. Hemant Mallapur is a Co-founder and Vice President of Engineering at Saankhya Labs - an innovative Indian startup developing its own wireless communication products.Saankhyahas developed World's first TV White Space based wireless rural broadbandproducts compliant to IEEE802.22 standardusing its own semiconductor chipsets.It is privately-held and funded by Intel Capital and holds many key patents for its Software Defined Radio technology.

Hemant has over 22 years of industry experience in semiconductor and electronic product development. He was one of the early members of semiconductor company Sage Inc. which went public in 1999 (later merged into Genesis Microchip & ST Microelectronics) where he led the development of award-winning chipsets for HDTV's & LCD Displays. He was nominated for the EDN ASIA Innovator Award in 2000. He has been granted 3 US patents and co-authored 3 papers in international conferences.