Wi-Fi based Connectivity Solutions for Smart Villages in India

A Whitepaper

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Introduction

Since 2020 India has already made the giant progress in the digital revolution, however, there is still a long way to connect the unconnected in India. As per a report by the Telecom Regulatory Authority of India (TRAI), there is a 93% broadband penetration in urban India versus a mere 29.3% in rural India. Post COVID-19, this digital divide is worsening the existing societal and economic inequalities in the country. Further, there are concerns about widening the divide due to adopting new digital developments such as digital wallets, Internet of Things, and Artificial Intelligence (AI).

There is a need to empower the rural community members through reliable connectivity and provide them with access to the Internet so they can enjoy the benefits of the modern society and also participate in the digital revolution that is currently underway. Leveraged and scaled, the power of information exchange can provide various opportunities such as smart agriculture, education, telemedicine services, ease of transfer of payments through government schemes, e-commerce, awareness on urban developments, and remote job opportunities.

The major challenges that exist when increasing internet penetration in India are unreliable electricity, affordability of the connectivity and user equipment, negligible industry incentives for low-cost ICT, topographical challenges, cost of infrastructure, backhaul issues, and the performance tradeoffs. Further, the lack of digital awareness in using technology and the cultural reservations as well as language causing the digital divide a huge challenge in India.

Bharatnet

But in the last few years, India has seen more internet-growth in rural areas than in its urban counterparts. This has been a result of an emphatic push for digital connectivity and Digital India, a Government of India campaign, with its dedicated digital drives across rural areas through ambitious governmental schemes, like the flagship BharatNet Project. In the past, rural connectivity grew through undependable microwave links, legacy copper cabling and a little bit of fibre-laying. But fibre-optic technology gained momentum as the game-changer in the network infrastructure-development. Optical Fiber Cables (OFCs) opened up a world of possibilities, in terms of high-speed broadband and low-latency connectivity. OFC-based networks provided reliability in connectivity and drove internet-inclusiveness. The objective of BharatNet was to provide OFC-based connectivity to all villages, with large-mile connectivity to be provided by Wi-Fi or Telecom networks, capitalizing on the high bandwidth fibre-backbone, built under the project. Internet-connectivity and high-speed data-availability, made possible through the OFC-network created by BharatNet, have gone on to assimilate the unconnected & underserved in economy & fulfill the vision of Digital India.

Usecases for Wi-Fi Connectivity

Wi-fi connectivity at common places in villages, CCTV-surveillance, tele-medicine, online education, e-farming, payment-facility for telephone, gas or electricity-connections and easy accessibility to varied governmental schemes will present the rural people with many unique opportunities in life and for living. Young people, being the natural adopters of new technologies, will have access to digital facilities

to get into contact with the broader world, opening up their pathways to education and vocational training in a very cost-effective way.

The following section highlights various usecases that can be adopted in Indian villages to transform the lives of the citizens:

Fig. 1. Rural connectivity use cases

Agriculture:

Over the years, a declining employment size of the agricultural sector has been observed. The internet can improve agricultural productivity such as for sharing essential information on sowing, crop protection, improving soil fertility and weather. Early-Warning-Systems (EWS) provide disaster management support helping farmers prepare for sporadic events such as floods, drought, or even pest and disease outbreaks, thus preventing significant crop loss. It allows for a structured distribution of subsidies such as fertilizers.

Livestock:

Internet helps farmers manage livestock. It enables the improvement of various aspects of livestock production and education and disease prevention. IOT enabled technologies can be used for live tracking and improving the health and quality of the livestock.

Healthcare:

Monitoring health and remotely accessing healthcare services by rural or isolated communities can be achieved through reliable connectivity. Tele-health includes long-distance clinical health care, patient and professional health-related education, public health, and health administration.

Education:

Connecting rural communities will help enable distance education in remote parts of the country, including vocation training classes to build skill-sets such as tailoring and weaving. Digitizing and

recording teaching material for students with visual impairments is making the education sector even more inclusive.

E-governance:

Various government services related to jobs, education, wellness, pension, justices are available on the National Government Services Portal. Connectivity is critical to rural sector to easily avail these e-services.

Banking:

Internet connectivity can strengthen rural access to financial services enabling them to find appropriate insurance, support to manage and mitigate risk. It will assist with better farmer profiling systems for agricultural credit decisions and protection for farmers in times of bad weather or disaster. Governments also use the internet to increase their outreach, improve understanding of policies, and expand credit penetration.

E-commerce:

E-commerce opportunities have been crucial in purchasing and selling agro-based products and handicrafts. With connectivity, comes access to regional and global markets. Rural communities have a platform to showcase diverse cultures and crafts promoting tourism. Indian government initiative called the GeM portal is an e-marketplace from where everyday common consumer goods can be procured.

Challenges

Though the government is encouraging initiatives and projects to improve rural connectivity, there are depth of challenges in providing last-mile connectivity and scale the network. Furthermore, the key challenges as described below with respect to costs, ARPU, digital awareness, power, spectrum bands, and terrain, needs to be addressed to tackle the connectivity issues.

Topography and population distribution:

India has diverse topography ranging plane, plateau to mountain and desserts and extreme climatic conditions. The topography of the village and its population distribution plays a crucial role in the internet connectivity. A sparsely populated village is given lowest priority while deploying networks.

Cost:

The main factor which makes rural connectivity difficult is high cost of providing internet solutions in rural areas. This cost of network is due to various factors such as nonexistence of either backhaul or close by point of presence (PoP), cost of equipment, repair and maintenance, and spectrum licensing in hard to reach locations.

Per-capita income:

Generally, the people living in rural areas have lower per-capita income compared to urban areas. The pricing should be attractive for people living in rural areas to spend on digital applications. There is a need for innovation in lower costs and new revenue models to attract rural areas customers to enroll for internet services.

Business models:

The lack of innovative business models is the major challenge for rural connectivity. The traditional business models are not suitable for rural scenarios as these focuses on high ARPU, high customer base, and high investment duration. In rural scenarios, the traffic generated is low and it is a loss making business. This fuels the need to find innovation in business models to convert this business to profitmaking.

Funding and investment:

The MNOs and ISPs build network with future profits in mind. They obtain funding and investment from big banks and government agencies. As the rural telecommunication business is non-profitable for a new entrant or ISP, the lack of funding allocated for rural last-mile connectivity and its development is another major roadblock.

Technology:

The mobile communication technology needs to be specifically modified for meeting the rural communities' requirements. The key focus of rural networks is on factors such as high coverage (up to 10 km radius), high data rates (100 Mbps or more), high energy efficiency, high spectral efficiency, support all use-cases using single network and smooth roaming.

Electricity:

The rural areas have irregular or unreliable power supply issues. The rural telecommunication system highlights the need for renewable energy sources and highly power efficient system.

Digital awareness:

Another challenge that needs to be addressed is digital awareness among the rural users. The people need to be educated on the benefits and usage of digital solutions. When people understand the advantages of rural digital solutions and how it will improve their life, then people would demand for better services. Another factor which needs to be considered for the Indian setting is the local language in different parts of the country.

Proposed Connectivity Solution

While there has been lot of solutions deployed to address the above challenges in the Western countries, it is imperative for India to build its own rural connectivity solutions. Given that India and similar developing countries have some distinct characteristics, the technologies built in the Western world may not be appropriate for the local markets.

According to our research, the following technologies need to be developed to address the rural connectivity gaps in India:

1. Internet Backhaul
2. Last-Mile Connectivity
3. Infrastructure Management Platform
4. Subscriber Management Platform
5. Subscriber Mobile App

Connectivity Backhaul

This section discusses the possible backhaul technologies that can be used for bringing Internet connectivity to rural areas in India.

The current rural connectivity objective must overcome numerous obstacles highlighted in the earlier section for which new technology innovations are needed. At present, several rural areas near highways and large cities are covered with 5G or 4G services. However, as you move into interior regions, the 4G coverage is spotty, slow and unreliable.

Therefore, other technologies like satellite Internet, Long-range WiFi networks, TV whitespaces, CBRS need to be explored to bring affordable, reliable and decently fast Internet service to these areas. It should be also noted that rural regions lack reliable power hence alternative energy sources need to be planned to have always-on networks.

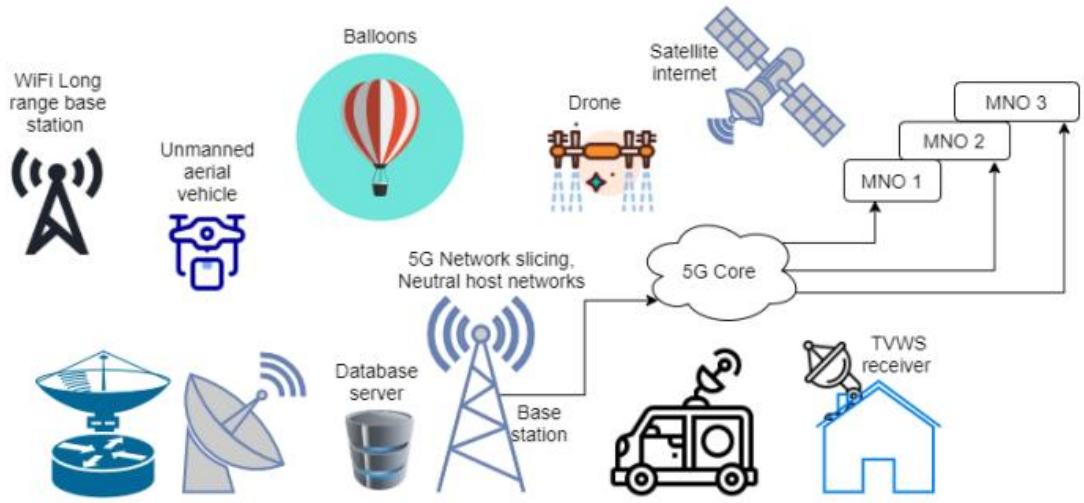


Fig. 2. Different rural technologies

4G / 5G Networks:

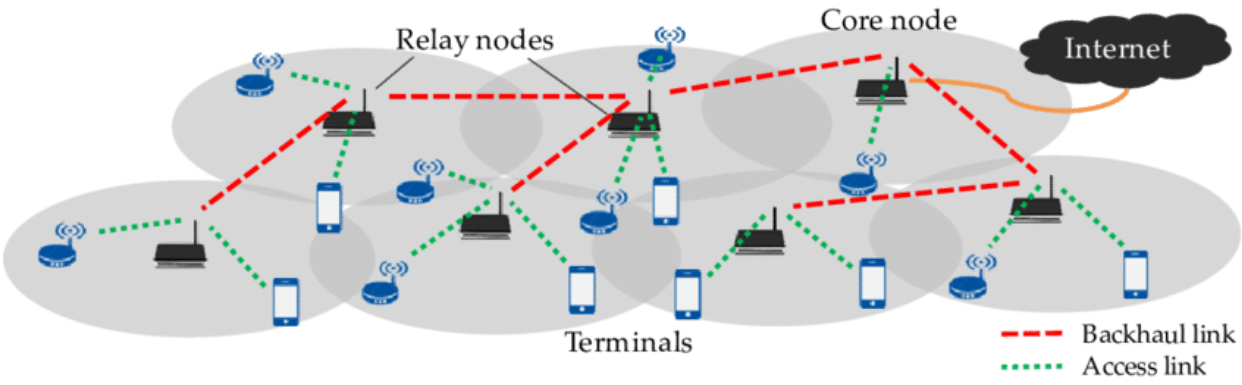
Companies like Airtel and Jio are slowly expanding their 5G networks into rural areas. However, it has been observed that their networks are slow and unreliable as you venture deeper into hinterlands of India. This is primarily because these networks take long time to deploy 100% coverage and are much more costly to operate and maintain where the ROI is low.

Moreover this technology can bring Internet service directly on end-user's devices without having to invest in last-mile connectivity.

Fixed Wireless Networks:

FWA can be a great way to bridge the digital gap that still permeates India, especially in the rural and semi-urban areas of our country. The biggest benefit of FWA is that it can reach areas where wires simply cannot. Thus, if you have any area that gets blacked out from wired broadband services, FWA will

now come to your help. FWA is great technology to deliver the Internet backhaul from the nearest POP to the villages.



Instead, private 5G networks can be installed to deliver broadband to various places in the village and can be couple together with Wi-Fi hotspots to deliver low-cost Internet access to the villagers.

WiFi long range:

WiFi long range technology uses unlicensed spectrum to deliver Internet connectivity over longer distance. The key advantages of long range WiFi is low cost and quick deployment but the challenges lies in the maximum permissible operational power levels as it is operates in unlicensed spectrum bands. This technology also uses MIMO systems to provide long range coverage in rural areas and adhere to the usage policy of unlicensed spectrum bands.

Satellite internet:

Low-earth orbit satellites have started providing Internet connectivity in hard to reach rural areas and other topography areas like islands, border areas, etc. Companies like Starlink, OneWeb, Eutelsat are providing satellite based Internet services for different applications. Although the price for satellite Internet is relatively higher than terrestrial broadband, new business models have emerged whereby the community WiFi networks can be deployed to allow multiple people access the same satellite connection.

Last Mile Connectivity

Once the Internet access reaches particular place in the village like local panchayat office, primary school, health center, CSC center, it is important that the Internet service needs to be made available to the villagers. Given the low ARPU in villages and maintenance overheads, it is not practical and affordable to run fiber or aDSL to individual homes. Moreover, many individual home owners will be reluctant to spend on fixed broadband connection into their homes.

The more practical approach is to enable a pay-as-you-go home for the villagers to access Internet service. The prepaid model will provide flexibility to the villagers to access the Internet service when they require and also pay the amount that they can afford.

Fundamental Requirements

The following are the fundamental requirements for providing last-mile through WiFi technology are as follows:

1. WiFi coverage should be available in most areas with minimal blind spots
2. Simple to use – Users should find it very easy to register and use WiFi hotspots
3. Legal and Regulatory compliance – All user's identity needs to be verified and recorded by the system
4. Subscriber database along with the call detail records should be properly maintained
5. Sound Business Model – the system should be based on simple and financially viable business model
6. Roaming – The user should be able to purchase their access at any hotspot and use the service across all the other hotspots in country
7. Open to all – Any player should be able to build and operate the WiFi hotspot
8. Security – the system should put in place all the necessary security provisions to ensure end user's data privacy

Village WiFi Hotspots

Wi-Fi hotspots are currently one of the most viable, affordable and practical technology to deliver the last-mile connectivity in rural areas. They can utilize Internet service from any type of backhaul and provide localized access to the users through their mobile devices. Unlike FWA, Fiber or satellite, there is no need to purchase a home CPE device thus making WiFi service very compelling for end users.

In low income communities data is mostly provided via mobile networks and is expensive. An alternative is to provide internet via a fixed wireless point to multipoint distribution. The cost of an installation of a Subscriber Unit per household is too costly for both ISP and the end user as the users are mostly prepaid voucher based and not on any committed monthly contract.

Typical Components of WiFi Hotspot

As per our experience, the following components are needed to deploy and operate a reliable WiFi hotspot solution in villages

1. Good quality, Long-range, outdoor Wi-Fi Access Point
2. Wireless LAN Controller (WLC)
3. Solar Charging / Battery Setup (optional)
4. Optical (ONT), Satellite Modem or aDSL termination for Internet connectivity
5. Electricity from local shop / house
6. AAA system for authentication and authorization of end users
7. Billing, Charging and Revenue Collection Platform
8. KYC and End User database system
9. Mobile Application for end users and local resellers
10. Security Log Server for compliance with Law Enforcement Agencies (LEA)

Outdoor Wi-Fi Access Point

In order to provide internet access to users across a residential community the best cost effective method is using an outdoor Wi-Fi Access Point to provide outdoor and indoor Wi-Fi signal coverage and billing per device (MAC address). Using a strong outdoor Wi-Fi Access Point has shown that a radius of at least 150m outdoor and 80m indoor coverage can be achieved. As shown in the picture below:

Figure 1: Wi-Fi coverage radius

In our recent deployment, the outdoor Wi-Fi Access points have shown this to be very effective in providing Wi-Fi service within households in the radius shown above. Users can access the public Wi-Fi hotspot using their pre-paid vouchers. The successful connection of smart devices has enabled users to livestream TV within their household. The outdoor Wi-Fi range of these devices was impressive that an acceptable Wi-fi signal was observed between the Wi -Fi hotspot and the main tower, a distance of 430m:

The Wi-Fi signal range has successfully provided cost effective internet connectivity to the residents of the village of up to 100 concurrent users from a single Wi-Fi Access Point across a radius of 150m outdoors and 80m indoors. In this manner the ISP is able to provide affordable internet to the end users.

Solar Powered Wi-fi Hotspot

Using a Solar Powered Battery back power unit provides and reliable and continuous uninterrupted internet service to the community. Having a continuous service ensure the ISP can keep connectivity for its users and ensure a steady income.

Coverage Models

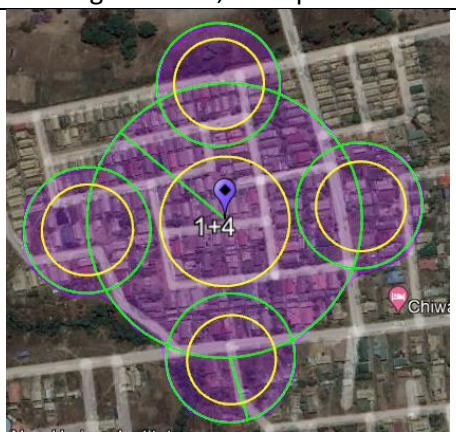
This section provides insights into how to deploy a mesh-enabled Wi-Fi setup in a village to increase the range of Wi-Fi signal.

Various deployment scenarios are discussed along with the approximate coverage area for each scenario

Single Outdoor AP
Coverage area: 70,000 sq.m

Two Outdoor APs
Coverage Area 98,000 sqm

One Base Station and 3 Satellite APs
Coverage Area: 117,000 sqm



One Base Station and 4 Satellite APs
Coverage Area: 148,000 sqm

As you can observe, the WiFi mesh technology can be used to increase the coverage for a given Wi-Fi hotspot further without having to run data cables from one AP to another.

Infrastructure Management Platform

The next critical component of public Wi-Fi hotspots is the infrastructure management platform. This platform is used for provisioning, managing and monitoring the devices needs to operate the Wi-Fi hotspots. Given that all the public Wi-Fi deployments are remote, it is not possible for IT administrators to configure and monitor them individually.

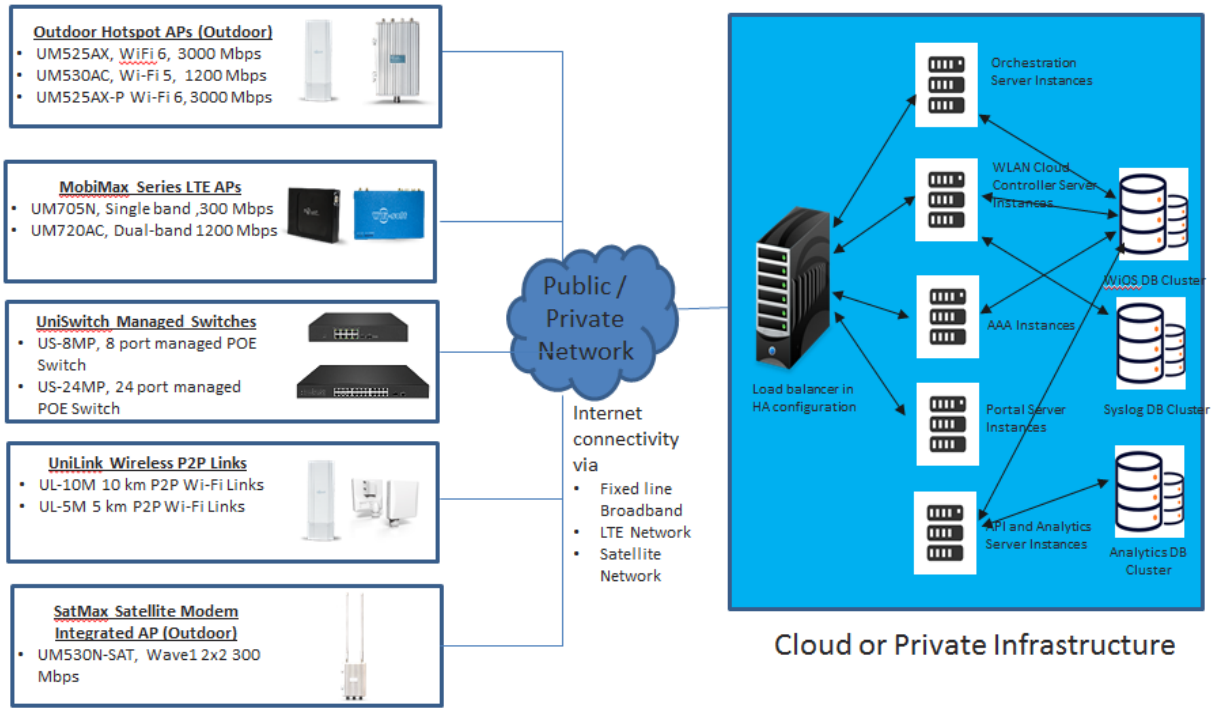
A robust central platform is needed that will provide a single interface to manage and monitor these remote devices.

The Infrastructure Management Platform needs to be built on a scalable, redundant architecture to ensure that the system handles the increase in load as the number of hotspots and subscribers increase. Redundancy needs to be achieved by developing a replication model to operate the services on different servers while preserving the consistency of the data.

The servers can be located in geographically separate data centres to ensure high reliability and availability of the service. Scalability is achieved by using tiered software architecture that can be segmented on separate servers to improve speed and performance of the servers.

The diagram below explains how the central management platform will be used for managing and monitor various devices like Wi-Fi access points, 4G routers, Managed Switches, Wi-Fi P2P radios and satellite devices.

Ideally a single platform is desirable that will manage all these devices from a single interface.



It is also recommended that the infrastructure platform is built on open-source, vendor neutral and open-standard based systems to ensure that infrastructure will interoperate with different systems and will not remain locked into specific vendors.

Technologies like TIP, ONF, OpenWiFi and OpenLAN Switch can be adopted for managing the backhaul, Wi-Fi and switching infrastructure from the central management platform while offering open environment for other vendors to integrate with the existing infrastructure.

The following functions are desired from the Infrastructure Management Platform:

- Device Provisioning
- Device discovery
- Device Management
- Configuration Profiles
- Firmware upgrades
- Network Hierarchy
- Roaming Management
- Network Health monitoring
- Usage and bandwidth Statistics
- Admin Dashboards
- Alarms and Alerts

The Infrastructure Management Platform should be designed to manage and monitor remote backhaul networks and WiFi hotspots from a single console. The platform should be multi-tenant so it can handle multiple network operators on the same infrastructure. It should be independent of any cloud infrastructure so it can be managed in any data center. Lastly, the platform should be highly scalable to handle millions of devices in the field.

Subscriber Management Platform

AAA, Billing and Compliance Platform for Wi-Fi Hotspots

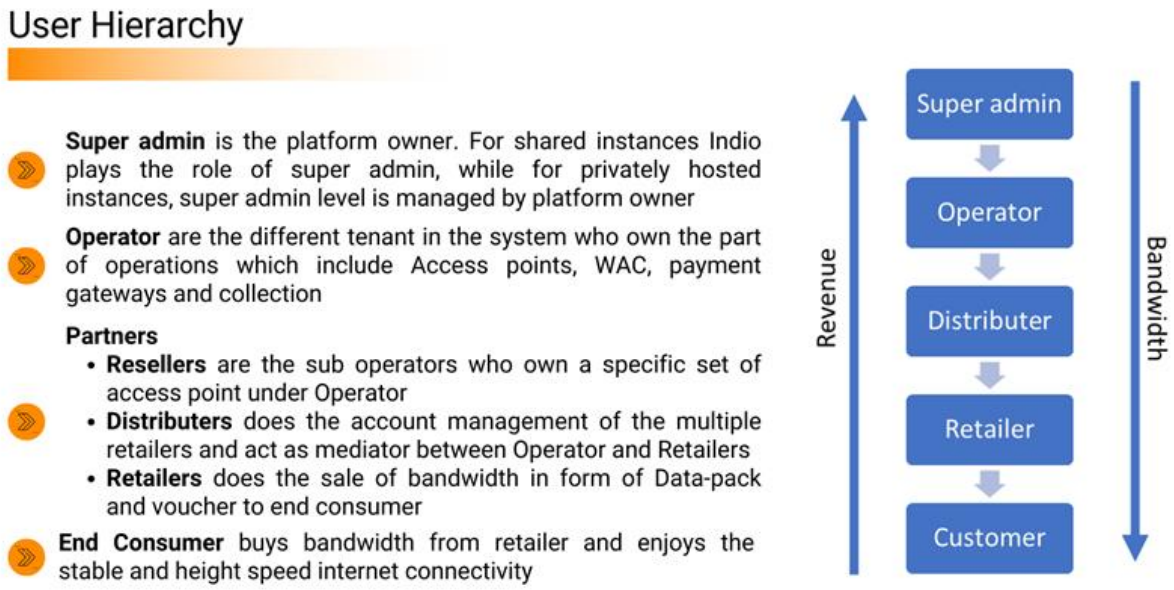
The next important of component of Wi-Fi hotspots is the subscriber management platform that is used for managing the life cycle of the network subscribers and provide the billing and charging platform. The platform provides various features for managing the lifecycle of users including their online registration, captive portals, billing/charging, enforcing policies, tracking usage and compliance with the local laws.

Based on our experience managing Wi-Fi hotspots over the years, this platform needs to be fine tuned to handle the specific requirements of community networks. Facebook had built a good platform called ExpressWiFi in 2016 that was adopted by network operators around the world. The platform had the correct set of features designed specifically for managing public/community Wi-Fi networks.

It offered micro-billing services and charging to the end users and created a hierarchical management to include all the stakeholders in the billing process. The data bandwidth was sold in small data packs to

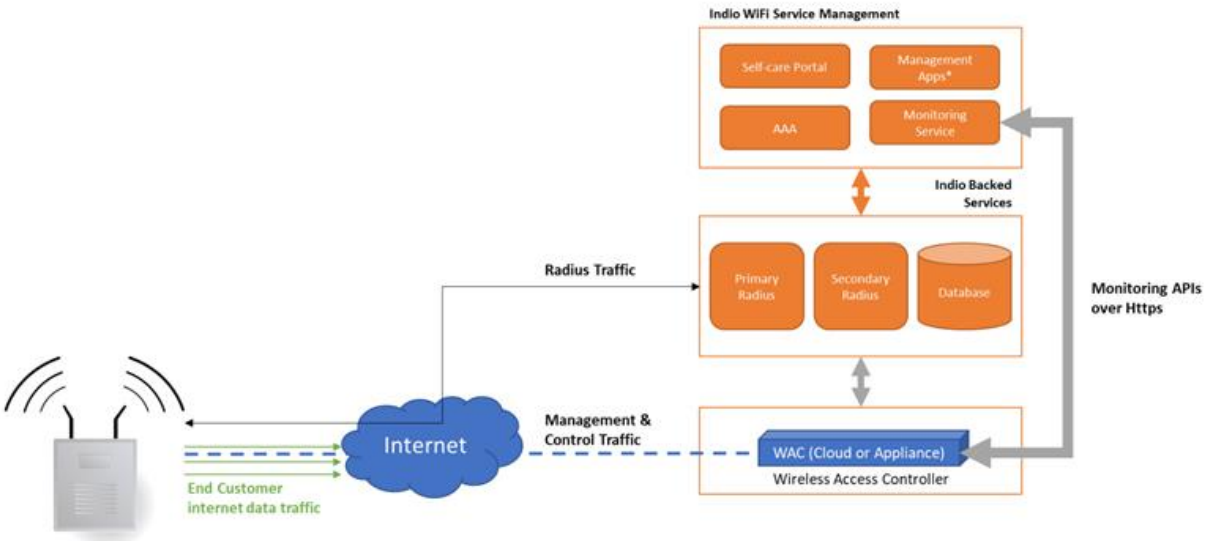
the end users thus making it affordable to the rural communities. The network operators also designated the local shops as point-of-sales (POS) locations where the villagers could purchase the data packs and avail the Internet service.

The diagram below shows the hierarchical management and flow of revenue through the various stakeholders of the business:



The subscriber management platform needs to be hosted centrally so all the Wi-Fi hotspots can use the same infrastructure. The whole architecture needs to be designed so it can be scaled to handle thousands of Wi-Fi hotspots with minimal downtime.

The diagram below depicts the architecture of public Wi-Fi system:



The platform should support the following functions:

Central AAA System

1. Provides complete authentication services using various methods
2. Mobile Number – OTP validation
3. Pin based authentication
4. Enables pan-India roaming for end users
5. Central policy management for all end users

Central Payment and Charging System

1. Micro-billing platform for PDO and PDOA
2. Real-time, online payments using UPI and payment gateways
3. Enables e-Wallets for end users, PDO and PDOA
4. Online Voucher generation
5. Calculates commission on sales for PDO and PDOA
6. Promotes with Digital India Mission

Integrated Security Management System

1. Can be installed with central authority like DOT
2. Maintain all session history for end users in real-time
3. Storage and retrieval of session logs for all WiFi users as per TRAI norms
4. Access to LEA for investigation and analysis
5. No liability on PDOA or PDO

Central User Database

1. Maintain central data repository for end users
2. User Profile Management
3. E-Wallet and Transaction History

Subscriber Mobile App / User Interface

The next important component of public or community Wi-Fi hotspots is a mobile app or the web portal that the end users can use for gaining access to the service.

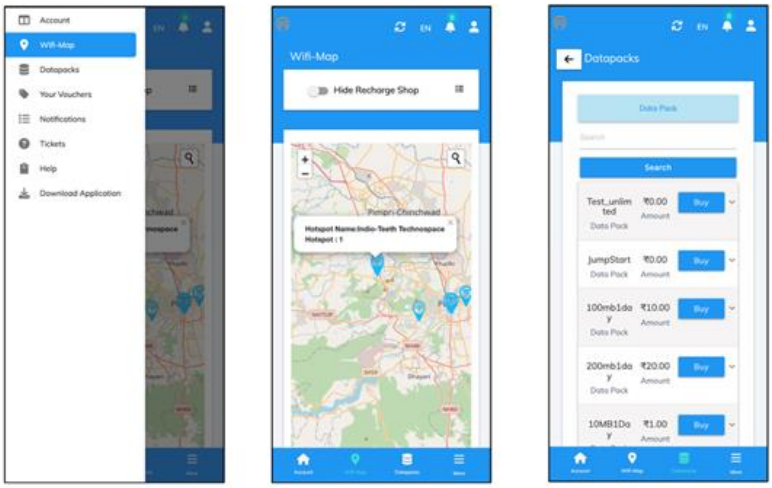
Most of the end users of rural Wi-Fi networks will be villagers and low-skills people. These people lack the necessary computer and technical skills to use smart phones and Wi-Fi services. Based on various industry reports, poor UI/UX has played an important role of dismal adoption of public Wi-Fi technology.

In India this issue is further exacerbated by the fact that government regulation needs that every Wi-Fi user needs to be verified and authenticated using the SMS/OTP mechanism.

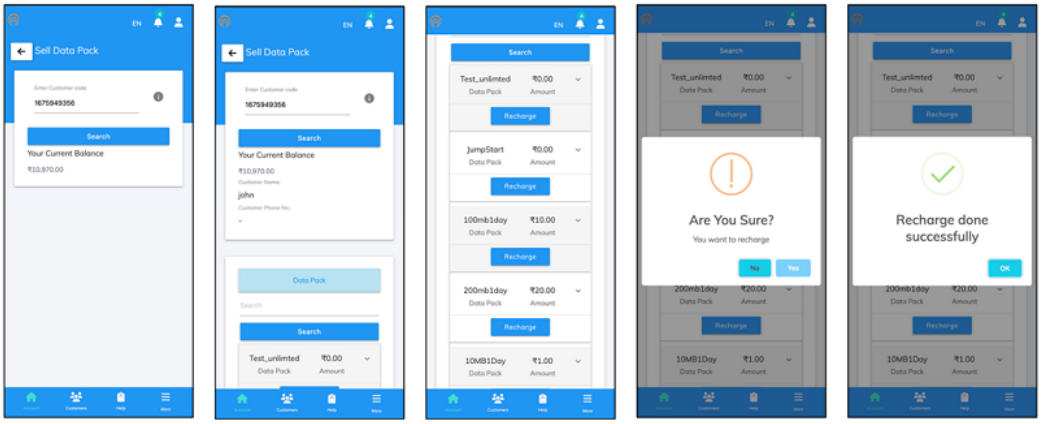
Having a simple UI/UX in the local languages is an important consideration for public Wi-Fi adoption in India. The web or mobile app should offer minimal steps for the end users to register and pay for the service. The system should be intelligent to ensure that user once registered can keep recharging his account using very easy steps or the local shops (POS) should be able to help the end users perform the recharge using the once widely used “Kirana store” recharge model.

Here are some examples of UI/UX for the subscribers and point-of-sales terminals:

Customer: Mobile App View



Retailer: Data Pack Sale



Leveraging PMWANI

The Prime Minister Wi-Fi Access Network Interface (PM WANI) scheme is set to revolutionize public Wi-Fi in India. PM-WANI can be a potential game-changer for India's digital public infrastructure. The scheme enables public Wi-Fi data service through small retail data offices, which can potentially bring broadband internet to remote locations at a minimum investment.

The PM-WANI, launched by the Department of Telecom (DoT) in December 2020, is one key scheme launched to bolster the penetration of public WiFi hotspots to establish a robust digital communication infrastructure throughout the nation, especially in rural areas. It is a framework that enables any entity, such as a shopkeeper, a tea stall owner, or a Kirana store owner, to set up a public Wi-Fi hotspot and provide internet service to customers.

PM-WANI consists of four elements:

- Public Data Office (PDO): PDO is the entity that establishes, maintains, and operates the Wi-Fi hotspot and provides last-mile connectivity to the users by procuring internet bandwidth from telecom service providers or internet service providers.
- Public Data Office Aggregator (PDOA): PDOA is the entity that provides aggregation services, such as authorization and accounting, to PDOs, and facilitates them in providing services to the end users.
- App Provider: It is the entity that develops an application to register users and discover and display PM-WANI compliant Wi-Fi hotspots in proximity for accessing the internet service and also authenticate the potential users.
- Central Registry: It is the entity that maintains the details of App Providers, PDOAs, and PDOs. It is currently maintained by the Centre for Development of Telematics (C-DoT).

The infrastructure and subscriber management platform should be compliant with the PMWANI architecture so the operators and PDOA in India will be able to leverage and benefit from the PMWANI government scheme.

Conclusion

This whitepaper highlights how Wi-Fi technology can be utilized to deliver low-cost, fast and reliable connectivity to rural India to improve the lives of millions of people who are unable to join the Internet community. There are several case studies worldwide whether the Wi-Fi technology has been successfully implemented and have transformed the lives of people in these countries. Indian government also needs to create a comprehensive program that is built on workable business model and is easy to implement and scale.

Currently there are several discussions on using private 5G technology, CBRS to implement connectivity solutions for the rural India. However, given the low ARPU and high TCO for rural Internet, we believe these technologies can become uneconomical and unsustainable to build and operate.

If Wi-Fi technology can be exploited correctly, the same solutions can be implemented at much lower cost and can be easily maintained over long run. Although PMWANI has not been successful, we believe that if the correct business model is implemented and the Internet backhaul can be subsidized for the local entrepreneur, the Wi-Fi based Internet options can become sustainable and practical for rural India.