

Study Paper on Technologies to enable Broadband for Rural Areas in India

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[This study paper is based on a report submitted by the committee to frame the architecture of an integrated last mile technological solution for delivery of various services in rural areas under digital India program.]

1.0 Introduction

- 1.1. Internet Protocol (IP) has become a uniform protocol and mechanism over which different services including the existing services and new services could be built and transported. Hence all the TSP's started their migration to IP based transport networks. IP network was originally built as a data transport platform. However, now IP has become a platform over which voice, video and data could be transported. The standardization, cheaper availability of products and easiness of access from a variety of access devices, irrespective of the location, has helped the development of large amount of applications over the IP network. Therefore, it is suggested that IP based end to end access and transport network is the basic requirement for delivery of various types of services under Digital India program.
- 1.2. The broad solution architecture of the overall network is to be built as mentioned in the terms of reference. For this, the guiding principle suggested in the TRAI consultation paper as well as the traffic requirements were used.
- 1.3. The overall network architecture of the IP network comprising of the Core network, Edge network, Aggregation network and the access network is given in Figure-1 below. Architecture as given below indicates a wide variety of access devices i.e. PC's, Laptops, Tablets, Smart phones, sensors, and other devices accessing different contents & applications through an IP network. There are a vast number of applications including web browsing, e-mail, YouTube, Social networking, Android market place applications etc., catering to different segment of services including education, health, entertainment, banking etc.

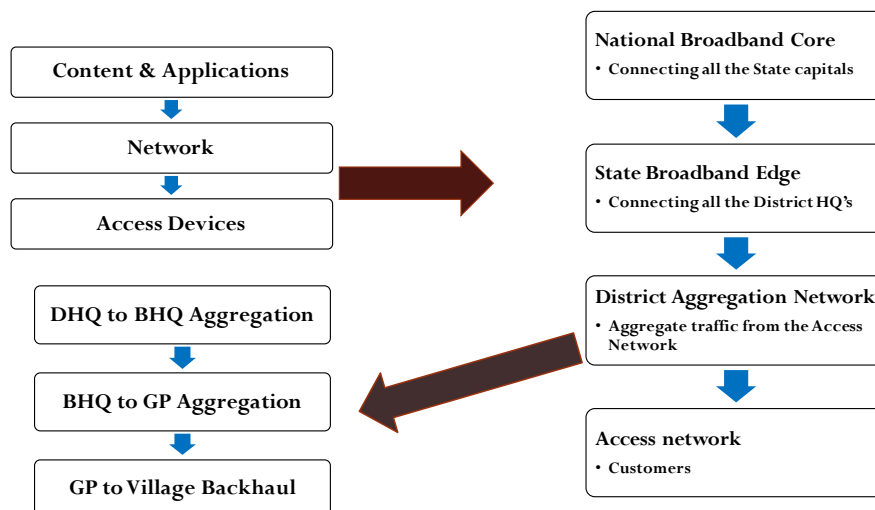


Figure-1: Overall Network Architecture

- 1.4. The network can be sub divided into different hierarchies like Core network, Edge network, Aggregation network and the access network. The primary objective of the network is to collect the data from/to the access devices to/from the different applications with an acceptable quality of service. The network may allow peer-to-peer connectivity i.e., connectivity between access devices or connectivity between applications as per requirement. Blocks indicating the different parts of the solution architecture are given in Figure-1.
- 1.5. Backhaul technology using Point to Point Radio from the BHQ to the GP and GP to villages has also been examined as a possible alternative for those GP's and villages where fiber access is difficult, but Line of Sight is possible.
- 1.6. The access technology options available are Broadband over DSL, GPON Access, Wi-Fi Access, Broadband Wireless Technologies such as LTE, Cable TV and Satellite technology. It is worth mentioning that every technology has its application area and same shall be suitably selected based on the suitability for the site.
- 1.7. The overall network architecture of the IP network comprising of the Core network, Edge network, Aggregation network and the access network are given in Figure-2.

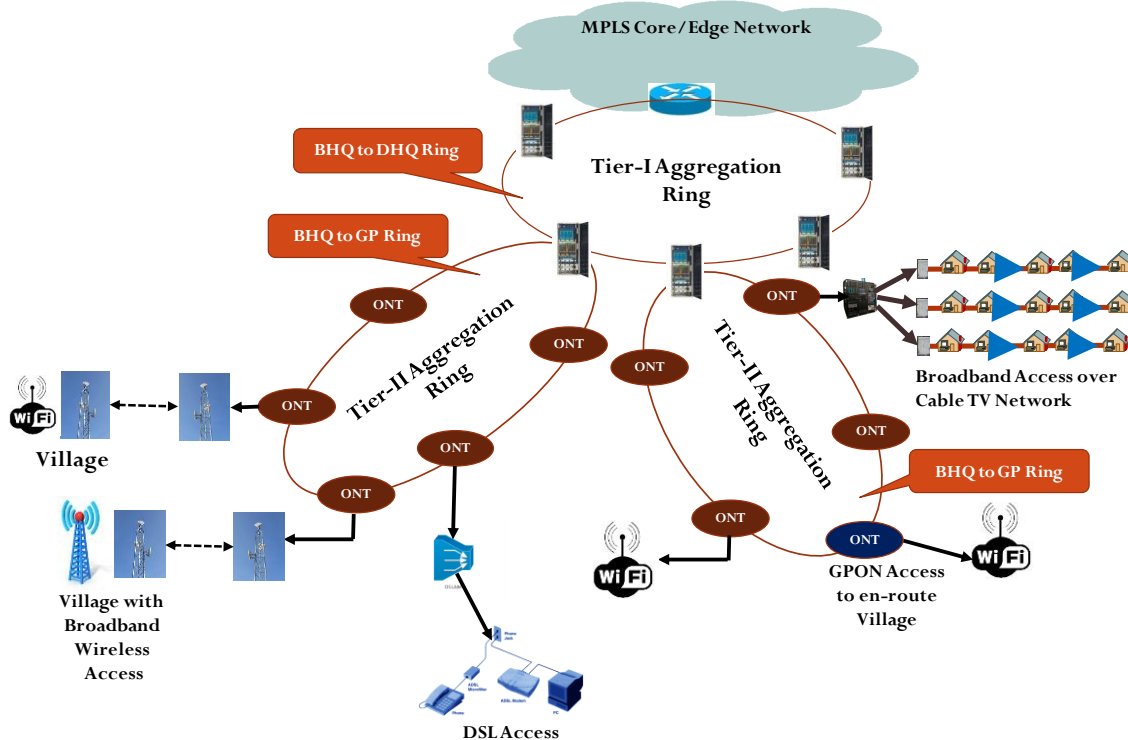


Figure-2: End to end Network Architecture consisting of Core, Edge, Aggregation & Different Access Technologies

- 1.8. The selection of technology for rural communication shall also be based on roll out obligations of the TSP/ISP's as per their licensing and regulatory requirements

2.0 IP Transport Network

2.1. National Core Network:

- 2.1.1. The core network is the highest layer in the hierarchy. The Core network uses Core Routers with MPLS Technology. The function of the core routers is to switch the packets at the

highest layer with the desired quality of service. Suggested architecture is given in Figure-3.

- 2.1.2. Interface requirements based on the traffic calculations leads to around 100*10G interfaces to start with towards Core and 100*10G interfaces towards the lower levels initially including the network redundancy requirements. However in future, the interfaces can be migrated to 40G/100G interfaces.

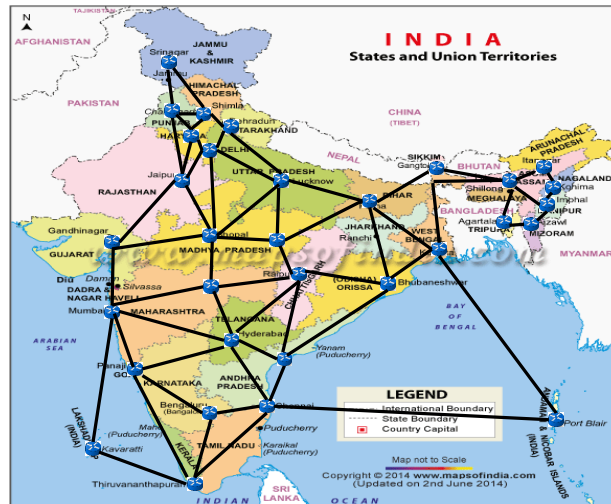


Figure-3: MPLS Based National Broadband Core Network

- 2.1.3. The connectivity proposed at the national level is a partial mesh architecture as shown in Figure-3. This will enable required redundancy in the network. The traffic meant for distant nodes can traverse multiple nodes as the now technology has improved reducing the node level latency in the order of micro seconds. This traffic handling needs the connectivity of the Core Routers through 40/80λ, 10G DWDM systems over Fiber infrastructure. At the state HQ, there would be connectivity with the State data centers, other service providers, various content providers etc.
- 2.1.4. Today the connectivity to the islands i.e. Port Blair / Lakshdweep is through satellite communications. However the exponential growth in the data traffic cannot be handled through the satellite media. Also the people in these difficult terrains also need to have an equivalent connectivity experience as those in the main land. This can be only achieved through fiber connectivity to Port Blair / Lakshadweep Islands with sufficient redundancy.
- 2.1.5. There can be different models of implementation like building government own network or can be hired / connected to Service Providers networks at State HQ level. The hiring could be at different levels like Fiber, 10G λ bandwidth or direct Core Router as a shared infrastructure.
- 2.1.6. As far as fiber connectivity in the main land is concerned, it may be noted that once a network from a GP level upto the district level is already planned to be built, the need would be to plan a fraction of missing gaps and a small investment in the electronics like the DWDM systems and around 32 Core Routers.

2.2. State Edge Network:

2.2.1. The objective of the State Edge network is to transport the traffic originated at the District HQ's to other district HQ's, State HQ or the national network. State Edge Network uses MPLS technology Edge Routers. One Edge Router is placed in every DHQ. The suggested architecture for one state of Gujarat is given in Figure-4.



Figure-4: State Broadband Edge Network using MPLS Edge Routers showing connectivity in one State

2.2.2. This network acts as a traffic collection network where there is no MPLS Edge router accessibility by the ISP's or by the State administration. There is a need for collection of traffic to the State Capital or nearby DHQ where there is a presence of the ISP or the State administration. Moreover this network is proposed to be part of the Government user network.

2.2.3. The capacity of the Edge router is based on the traffic load projections. This would require 8*10G interfaces for uplinks including redundancy and multiple 10G and 1G links for connectivity towards blocks, district data centers and other service providers. The connectivity among the Edge Routers is proposed directly over dark fiber. Where ever distance between two adjacent Districts are more than 70Km, DWDM systems can be used.

2.2.4. As shown in the Figure-4, partial mesh architecture is proposed. This will provide sufficient redundancy and multiple alternate paths over prominent fiber routes. This DHQ MPLS Edge Router acts as the point of service creation, label insertion and QoS assurance. The DHQ MPLS Edge Router provides connectivity to the neighboring DHQ Routers, different telecom service providers having MPLS POP in the DHQ, district data centers of the state government, BHQ traffic aggregation Rings over MPLS-TP etc. The different connectivity envisaged is shown in Figure-5.

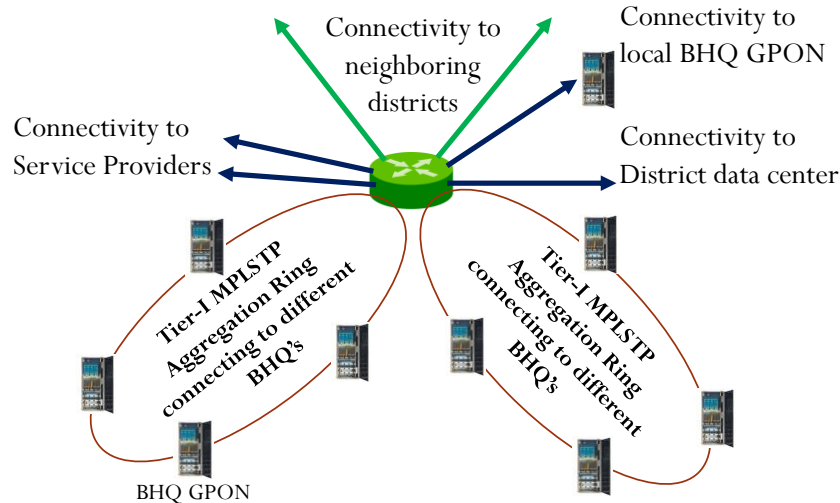


Figure-5: Different connectivity envisaged at the DHQ MPLS Router

2.2.5. The fiber connectivity from the DHQ to all the BHQ's and BHQ up to the GP has already been planned. This connectivity would require marginal additional fiber connectivity at the boundary only. No additional electronics also is envisaged as the requirement is only to interconnect the edge routers already being planned at the DHQ.

2.3. BHQ Aggregation Network

2.3.1. The purpose of this connectivity is to aggregate the traffic from the BHQ to the DHQ Edge Router. It is assumed that a GPON OLT of CDOT Technology is already installed or is being planned at every BHQ. The Ring architecture is proposed for connecting different BHQ's to the DHQ. Ring architecture provides the advantage of high reliability. It may be possible to aggregate different BHQ's to the DHQ in one or more Rings depending upon the geography of the district.

2.3.2. An integrated as well as a discrete solution is proposed. In the integrated solution, an Ethernet Ring Protection System (ERPS) as per ITU G.8032 is proposed. In this method, within the GPON OLT uplink over Gigabit Ethernet Interface, CDOT can be asked to develop ERPS protocol. MPLS-TP also has standardized ERPS as its protection switching standard. These rings can get terminated at the DHQ Router. This offers advantage of less power consumption; ease of maintenance and less CAPEX. The connectivity diagram is shown in Figure-6. In the discrete solution, at every BHQ there will be an MPLS-TP Router which aggregates the traffic from the GPON OLT. The technology preferred for the BHQ router is MPLS-TP over MPLS/MPLS-TE because of less cost, easy GUI based remote management and ring topology.

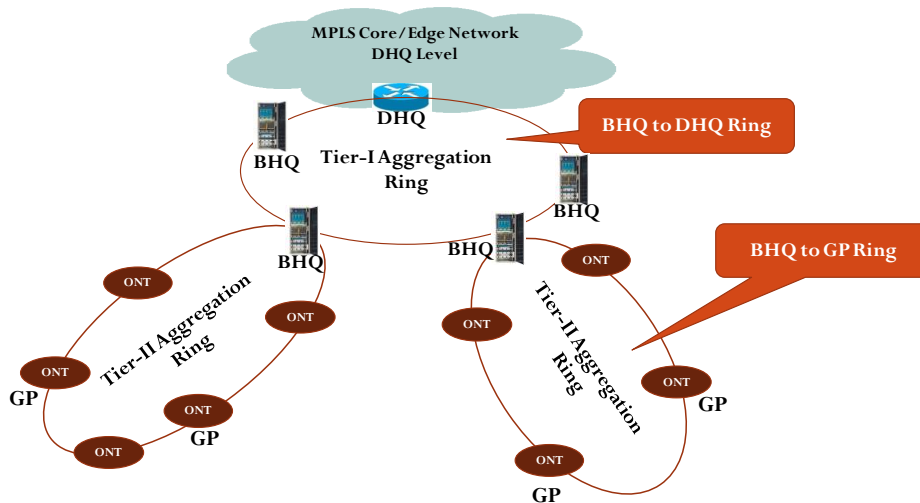


Figure-6: Ring connectivity to BHQ and GP using GPON based Aggregation Network

2.4. Traffic aggregation from GP to BHQ

- 2.4.1. This is the lowest tier in the traffic aggregation network. This tier aggregates the traffic from the Gram Panchayats to the BHQ. GPON based aggregation network has been planned under NOFN and it is under implementation by BBNL. The technology under implementation is from CDOT.
- 2.4.2. GPON technology can provide speeds upto 1Gbps in a GP. In the majority of the Gram Panchayats 1Gbps speed will be adequate for the next few years.
- 2.4.3. The architecture planned is linear for this connectivity. It may be noted that ring architecture offers higher reliability and preferred option. During one of the discussions with CDOT, they have indicated that they developed ONT's which can work in the Ring architecture. In such a scenario, GPON on Ring architecture is a preferred option. This is shown in Figure-6. There are many locations where GPON access is not feasible. For providing connectivity to such locations, alternate technologies such as Radio backhaul or Satellite backhaul is preferred. The possible options under these scenarios are discussed under the Backhaul technologies.

3.0 Backhaul Technologies for GP to Village Connectivity

Backhaul technology deals with the back-end or aggregation network for aggregating the IP traffic generated from the access devices over the access network to the Core network. One of the following technologies shall be deployed at one site for backhauling depending on the site conditions.

3.1. GPON Systems

- 3.1.1. BBNL is already deploying GPON technology for the connectivity of the Gram Panchayats to the BHQ. GPON as a technology is highly futuristic and can provide very high and reliable bandwidth.
- 3.1.2. Many broadband access locations like schools, police stations, local government offices, primary health centers, post offices etc. may be falling in the fiber route itself and such locations can be planned over GPON access itself. This is shown in Figure-7. If required, a small span of fiber to reach inside the building/room where the equipment is kept needs

to be laid. This is the best, high bandwidth, simplest and cost effective connectivity to such locations as the fiber infrastructure is already in place.

- 3.1.3. Since, this method of connectivity of the 'end user locations' is not planned in the execution under progress by BBNL, higher capacity GPON splitters would be required. Higher capacities of splitters like 16 / 32 / 64 are available with CDOT, the technology provider for covering these locations depending upon the additional points to be covered.

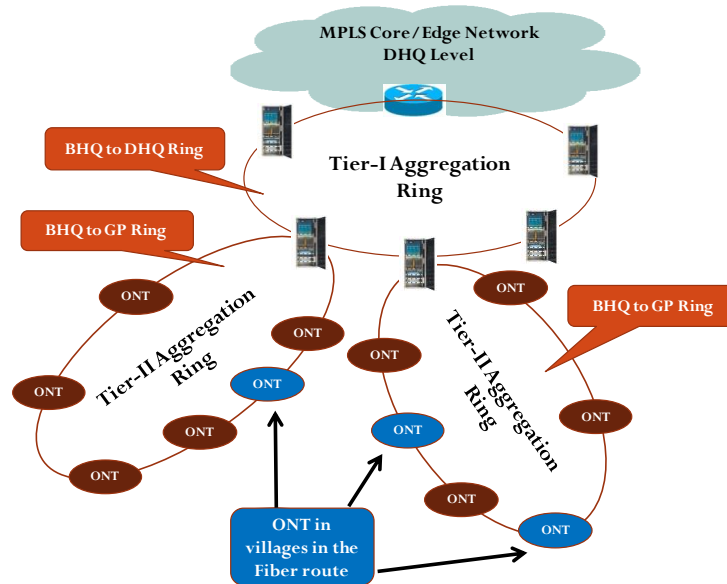


Figure 7: GPON Connectivity to Villages in the Fiber Route

3.2. Point to Point Radio Systems

- 3.2.1. Most of the Gram Panchayat locations where broadband aggregation is possible through Fiber technology are planned through GPON. But, there are many Gram Panchayat locations where providing broadband access using fiber technologies such as Optical Fiber (GPON) is not feasible. Moreover, there are many villages where Fiber based backhaul cannot be extended from the GP. These places have difficult terrains such as hilly areas or hard rocky areas etc., where laying fiber is very difficult. For such locations, if Line of Sight is available, Point to Point Radio is an alternative.
- 3.2.2. If line of Sight (LOS) is available, Point to Point Radio can be deployed between the BHQ and the GP. The backhaul connectivity network diagram integrating into the main system is given in Figure-8 below.

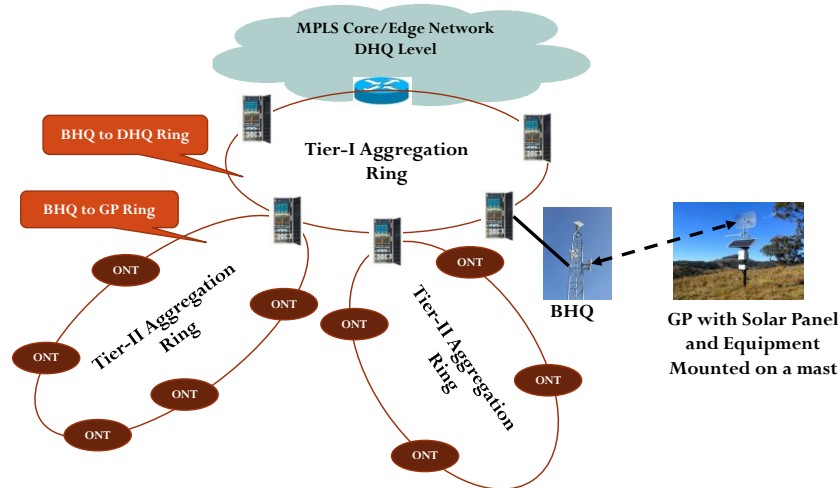


Figure 8: BHQ to GP Point to Point Radio Link with Line of Sight

3.2.3. Similarly, if line of Sight (LOS) is available, Point to Point Radio can be deployed to the village from BHQ or GP. The backhaul connectivity network diagram integrating into the main system is given in Figure-9 below.

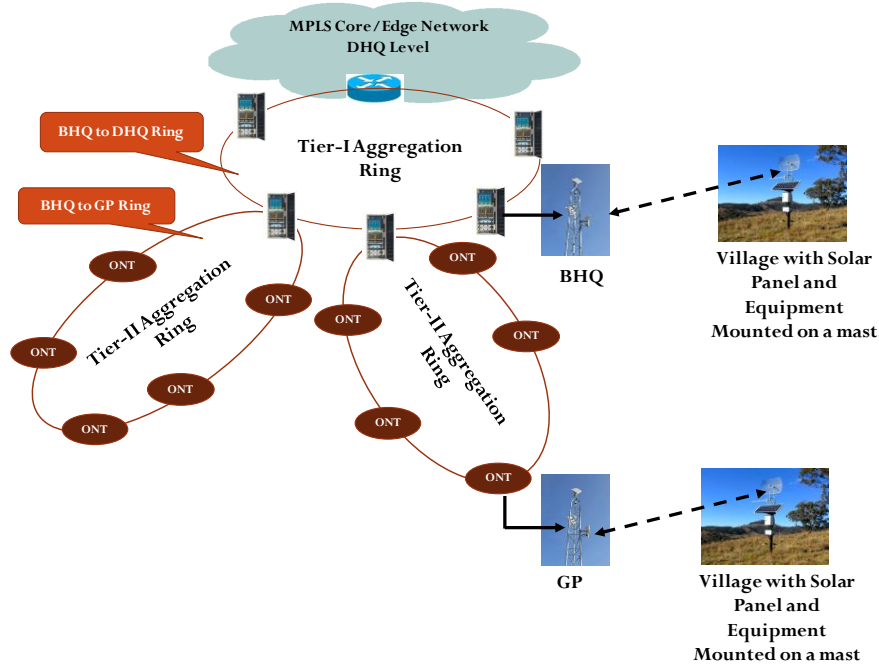


Figure 9: BHQ/GP to Village Point to Point Radio Link with Line of Sight

3.2.4. The site survey needs to be carried out using contour maps for clear line of sight for deciding the tower/antenna height requirements. In 2.4GHz de-licensed band, it is limited to 5mt above the roof top. At the GP/Village, the Wi-Fi access point can be connected on the same tower.

3.2.5. Sample calculations for data rates at different frequency bands and distances are given in Table-1. The Radio can be in licensed or de-licensed frequency bands. The theoretical download speeds attainable under different scenarios have been analyzed in Table-1. The choice of the frequency band of operation should be based on the data rate requirements

as well as the WPC guidelines. A minimum 100Mbps of data rate from BHQ to Gram Panchayat or 10Mbps from GP to Village needs to be addressed through this backhaul method as it is suggested as an alternative to GPON.

Table-1: Data rates at different frequency bands and distances

Scenario	Frequency GHz	Tx Power dBm	Cable/ Connector Loss dB	Antenna Gain dBi	EIRP	Distance Km	Free Space Loss dB	Fade Margin dB	Rx Power dBm	Modulation	data rate (20MHz Channel) Mbps	data rate (28MHz Channel) Mbps	data rate (40MHz Channel) Mbps
De-Licensed Band Near LOS	5.8	20	3	17	34	1.1	108.5	6	-66.5	64QAM	52		81
	5.8	20	3	17	34	5	121.66	6	-79.66	BPSK	6.5		13
De-Licensed Band LOS	5.8	11	3	26	34	3	117.22	6	-66.22	64QAM	52		81
	5.8	11	3	26	34	5	121.66	6	-70.66	16QAM	26		54
Licensed Band Near LOS	3.3	30	3	17	44	6	118.34	6	-66.34	16QAM	24		50
	3.3	30	3	17	44	3	112.32	6	-60.32	64QAM	50		80
Licensed Band LOS (*)	3.3	30	3	26	53	50	136.76	6	-66.76	16QAM	24		50
	3.3	30	3	26	53	25	130.74	6	-60.74	64QAM	50		80
	7	25.5	3	26	48.5	60	144.87	6	-79.37	16QAM		100	
	7	23	3	26	46	12	130.89	6	-67.89	256QAM		200	
	13	24	3	26	47	25	142.65	6	-78.65	32QAM		100	
	13	23	3	26	46	6	130.25	6	-67.25	256QAM		200	
	15	24	3	26	47	20	141.95	6	-77.95	32QAM		100	
	15	22	3	26	45	5	129.91	6	-67.91	256QAM		200	
	18	23	3	26	46	14	140.44	6	-77.44	32QAM		100	
	18	20	3	26	43	3	127.06	6	-67.06	256QAM		200	
	23	23	3	26	46	9	138.73	6	-75.73	32QAM		100	
23	21	3	26	44	3	129.18	6	-68.18	256QAM		200		

* In the licensed band, LOS, it is possible to achieve around 1.7 times the above bandwidth by using Cross Polarisation Interference Canceller (XPIC)

- 3.2.6. The de-licensed band uses either 2.4GHz or 5.8GHz. Since 2.4GHz is used for Wi-Fi access, 5.8GHz band is generally used for the Backhaul radio systems. Moreover in 2.4GHz, the antenna height is limited to 5mt above the roof top. While using in de-licensed frequency bands, the point to point radio needs to follow the de-licensing conditions of WPC w.r.t the antenna height and transmit power. As can be inferred from Table-1, the de-licensed band radios give less distance coverage due to the EIRP limitations but consume less power and are less costly because of the large scale use and advancement of technology in this area.
- 3.2.7. In licensed frequency bands, IP microwave radio equipments operate at 7GHz, 13GHz, 15GHz, 18GHz or 23GHz frequency bands. At higher frequencies, the link lengths will be less as can be seen from Table-1.
- 3.2.8. However, point to point radio systems shall not use CSMA/CD as per IEEE 802.11, as being a multiple access technology, it has security concerns.
- 3.2.9. The whole system can be powered through solar system.

4.0 Access Technologies

This section deals with the connectivity options for providing Broadband access in Villages, Schools, Police stations, Primary Health Centers, Government offices etc. No single solution is feasible and can be suggested due to different topologies, geographies and local conditions of the site. Hence multiple solutions as given below for access need to be used for delivering the services in rural areas.

4.1. Broadband Access using DSL

- 4.1.1. DSL is a copper based technology. Copper network is inherently fault prone. Further the condition of the copper network available is not very good. The speed of the Broadband connection depends upon the distance between the Telephone Exchange and the customer location and the condition of the copper.
- 4.1.2. BSNL is the biggest provider of Broadband Access using copper based DSL technologies i.e. ADSL & VDSL. Other service providers are also providing Broadband access over DSL.
- 4.1.3. BSNL has equipped most of its rural telephone exchanges to the tune of around 28,000 with Broadband service capability. BSNL is providing Broadband to the rural areas through USO fund subsidy scheme. This scheme is covering more than 1Lakh villages and more than 80,000 Gram Panchayats.
- 4.1.4. The ADSL broadband speeds vary from 512Kbps for locations around 3Kms to 24Mbps for locations within 500mt. VDSL can provide broadband speeds upto 100Mbps for locations within 200mt. So the choice of ADSL Broadband depends upon the speed requirement at the village as well as the distance of the village from the Exchange. Hence the Broadband requirement of such villages can be met very well by DSL itself from any of the TSP's providing DSL Access.
- 4.1.5. Such TSP network be connected to the MPLS backbone network being proposed here at the DHQ levels where the TSP MPLS POP is available for accessing the services hosted in the State data centers etc.

4.2. Broadband Access using Wi-Fi

- 4.2.1. From the Gram Panchayats or villages, access can be provided using Wi-Fi to locations within 500mt with line of sight or within 100mt having near line of sight.
- 4.2.2. The Wi-Fi technology is as per IEEE 802.11 standards. This is a shared access technology using CSMA/CD. The download speeds depend upon the distance from the hotspot and the number of simultaneous users. With around 5-6 users, an average download speed of 10Mbps is achievable at short clear line of sight locations.
- 4.2.3. A network diagram with Wi-Fi access is given in Figure-10 and Figure-11 below.

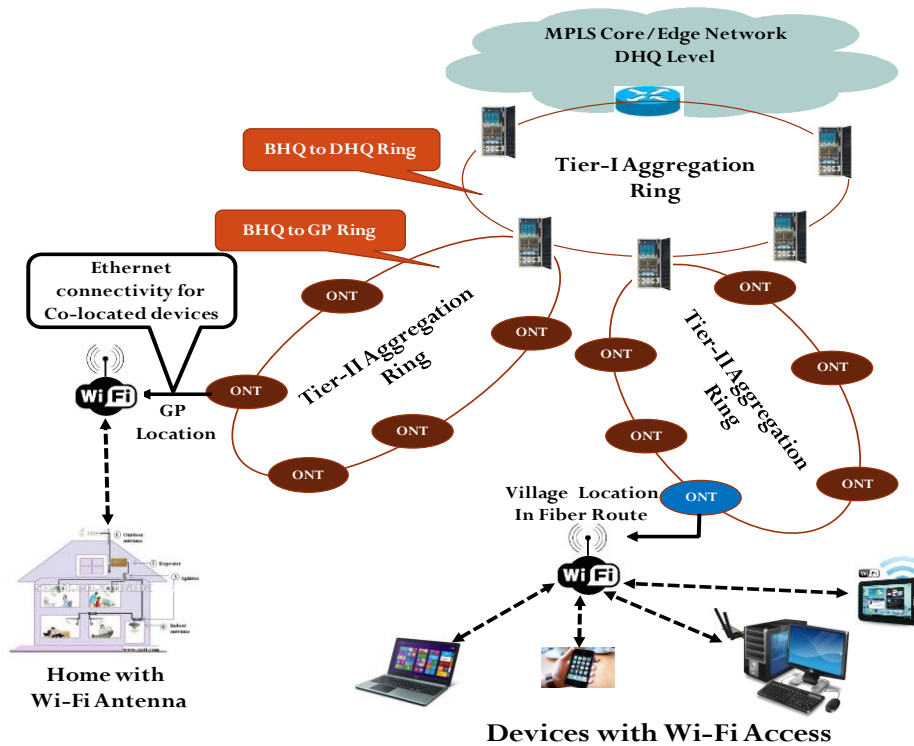


Figure 10: Wi-Fi Access Methods using GPON backhaul

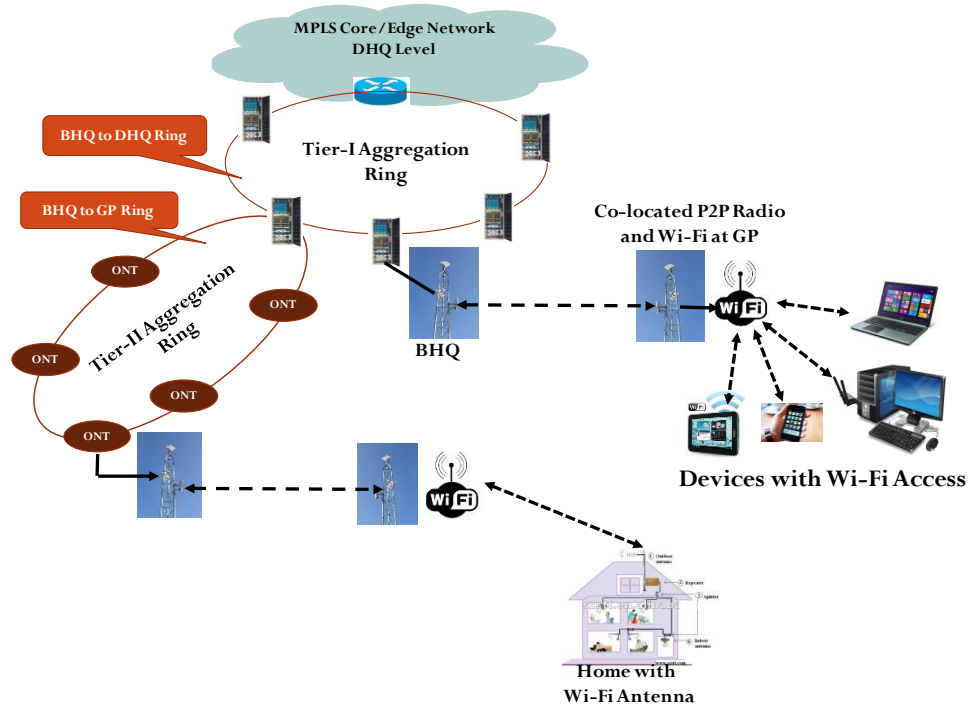


Figure 11: Wi-Fi Access Methods using Point to Point Radio Backhaul

4.2.4. Wi-Fi access could become one of the most prominent access mechanisms. This is all the more important due to the availability of the Wi-Fi interface in almost all types of access

devices. Hence the access locations which are within the acceptable range of good Wi-Fi signal strength can use devices like laptops, desktops with Wi-Fi adapter or smart phones, tablets etc. for access.

- 4.2.5. User access locations where good signal strength is not available can be provided with a pole mounted Wi-Fi directional antenna and Wi-Fi terminal. The electrical Ethernet interface from the Wi-Fi device can be connected to the PC or Laptop etc.

4.3. Broadband Access using Broadband Wireless Technologies

- 4.3.1. Long Term Evolution (LTE) is another important access technology. LTE family of BWA technologies can provide broadband speeds per sector as given below in Table-2:

Table-2: BWA technologies and the broadband speed per sector

Technology	Broadband Speed per Sector	
	Uplink	Downlink
HSPA EvoRel 7	11.5Mbps	28Mbps
HSPA EvoRel 8	11.5Mbps	42Mbps
LTE/SAE Rel 8	58Mbps	173Mbps
LTE/SAE Rel 9	84Mbps	326Mbps

However, the actual speed depends upon the number of simultaneous users per sector, line of sight availability as well as the distance from the LTE Base station.

- 4.3.2. Telecom Service Providers in India are deploying Broadband Wireless Technologies such as LTE based networks in urban areas and rural areas based on the rollout obligations of the license conditions.
- 4.3.3. The choice of the Broadband Wireless Technology shall be such that it shall be possible to deliver at least 10Mbps of access bandwidth.
- 4.3.4. Smart phones or other devices with SIM card would be able to access internet and other services over Broadband Wireless Access.
- 4.3.5. TSP's Broadband Wireless Technology solution such as LTE may use their own backhaul and aggregation network or use the aggregation network deployed by the government. A network diagram with TSP's using the aggregation network deployed by the Government is shown in the Figure-12 below.

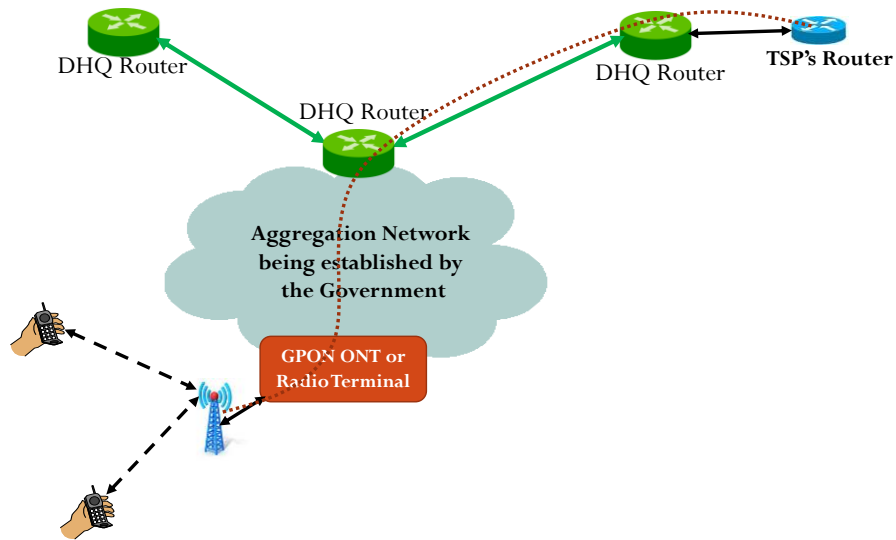


Figure 12: Broadband Wireless connectivity such as LTE using Government Aggregation Network

4.4. Broadband Access using Cable TV Technologies

- 4.4.1. Rural India has a representative penetration of cable TV networks. Utilizing the cable TV network would be one of the possible methods to achieve wider Broadband coverage.
- 4.4.2. The cable TV transmission is one-to-many in nature whereas the Broadband is one to one in nature. Further the cable TV network is unidirectional in nature whereas the Broadband network is bi-directional. Hence, the total Broadband volume which can be delivered over the cable TV infrastructure is limited. However considering the reasonable penetration, Cable TV network is identified as a good candidate for providing the Rural Broadband connectivity.
- 4.4.3. Broadband can be provided over the Cable TV infrastructure using the IPTV and DOCSIS standards. DOCSIS is cheaper and predominantly used in USA. However selection of technology depends upon the Service Provider. A cable TV network delivering internet is shown in Figure-13 below.

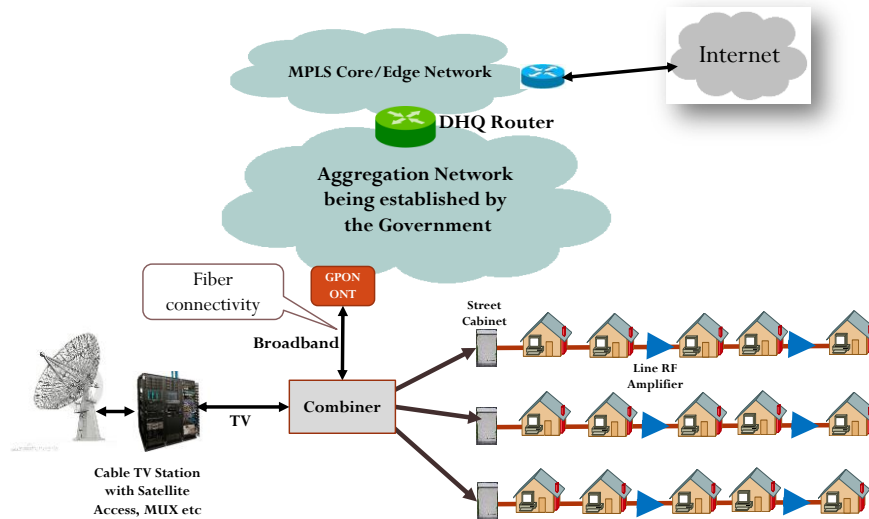


Figure 13: Cable TV networks delivering Internet

4.4.4. In this method, the local cable TV service provider's station is connected to the GPON ONT over Fiber connectivity. The cable TV set-top boxes installed in the houses shall have internet access capability. Cable TV SP shall maintain authentication servers for providing authentication and security.

4.4.5. The cable TV Service Provider requires ISP license for providing the Internet service

4.5. Satellite Access Technology

4.5.1. There are many locations in India where the Broadband connectivity cannot be provided using Optic Fiber, Copper cable, Cable TV or Wireless backhaul technologies.

4.5.2. Andamans & Nicobar and Lakshadweep are group of islands far apart. Even if fiber connectivity can be provided to Port Blair or Kavaratty, extending fiber to all the islands will be very difficult. Hence to the other islands in the group, satellite access is the only solution.

4.5.3. There are many locations in the Himalayan belt falling in Jammu & Kashmir, Himachal Pradesh, Uttarakhand, West Bengal (Darjeeling area), and North Eastern states etc., where fiber connectivity or line of sight radio is not possible. There are other places in the main land like Naxal affected areas, villages inside dense forest areas of Jharkhand etc., where also fiber connectivity or line of sight radio is very difficult.

4.5.4. Such locations in the Islands and remote difficult terrains in the mainland can only be covered through satellite technology.

4.5.5. VSAT terminals can be installed in the BHQ, GP or Village from where the bandwidth can further be extended over other access technologies such as Wi-Fi to the end user.

4.5.6. The 'Ka' frequency band can be used for this purpose. Ka Band has lower antenna size; however it suffers from higher Rain attenuations. Many coding and modulation techniques are now being used in the satellite transponders as well as the Ground station and VSATS for mitigation against rain attenuations. This band has very high capacity to the tune of 100Gbps and many orbital spots are also available. International satellite service providers will be able to provide the satellite bandwidth based on requirement. It is understood that ISRO is also planning Ka band satellites.

4.5.7. A network diagram for the satellite access is shown in Figure-14 below.

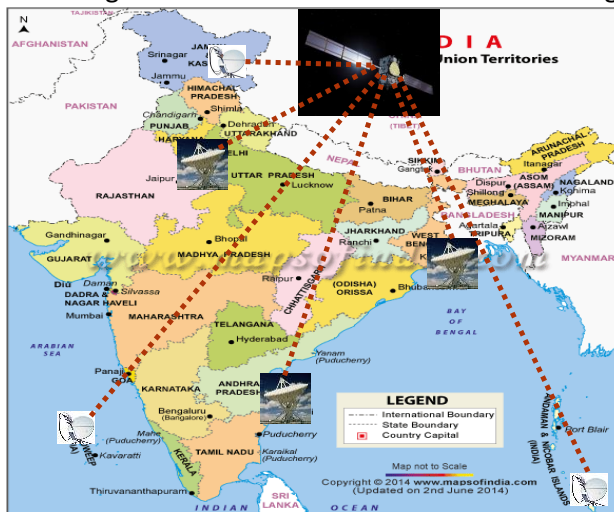


Figure 14: Satellite Connectivity

5.0 Deployment Scenarios

5.1. GP Locations with GPON based backhaul to BHQ & Wi-Fi Access to users in GP

Brief Description of the Architecture along with the Network Diagram is shown in Figure-15.

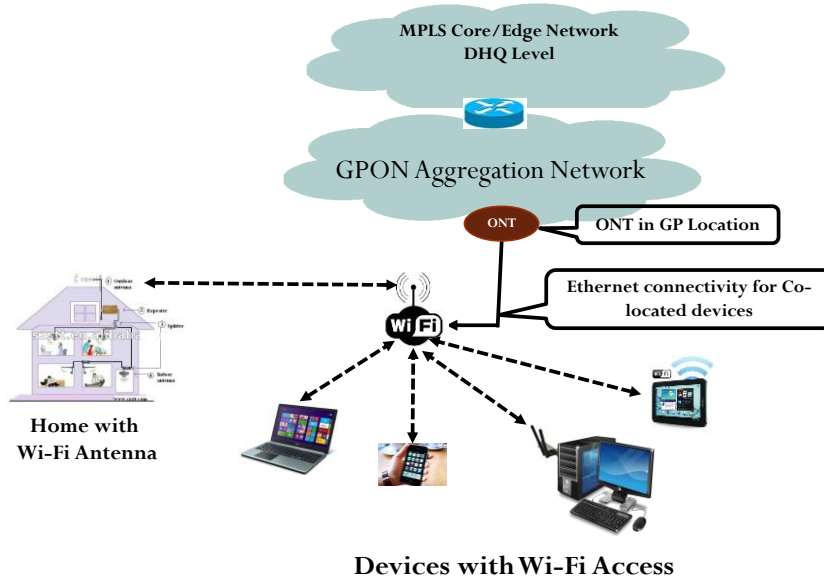


Figure-15: Connectivity of a GP location with GPON Backhaul and W-Fi Access to users

- 5.1.1. This case is for providing Broadband access to users around a Gram Panchayat location.
- 5.1.2. In this architecture, the backhaul connectivity from the GP is using GPON based network.
- 5.1.3. The users in different locations get the Broadband services over Wi-Fi.
- 5.1.4. The equipments used in this architecture are given in Table-3 and the power consumption requirement by equipments are given in Table-4.

Table-3: Equipment Requirement

Sl. No	Item	Quantity
1.	GPON ONT	1
2.	Roof top mast – 5mt	1
3.	Wi-Fi Access Point including outdoor antenna	1
4.	Tower mounted water proof enclosure	1
5.	Solar Panel with Charge controller	1
6.	Battery	1
7.	Inverter	1

Table-4: Power Requirement

Item	GPON
GPON ONT	10W
Wi-Fi AP	15W
Total Power Requirement	25W
Solar Panel Capacity with CCU	48V,240W x 2
Battery Capacity	48V, 40AH
Inverter Capacity	1KVA

- 5.1.5. Bandwidth Availability
Approximate bandwidth which will be available to the users accessing over Wi-Fi access is given in Table-28.

5.2. **GP Locations with Point-to-Point Radio backhaul to BHQ & Wi-Fi Access to users in GP**
 Brief Description of the Architecture along with the Network Diagram is shown in Figure-16.

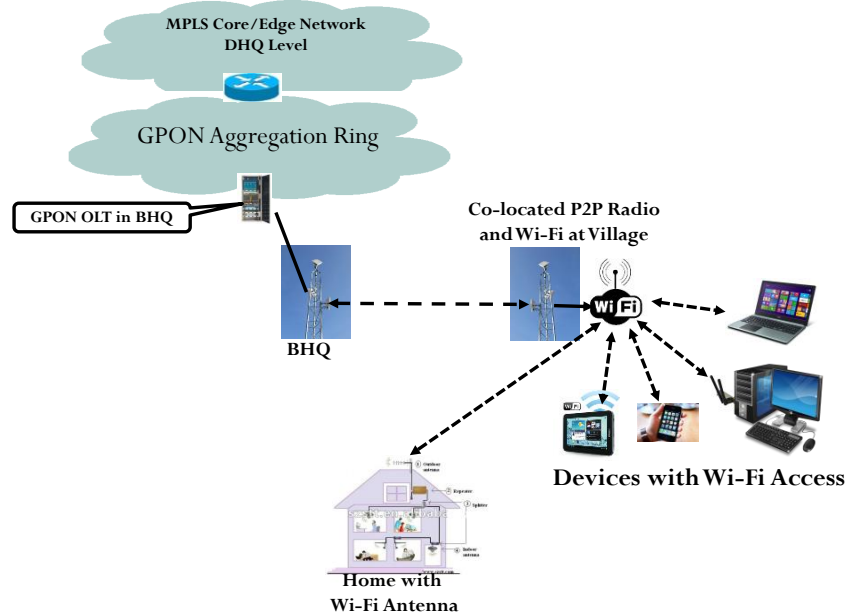


Figure-16: Connectivity of Point-to-Point Radio backhaul to BHQ & Wi-Fi Access to users in GP

- 5.2.1. This case is for providing Broadband access to users around a Gram Panchayat location.
- 5.2.2. In this architecture, the backhaul connectivity from the GP to the BHQ is using the Point to Point Radio system.
- 5.2.3. The users in different locations get the Broadband services over Wi-Fi.
- 5.2.4. The equipments used in this architecture are given in Table-5 and the power consumption requirement by equipments for different radio frequency bands are given in Table-6.

Table-5: Equipment Requirement

Sl. No	Item	Quantity
1.	Ground Based Mast	1
2.	Point to Point Radio terminal	1
3.	Dish Antenna for radio backhaul Access	1
4.	Wi-Fi Access Point including outdoor antenna	1
5.	Solar Panel with Charge Controller	1
6.	Battery	1
7.	Inverter	1

Table-6: Power Requirement

Item	Radio (De-licensed band)	Radio (Licensed band)
Wi-Fi AP	15W	15W
Backhaul Radio	25W	70W
Total Power Requirement	35W	85W
Solar Panel Capacity with CCU	48V,300W x 2	48V,300W x 5
Battery Capacity	48V, 60AH	48V, 150AH
Inverter Capacity	1KVA	1KVA

- 5.2.5. Bandwidth Availability
- The total bandwidth available at the GP location over the Point to Point Radio link is as given in Table-26&27.
 - Approximate bandwidth which will be available to the users accessing over Wi-Fi access is given in Table-28.
 - This access mechanism may be chosen based on the bandwidth availability at the GP location, bandwidth which can be made available to the users and the bandwidth requirement based on the application requirement.

5.3. GP Locations with GPON Backhaul to BHQ, Point-to-Point Radio connectivity to Villages & Wi-Fi Access to users in GP

Brief Description of the Architecture along with the Network Diagram is shown in Figure-16.

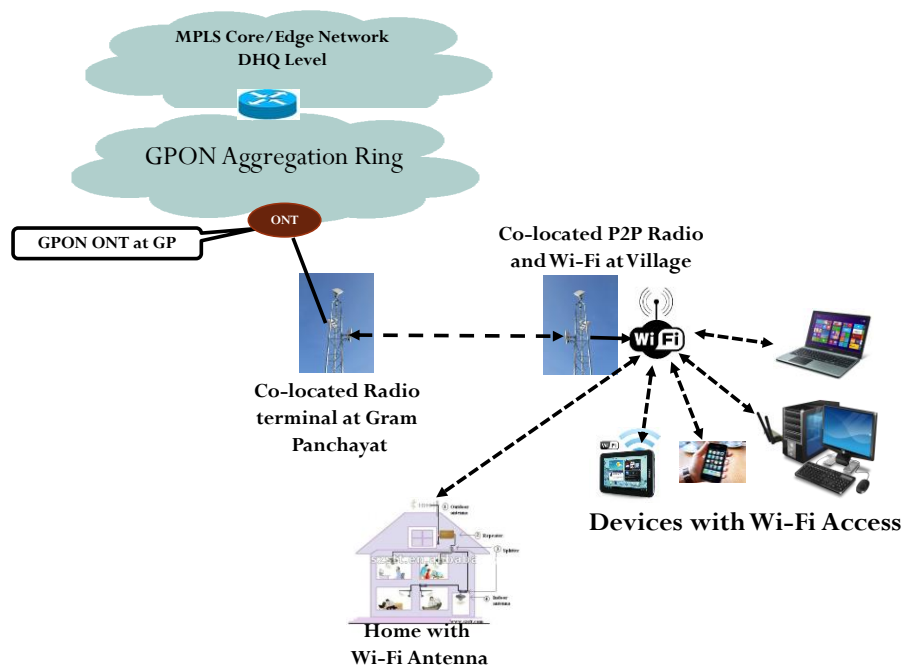


Figure-16: Connectivity of GP Locations with GPON Backhaul to BHQ, Point-to-Point Radio connectivity to Villages & Wi-Fi Access to users in GP

- This case is for providing Broadband access to users around a Gram Panchayat location.
- In this architecture, the backhaul connectivity from the GP is using GPON based network.
- The users in different locations get the Broadband services over Wi-Fi.
- In such locations there may be one or more Radio links for connecting nearby villages.
- The equipments used in this architecture are given in Table-7 and the power consumption requirement by equipments for different radio frequency bands are given in Table-8.

Table-7: Equipment Requirement

Sl. No	Item	Quantity
1.	GPON ONT	1
2.	Point to Point Radio terminal	1
3.	Ground Based Mast	1
4.	Dish Antenna for radio backhaul Access	1
5.	Wi-Fi Access Point including outdoor antenna	1
6.	Solar Panel with Charge Controller	1
7.	Battery	1
8.	Inverter	1

Table-8: Power Requirement

Item	GPON with village connectivity over Radio in De-licensed band Power Requirement	GPON with village connectivity over Radio in licensed band
GPON ONT	10W	10W
Wi-Fi AP	15W	15W
Backhaul Radio	25W	70W
Total Power Requirement	50W	95W
Solar Panel Capacity with CCU	48V,300W x 3	48V,300W x 6
Battery Capacity	48V, 80AH	48V, 150AH
Inverter Capacity	1KVA	1KVA

5.3.6. Bandwidth Availability

Approximate bandwidth which will be available to the users accessing over Wi-Fi access is given in Table-28.

5.4. GP/Village Locations with Satellite Backhaul and Wi-Fi access to users in GP/Village

Brief Description of the Architecture along with the Network Diagram is shown in Figure-17.

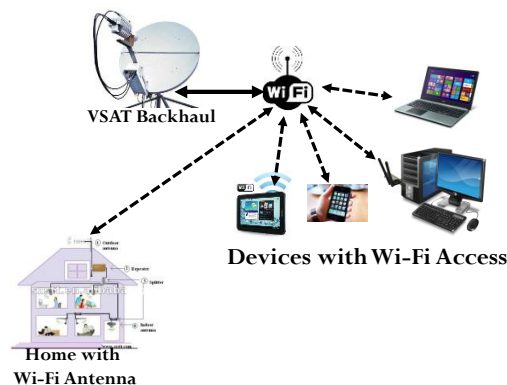


Figure-17: Connectivity of GP/Village Locations with Satellite Backhaul and Wi-Fi access to users in GP/Village

5.4.1. This case is for providing Broadband access to users around a Gram Panchayat or Village location.

- 5.4.2. In this architecture, the backhaul connectivity from the GP/Village is using VSAT network.
- 5.4.3. The users in different locations get the Broadband services over Wi-Fi.
- 5.4.4. The equipments used in this architecture are given in Table-9 and the power consumption requirement by equipments are given in Table-10.

Table-9: Equipment Requirement

Sl. No	Item	Quantity
1.	VSAT terminal	1
2.	Wi-Fi Access Point including outdoor antenna	1
3.	Solar Panel with Charge Controller	1
4.	Battery	1
5.	Inverter	1

Table-10: Power Requirement

Item	Power Requirement
Wi-Fi Hot spot	15W
VSAT Terminal	100W
Total Power Requirement	115W
Solar Panel Capacity with CCU	48V,300W x 7
Battery Capacity	48V, 200AH
Inverter Capacity	1KVA

- 5.4.5. Bandwidth Availability
1.2 / 1.8 meter Ku Band Antenna is capable of providing data transfer rate up to 2Mbps.
- 5.5. **GP/Village Locations with Satellite Backhaul**
Brief Description of the Architecture along with the Network Diagram is shown in Figure-18.

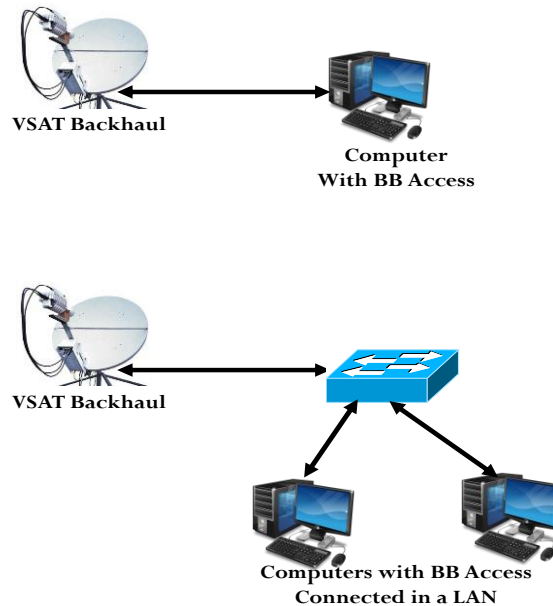


Figure-18: Connectivity of GP/Village Locations with Satellite Backhaul and Fixed access to users in GP/Village

- 5.5.1. This case is for providing Broadband access to users around a Gram Panchayat or Village location.
- 5.5.2. In this architecture, the backhaul connectivity from the GP/Village is using VSAT network. The users in different locations get the Broadband services over Fixed Ethernet connectivity.
- 5.5.3. The equipments used in this architecture are given in Table-11 and the power consumption requirement by equipments are given in Table-12.
- 5.5.4. Internet Connectivity to the Satellite Hub Station: The connectivity of the satellite network with the NOFN network and Internet is given in Figure-19 below.

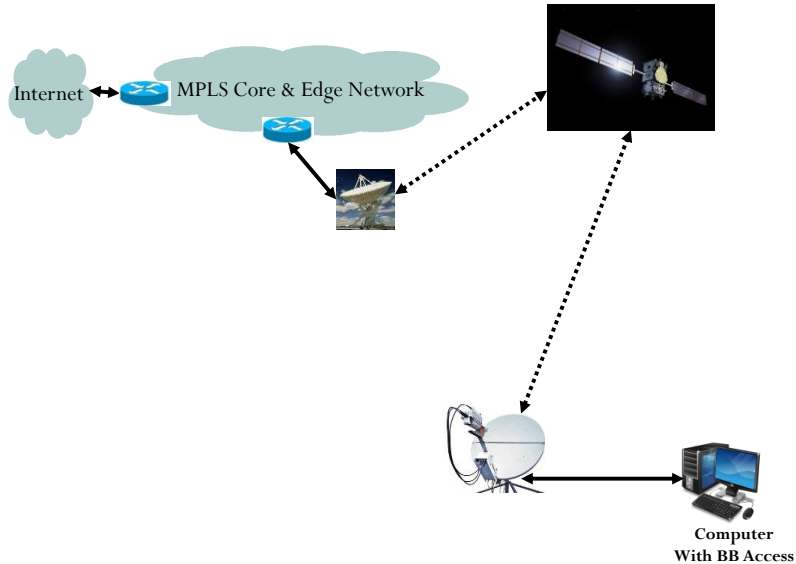


Figure-19: Internet/NOFN connectivity to Satellite Hub Station

Table-11: Equipment Requirement

Sl. No	Item	Quantity
1.	VSAT terminal	1
2.	Solar Panel with Charge Controller	1
3.	Battery	1
4.	Inverter	1

Table-12: Power Requirement

Item	Power Requirement
VSAT Terminal	100W
Total Power Requirement	100W
Solar Panel Capacity with CCU	48V, 300W x 6
Battery Capacity	48V, 150AH
Inverter Capacity	1KVA

- 5.5.5. Bandwidth Availability
1.2 / 1.8 meter Ku Band Antenna is capable of providing data transfer rate up to 2Mbps.

5.6. **Village Locations with GPON based backhaul and Access**

Brief Description of the Architecture along with the Network Diagram is shown in Figure-20.

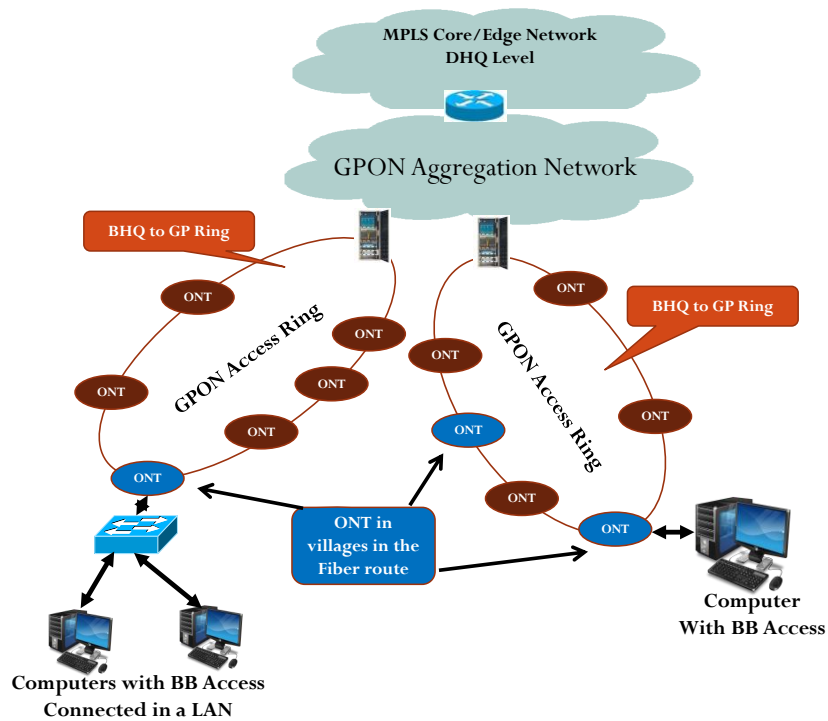


Figure-20: Connectivity of Village Locations falling in Fiber Route over GPON

- 5.6.1. This case is for providing Broadband access to users in a village location falling in the GPON fiber route.
- 5.6.2. This is a typical case of schools, primary health centers, police stations, state government offices etc., falling in the fiber route.
- 5.6.3. The equipments used in this architecture are given in Table-13 and the power consumption requirement by equipments are given in Table-14.

Table-13: Equipment Requirement

Sl. No	Item	Quantity
1.	GPON ONT	1
2.	Ethernet Switch – 8 Port	1
3.	Solar Panel with Charge controller	1
4.	Battery	1
5.	Inverter	1

Table-14: Power Requirement

Item	Power Requirement
GPON ONT	10W
Total Power Requirement	10W
Solar Panel Capacity with CCU	48V,240W x 1
Battery Capacity	48V, 40AH
Inverter Capacity	1KVA

- 5.6.4. **Bandwidth Availability**
Here the user can get upto a maximum of 100Mbps bandwidth.

5.7. Village Locations with GPON based backhaul connectivity to GP and Wi-Fi Access to users in Village

Brief Description of the Architecture along with the Network Diagram is shown in Figure-21.

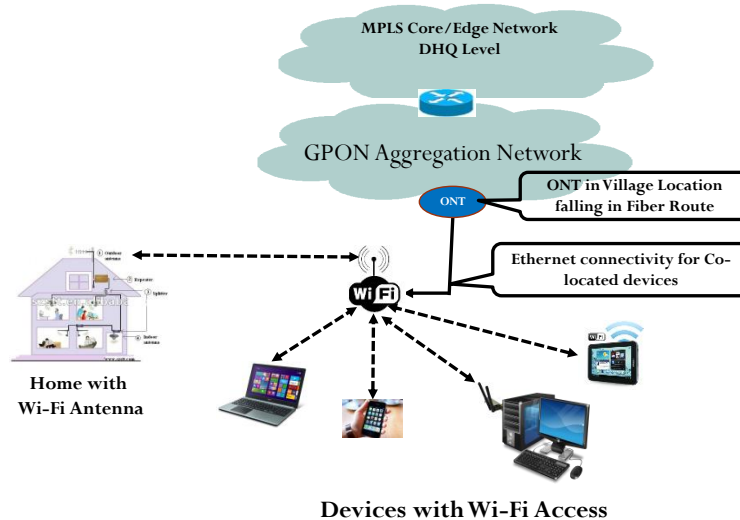


Figure-21: Connectivity of Village Locations falling in Fiber Route over GPON Access devices using Wi-Fi

- 5.7.1. This case is for providing Broadband access to users around a village location falling in the GPON backhaul network.
- 5.7.2. The users in different locations get the Broadband services over Wi-Fi.
- 5.7.3. The equipments used in this architecture are given in Table-15 and the power consumption requirement by equipments are given in Table-16.

Table-15: Equipment Requirement

Sl. No	Item	Quantity
1.	Roof top mast – 5mt	1
2.	Wi-Fi Access Point including outdoor antenna	1
3.	Solar Panel with Charge controller	1
4.	Battery	1
5.	Inverter	1

Table-16: Power Requirement

Item	Power Requirement
GPON ONT	10W
Wi-Fi Hot spot	15W
Backhaul Radio	NA
VSAT Terminal	NA
Total Power Requirement	25W
Solar Panel Capacity with CCU with 6Hrs of day light	48V,240W x 2
Battery Capacity	48V, 40AH
Inverter Capacity	1KVA

- 5.7.4. Bandwidth Availability: Approximate bandwidth which will be available to the users accessing over Wi-Fi access is given in Table-28.

5.8. **Village Locations with Point-to-Point Radio based backhaul connectivity to GP/BHQ and Wi-Fi Access to users in Village**

5.8.1. Brief Description of the Architecture along with the Network Diagram is shown in Figure-22 and Figure-23.

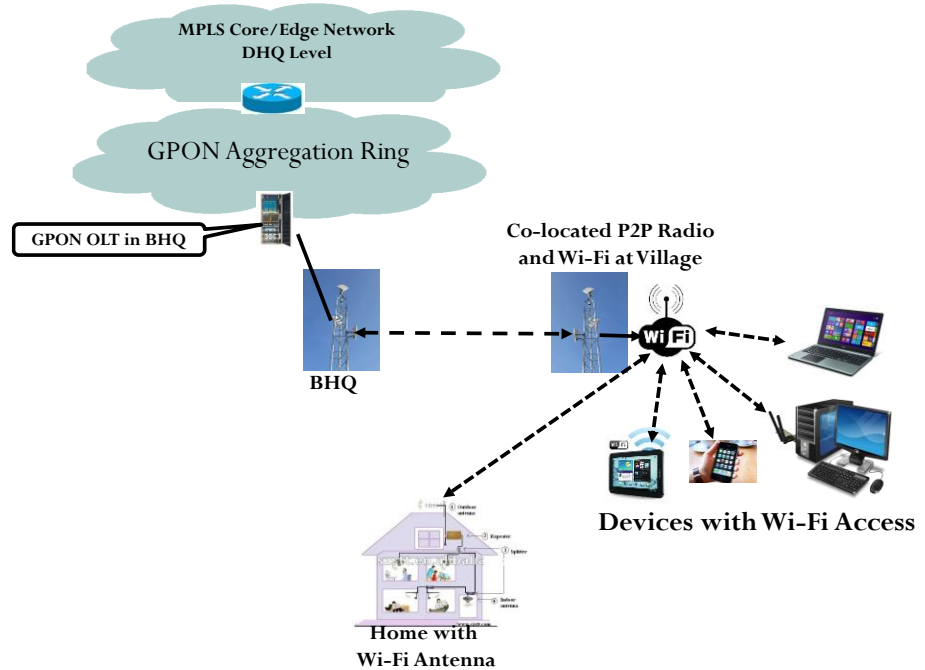


Figure-22: Connectivity of Village Locations connected on Point to Point radio backhaul from BHQ & Access devices using Wi-Fi

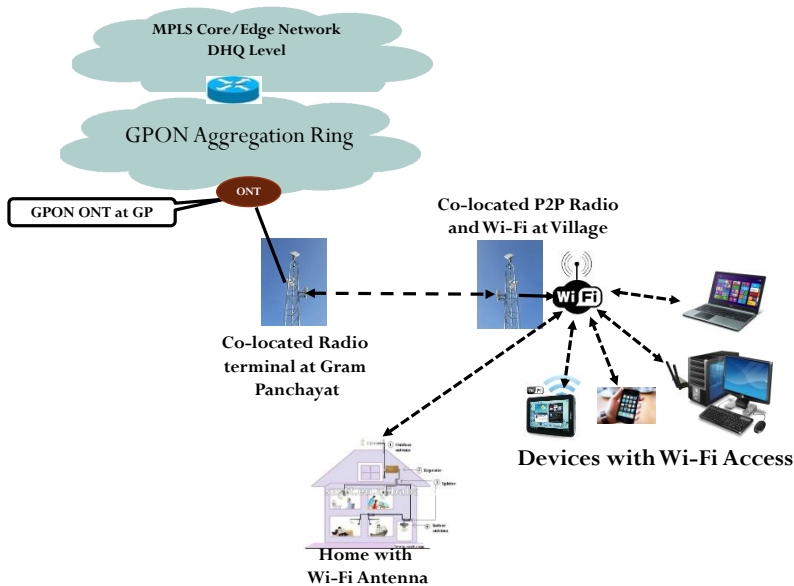


Figure-23: Connectivity of Village Locations connected on Point to Point radio backhaul from GP & Access devices using Wi-Fi

- 5.8.2. This case is for providing Broadband access to users around a Village location.
- 5.8.3. In this architecture, the backhaul connectivity from the Village to the nearest GP or BHQ is through Point to Point Radio Link.
- 5.8.4. The users in different locations get the Broadband services over Wi-Fi connectivity.
- 5.8.5. The equipments used in this architecture are given in Table-17 and the power consumption requirement by equipments for different radio frequency bands are given in Table-18.

Table-17: Equipment Requirement

Sl. No	Item	Quantity
1.	Ground Based Mast	1
2.	Dish Antenna for radio backhaul Access	1
3.	Wi-Fi Access Point including outdoor antenna	1
4.	Solar Panel with Charge Controller	1
5.	Battery	1
6.	Inverter	1

Table-18: Power Requirement

Item	Radio (De-licensed band)	Radio (Licensed band)
Wi-Fi Hot spot	15W	15W
Backhaul Radio	25W	70W
Total Power Requirement	40W	85W
Solar Panel Capacity with CCU	48V,240W x 3	48V,300W x 5
Battery Capacity	48V, 80AH	48V, 150AH
Inverter Capacity	1KVA	1KVA

- 5.8.6. Bandwidth Availability
 - a) The total bandwidth available at the GP location over the Point to Point Radio link is as given in in Table 26&27.
 - b) Approximate bandwidth which will be available to the users accessing over Wi-Fi access is given in Table-28.
 - c) This access mechanism may be chosen based on the bandwidth availability at the GP location, bandwidth which can be made available to the users and the bandwidth requirement based on the application requirement.

5.9. Connectivity from BHQ/GP to Villages over Point-to-Multi-Point Radio Systems:

5.9.1. Brief Description of the Architecture along with the Network Diagram is shown in Figure-24 and Figure-25.

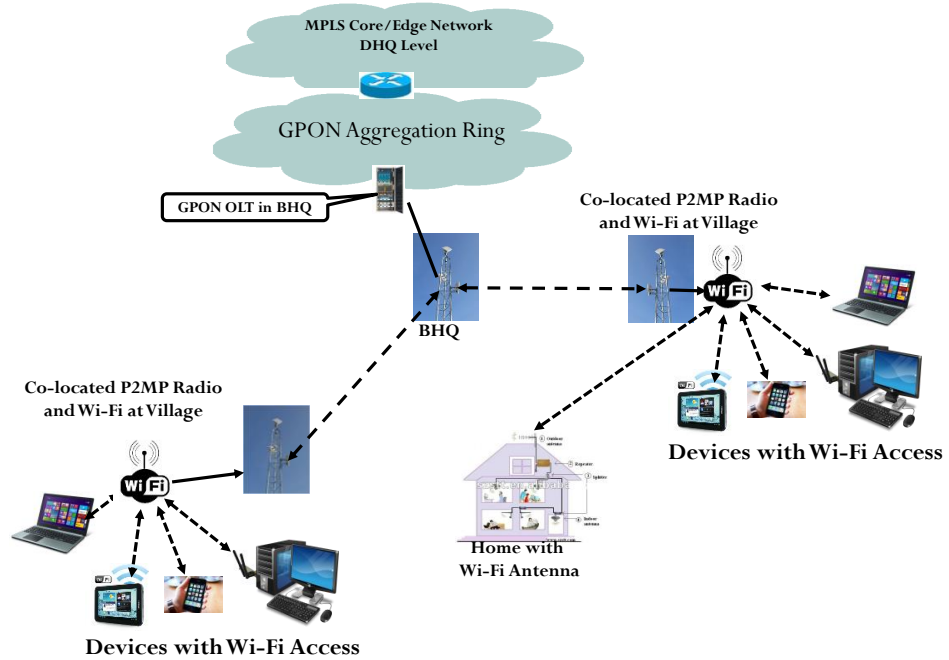


Figure-24: Connectivity of Village Locations connected on Point to Multi-Point radio backhaul from BHQ & Access devices using Wi-Fi

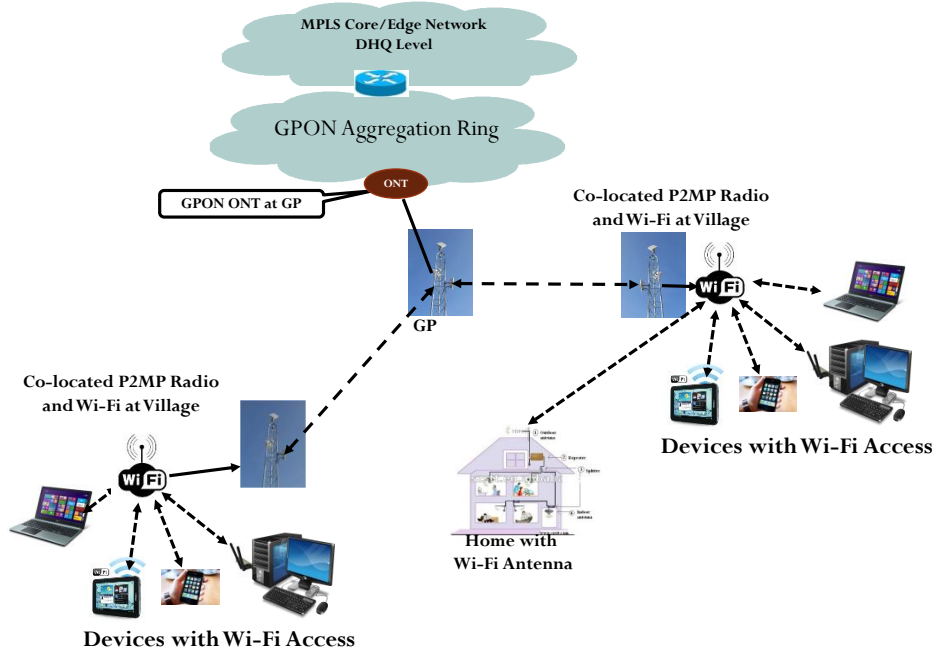


Figure-25: Connectivity of Village Locations connected on Point to Multi-Point radio backhaul from GP & Access devices using Wi-Fi

- 5.9.2. This case is for providing Broadband access to users around multiple Village locations.
- 5.9.3. In this architecture, the backhaul connectivity from nearest GP or BHQ to the Village is through Point to Multi-Point Radio Link because multiple villages are to be connected over Radio links from the BHQ/GP location.
- 5.9.4. The users in different locations get the Broadband services over Wi-Fi connectivity.
- 5.9.5. The equipments used in this architecture are given in Table-19 and the power consumption requirement by equipments for different radio frequency bands are given in Table-20.

Table-19: Equipment Requirement at the Village

Sl. No	Item	Quantity
1.	Ground Based Mast	1
2.	Dish Antenna for radio backhaul Access	1
3.	Wi-Fi Access Point including outdoor antenna	1
4.	Solar Panel with Charge Controller	1
5.	Battery	1
6.	Inverter	1

Table-20: Power Requirement at the Village

Item	Radio (De-licensed band)	Radio (Licensed band)
Wi-Fi Hot spot	15W	15W
Backhaul Radio	25W	70W
Total Power Requirement	40W	85W
Solar Panel Capacity with CCU	48V,240W x 3	48V,300W x 5
Battery Capacity	48V, 80AH	48V, 150AH
Inverter Capacity	1KVA	1KVA

- 5.9.6. Bandwidth Availability
 - a) The total bandwidth available at the GP location over the Point to Point Radio link is as given in Table-26&27.
 - b) Approximate bandwidth which will be available to the users accessing over Wi-Fi access is given in Table-28.
 - c) This access mechanism may be chosen based on the bandwidth availability at the GP location, bandwidth which can be made available to the users and the bandwidth requirement based on the application requirement.

5.10. GP/Village Locations with GPON Backhaul and Broadband over Cable TV Based Access

- 5.10.1. This case is for providing Broadband access to uses around a village location through the cable TV network.
- 5.10.2. In this method, the cable TV network gets is provided with broadband connectivity from the GPON ONT available in the GP location.
- 5.10.3. For providing this sort of broadband access, the cable TV network requires modifications.
- 5.10.4. Equipment/Power Requirement
No additional equipment or power is required in this model.
- 5.10.5. Bandwidth Availability

100Mbps bandwidth from the GPON backhaul network is getting distributed over the cable TV network. The bandwidth availability per customer depends upon the number of customers connected.

5.11. Village Locations with DSL Based Access

5.11.1. Brief Description of the Architecture along with the Network Diagram is shown in Figure-26.

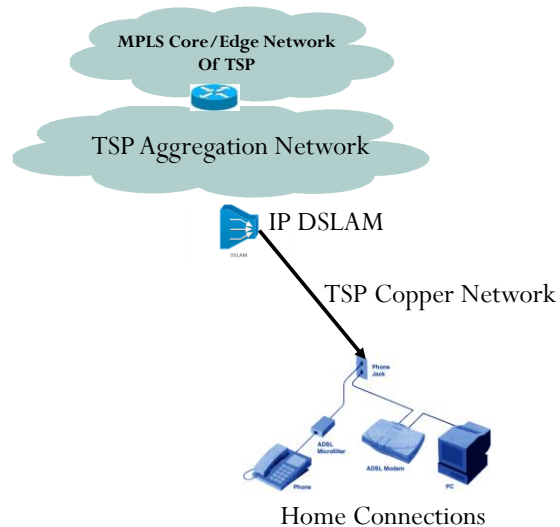


Figure-26: Connectivity of Village Locations over DSL based Access

- 5.11.2. This case is for providing Broadband access to users around a village location through the broadband access network of TSP's over ADSL based network.
- 5.11.3. TSP's will be extending broadband connectivity over copper from their nearby exchange locations to village locations say within 3Km.
- 5.11.4. The broadband speed depends upon the distance from the exchange.
- 5.11.5. Equipment/Power Requirement
No additional equipment or power is required in this model.
- 5.11.6. Bandwidth Availability
- ADSL connectivity can provide a minimum of 512Kbps bandwidth.
 - In case the connection is close to the Service providers POP, the ADSL can provide upto 10Mbps of Bandwidth. The bandwidth availability reduces with distance.
 - VDSL connectivity can provide a bandwidth upto 50Mbps at distances upto 1Km. However the VDSL deployment by the service providers is very limited and is available only in urban areas.

5.12. **Village Locations with Wireless Radio Access**

5.12.1. Brief Description of the Architecture along with the Network Diagram is shown in Figure-27.

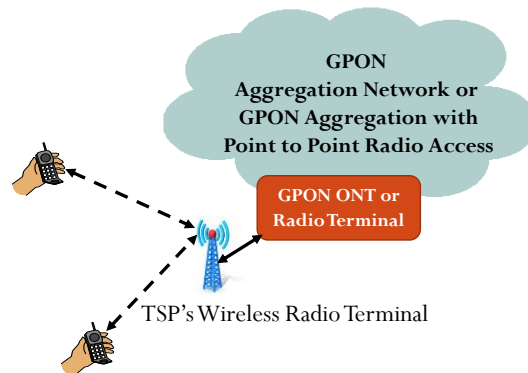


Figure-27: Connectivity of Village Locations over Wireless Radio Access

- 5.12.2. This case is for providing Broadband access to users around a village location through the wireless broadband access network of TSP's over wireless network.
- 5.12.3. TSP's will be extending wireless broadband connectivity from their tower locations to village locations say within 1Km.
- 5.12.4. The broadband speed depends upon the distance, technology used by the TSP as well as number of simultaneous users.
- 5.12.5. Equipment / Power Requirement
No additional equipment or power is required in this model.
- 5.12.6. Bandwidth Availability
The bandwidth available per sector for different Mobile access technologies is given in Table-21 below

Table-21: Maximum Bandwidth available per sector for different mobile access technologies.

Mobile Technology	Maximum bandwidth per sector
EDGE	20Mbps
LTE	300Mbps

6.0 **Network Management**

- 6.1. For operation of the system through remote monitoring and operations, a Network Management System is required. The NMS shall be operated centrally.
- 6.2. The two layer network management system. The two layers consist of the eMS and NMS systems.
- 6.3. First level of management of all the active network elements being procured shall be through the vendor/technology specific element management system (eMS). The eMS performs the direct interface with the network element (NE) generally through proprietary protocols. The eMS performs various faults and performance data collection as well as configuration of the devices. The NMS connects with the eMS over standard interfaces like SNMP, CORBA etc. The eMS does first level of filtering of the fault and performance management data and send the same to NMS.

- 6.4. The management of the various network elements is now being implemented using the network management system developed by CDOT. Therefore all the eMS's shall be integrated over the North bound interface to the CDOT NMS.
- 6.5. The infrastructure components like battery, CCU, solar panel voltage etc., also shall be possible to be monitored remotely so that corrective preventive maintenance actions can be initiated at the appropriate time.
- 6.6. Network Management architecture for different products are indicated below in Figure-28.

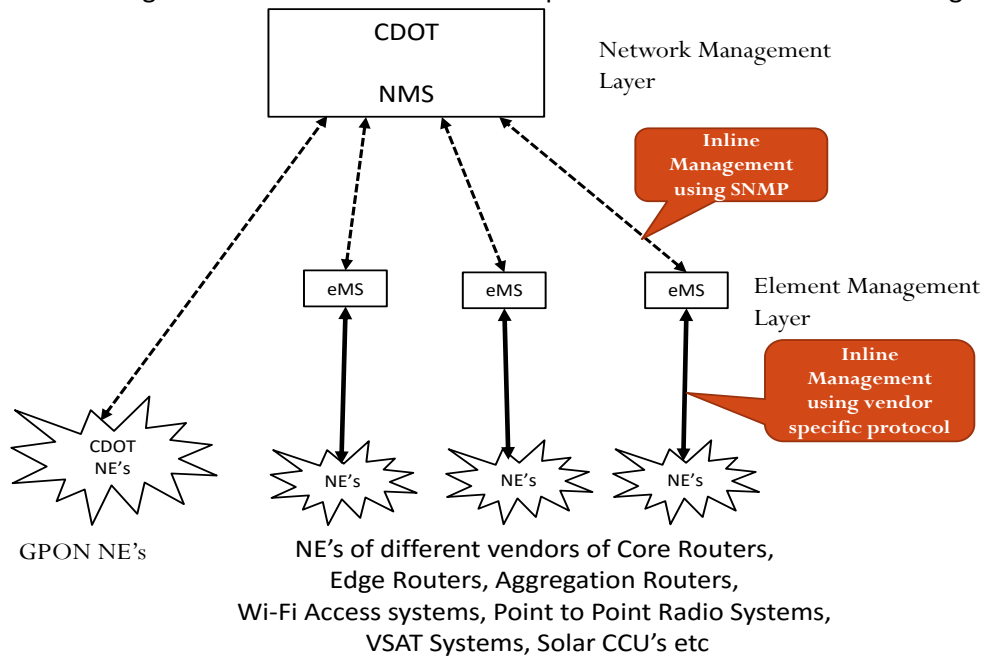


Figure 28: Network Management Architecture

- 6.7. The network management shall be inline i.e. within the network itself using the overall pan-India network infrastructure.
- 6.8. The NMS system should be centralized with main and standby systems at two different locations. Terminals for the NMS systems may be provided at the operations center at every District Head Quarters.

7.0 Inter-operability Issues & Interface Requirements

- 7.1. No inter-operability issues w.r.t connectivity are envisaged as all the connectivity's are at the standard Ethernet interface level.
- 7.2. But certain inter-operability issues w.r.t accessibility of services across networks are envisaged. The services running on the network would be voice, video, VPN and internet data. The services to the end customers (Government customers and general public) could be provided by the TSP or by the Government.

- 7.2.1. **Case-1: TSP Providing the Services:** In case of TSP providing Broadband Wireless Access services using technologies such as LTE, TSP's may either use their own backbone network or the Government aggregation network. In both the scenarios, the end customer shall have access to both TSP network as well as government services available in district/state data centers etc. TSP's shall connect to their MPLS POP in the major districts to the District

Edge Router available in their POP district as shown in Figure-2. This will enable both way access to the services.

7.2.2. **Case-2: Government providing Internet Data Service:** This is the most important scenario as maximum applications are likely to be hosted on the public Internet platform. While Government is building an overlay network, there will be different customers accessing the data from within network, from the TSP network or from outside the country. Customers also would be part different networks. For seamless connectivity all the networks are to be connected to the internet. The internet connectivity can be multi-tiered and can be a combination of international level, NIXI for national peering or at the district level.

- 7.3. Taking all the scenarios into consideration, the proposed horizontal connectivity's.
- a) Connectivity from the DHQ Router to all the TSP's MPLS POP's where the same is available.
 - b) Connectivity with NIXI for national peering.
 - c) Leasing of internet bandwidth directly from International Service Providers

7.4. Interfaces required keeping in view typical upgradation capabilities / requirements, interoperability issues etc.

The requirement of ports for different types of sites is tabulated in Table-22 below:

Table-22: Requirement of Ports in different types of sites

Sl. No	Type of Site	Equipment	Type of Port	No of Ports
1.	GP Locations with GPON based backhaul to BHQ & Wi-Fi Access to users in GP	ONT	10/100/1000 Ethernet	4
2.	GP Locations with Point-to-Point Radio based backhaul to BHQ & Wi-Fi Access to users	P2P Radio at BHQ / GP	10/100/1000	4
		OLT at BHQ	10/100/1000	2 Additional
3.	GP Locations with GPON Backhaul to BHQ, Point-to-Point Radio connectivity to Villages & Wi-Fi Access to users in GP	P2P Radio at GP	10/100/1000	4
		ONT at GP	10/100/1000	6
4.	GP/Village Locations with Satellite Backhaul and Wi-Fi access to users in GP/Village	VSAT Terminal	10/100 Ethernet	4
5.	GP/Village Locations with Satellite Backhaul	VSAT Terminal	10/100 Ethernet	4
6.	Village Locations with GPON based backhaul and Access	ONT	10/100/1000 Ethernet	4
7.	Village Locations with GPON based backhaul connectivity to GP and Wi-Fi Access to users in Village	ONT	10/100/1000 Ethernet	4
8.	Village Locations with Point-to-Point Radio based backhaul	P2P Radio at Village	10/100/1000	4

	connectivity to GP/BHQ and Wi-Fi Access to users in Village			
9.	Connectivity from BHQ/GP to Villages over Point-to-Multi-Point Radio Systems	P2MP Radio at Village	10/100/1000	4
		P2MP Radio at BHQ/GP	10/100/1000	8
		ONT at GP	10/100/1000	8
10	GP/Village Locations with GPON Backhaul and Broadband over Cable TV Based Access	ONT at GP	FE Optical	2

8.0 **Service Delivery**

8.1. The network is established the same can be used for the various services. There is a need to ensure that adequate content is also made available. The governance, education, agriculture, healthcare etc. can be improved once internet connectivity is available. Some of the important content/services which could be delivered over the network in different sectors are as follows.

8.2. **Services to be delivered**

8.2.1. **Education**

Users can have access to quality education & skilled teachers which are normally available in urban areas. Medium can also be used for skill development and placement assistance for rural youths. All schools connected with broadband can have access to education content repository which can be either availed from internet or government can also prepare it and host it for citizens. This will also enable digital literacy programs and online open courses to be implemented effectively.

8.2.2. **Healthcare**

Once connectivity is available, good quality healthcare can be provided to citizens through on line medical consultation, online medical records, online medicine supply and pan India exchange for patient information. Specialist advice from doctors in urban hospitals through remote consultation, information on doctors, diseases, medicine, networked dispensaries, access to test results from distant labs etc., can be provided to people sitting at remote places. A reliable network with minimal latency can enable testing with remote probes & remote surgery as well.

8.2.3. **Manufacturing**

Good connectivity is required for manufacture at remote places. It shall help them in having communication with raw material suppliers, customers, stockists, marketing agents and employers. Connectivity and applications over the connectivity shall help in improving the efficiency and reduce costs for manufacturers through Just-in-Time procurement, manufacturing and supply.

8.2.4. **Job Creation**

With good connectivity available at remote places can lead to job creations in a decentralized mode in remote areas. Manpower in small town & villages can be trained for IT Sector jobs. Service delivery agents can be trained to run viable businesses delivering IT services.

8.2.5. **Banking**

Banking services shall be nearer to home Citizens can have access to basic banking services, access to information on banking products sitting at home or services shall be available at short distances. Many new programs can be envisaged like mobile banking, micro ATM's etc. Post offices can also be used for financial services for financial inclusion

of citizen. Networking can also enable easy sanction and disbursement of loans from banks with linkages with the records of other statutory bodies.

8.2.6. Integrated government services

- i. The availability of connectivity in remote areas shall empower the citizens in rural India through integrated government services.
- ii. The government business processes can be improved by using IT and citizens can do so many services i.e. online application & tracking for their works, use of online repositories i.e. school certificates, voter ID's etc., can be easily made available. Services like UIDAI, payment gateways etc., can be integrated and provide different services.
- iii. Citizens in remote areas shall have easier access to services offered by government i.e. certificates for income, domicile, cast, birth, death, marriage, community ration cards, arm licenses, information on entitlements e.g. scheme for aged, widows and Right to information act, online payment of taxes, online payment of utility bills, payment of stamp duties, issue of driving license, vehicle records, registration of documents and issue of copies of certified documents etc.
- iv. The mentioned above guideline need to be hosted at the data centers, which should be accessible from anywhere.
- v. Creation of Electronic Databases by which all databases and information to be electronic is another requirement. This also requires Work flow in Government is to be atomized especially those related to inter-departmental activities. This will also avoid production of various certificates to other government agencies by automatic linkage of all the services with a citizen unique ID
- vi. Computerisation and linkage of state treasuries can integrate payments of salaries, expenses, reconciliation of accounts
- vii. Online linkage of fair price shops and Public distribution System can ensure that the subsidies from the Government are actually reaching the needy people.
- viii. Public Grievance Redressal using IT tool can be used to automate, respond, analyse data to identify and resolve persistent problems
- ix. Government can pro-actively engages through social media and web based platforms to inform citizens
- x. The planning process in Government can be improved using GIS based decision making
- xi. In the law & order and legal front, the police effectiveness can be improved through e-Police and speedy delivery of Justice through e-Courts

8.2.7. Agriculture:

- i. Connectivity in rural areas shall also help citizens in those areas to have an easy access for crop insurance, weather information, Marketing/sales of crops, price information. Connectivity can also help in facilitating real time alerts on weather information, farming tips & crop prices.
- ii. The agricultural eco system needs to be tailored for Agricultural Produce storage infrastructure, Market price/demand survey, Crop collection, storage, distribution to better priced markets, Requirement processing, Linkage with Banks for Online cash, loan &

relief payment with mobile banking, Online ordering the fertilizers, Seeds etc., Expert advice through Net / in Person for crop/soil problems, Linking of agricultural land with land survey system and satellite data, Availability of machinery from central location for making more land cultivatable, Collaboration for Group farming, Advice for crop rotation, Rain water harvesting and irrigation system etc.

8.2.8. Disaster warning and relief systems

Disaster warning and relief is another important government service which can be provided over the network. Government can provide prior intimation through IP enabled speaker systems regarding natural calamities, relief measures and instructions to the citizens. This can be linked with mobile emergency services, hospitals etc.

8.3. Bandwidth Requirement for various Services

8.3.1. The bandwidth required for various services which are immediately envisaged in the above project are tabulated below in Table-23. Many more services, other than mentioned below, may be existing at present.

Table-23: Bandwidth requirement for Various Services

Type of Service	Service Category	Name of Service	Bandwidth Requirement
Video	Education	Video Based Education Content	2Mbps
	Health Care	On line medical consultation	2Mbps
		Specialist advice from doctors in urban hospitals through remote consultation	2-10Mbps
		Remote testing with remote probes	2-10Mbps
		Remote surgery	10-20Mbps
	Job Creation	Training/Skill Development for IT Sector, Service Delivery Sector etc.	2Mbps
	Integrated government services	e-Courts	2-5Mbps
	Agriculture	Expert advice for crop/soil problems	2Mbps
		Linking of agricultural land with land survey system and satellite data	2Mbps
	Surveillance systems	Camera based local surveillance	1Mbps
Data	Education	Web Enabled Education Content	2Mbps
	Health Care	Online medical records / pan India exchange for patient information	2Mbps
		Online medicine supply	2Mbps
		Information on doctors, diseases, medicine, networked dispensaries	2Mbps
		Access to test results from distant labs	2Mbps
	Manufacturing	Communication with raw material suppliers, customers, stockists, marketing agents and employers for just-in-Time procurement, manufacturing and supply	2Mbps

	Banking	Access to basic banking services, information on banking products	2Mbps
		Mobile banking, micro ATM's	2Mbps
		Post offices used for financial services	2Mbps
		Loans from banks with linkages with the records of other statutory bodies.	2Mbps
	Integrated government services	Online application & tracking of application status for various government Services	2Mbps
		Integration of UIDAI, payment gateways etc to provide different services	2Mbps
		certificates for income, domicile, cast, birth, death, marriage, community ration cards, arm licenses, information on entitlements e.g. scheme for aged, widows and Right to information act, online payment of taxes, online payment of utility bills, payment of stamp duties, issue of driving license, vehicle records, registration of documents, issue of copies of certified documents etc.	2Mbps
		Creation of Integrated Electronic Databases with inter-departmental atomized Work flow	2Mbps
		Computerisation and linkage of state treasuries to integrate payments of salaries, expenses, reconciliation of accounts	2Mbps
		Online linkage of fair price shops and Public distribution System	2Mbps
		Public Grievance Redressal using IT tool	2Mbps
		Government interaction with citizens through social media and web based platforms	2Mbps
		GIS based decision making	2Mbps
		e-Police	2Mbps
	Agriculture	Access for crop insurance, weather information, Marketing/sales of crops, price information	2Mbps
		Real time alerts on weather information, farming tips & crop prices	2Mbps
		Online ordering the fertilizers, Seeds etc.	2Mbps
		Availability of machinery from central location for making more land cultivatable, Collaboration for Group farming, Advice for crop rotation, Rain water harvesting and irrigation system etc.	2Mbps
	Voice	Disaster warning, relief and surveillance systems	Prior intimation to citizens through IP enabled speaker systems on natural calamities, relief measures etc.

8.4. Network for Delivery of the Services

For the delivery of the above services, there are certain pre-requisites which are detailed below.

- 8.4.1. Data center: The contents are to be hosted in the data centers which can be accessible from anywhere.
- 8.4.2. Content delivery platform need to be installed in the SHQ's where the video contents can be hosted and delivered to the end customers.
- 8.4.3. Servers and Storage infrastructure is required in the data centers for hosting the content delivery platform.
- 8.4.4. Apart from having the physical infrastructure in the data centers, the contents integration is a very important aspect of efficient content delivery. One example is to integrate the official data, land records, building records, electricity/water supply, ration card, income tax etc., required for the citizen which are available today in a disjointed electronic form. Another example could be to integrate the agricultural information available from various sources into one point so that the exact requirement of the farmer can be served.

8.5. IP based surveillance camera and Announcement System:

A Typical use case for the surveillance camera with diagrammatic representation, interface requirements and bandwidth requirements is given below in Figure-29.

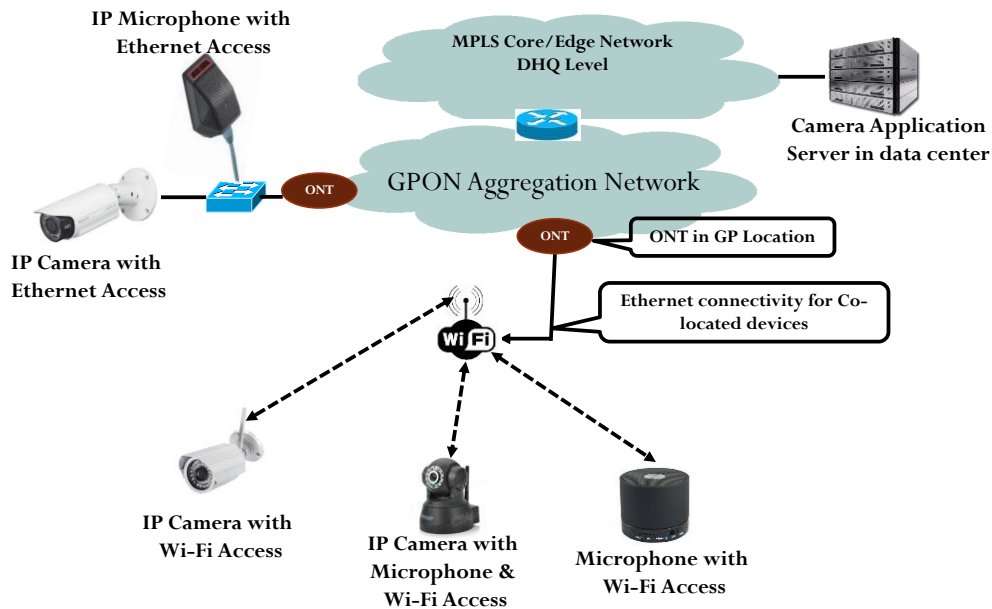


Figure-29: IP surveillance camera system

- 8.5.1. Interfaces: The IP camera and the Announcement Systems shall have 10/100 Ethernet interface for direct connectivity or shall have Wi-Fi connectivity for Wireless based IP camera.
- 8.5.2. Bandwidth Requirements: The Bandwidth requirements for the IP based Surveillance Camera system for different video resolutions and formats is given in Table-24 below. A typical announcement system requires 64kbps of bandwidth. Also the announcement is broadcast in nature.

Table-24: Bandwidth requirement for IP based Surveillance Camera Systems

Sl. No	Video Resolution	Pixels per Frame (Mega Pixels)	Video Format	Frame rate	Bandwidth Mbps	Additional bandwidth for Stable connection	Total bandwidth Mbps
1	320x240	0.0768	MJPEG	15	1.38	0.55	1.94
2	320x240	0.0768	MPEG4	15	0.52	0.21	0.73
3	320x240	0.0768	H.264	15	0.23	0.09	0.32
4	640x480	0.3072	MPEG4	15	2.07	0.83	2.90
5	640x480	0.3072	H.264	15	0.92	0.37	1.29
6		1	H.264	15	3.00	1.20	4.20
7		1	H.264	30	6.00	2.40	8.40
8		2	H.264	15	6.00	2.40	8.40

8.6. Local leased bandwidth connectivity

There would be a requirement of providing leased bandwidth to certain institutions etc., in the villages etc. Such bandwidth can be extended over Fiber. The network diagram for the same is given below in Figure-30. This arrangement can extend any bandwidth. But since the bandwidth available in one ONT location is 100Mbps, we can say that the bandwidth available will be 100Mbps.

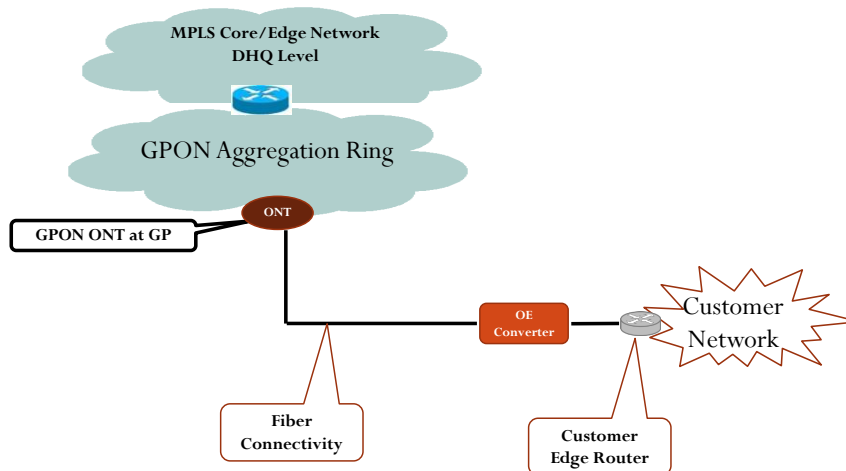


Figure-30: Leased line connectivity to specific customers

8.7. Internet Connectivity to the proposed network

- 8.7.1. The District HQ Edge Router to GPON/MPLS-TP based aggregation is expected to have connectivity to other service providers, District data center, and connectivity to other districts etc as shown below in Figure-31.
- 8.7.2. The same diagram is modified and reproduced with connectivity to the State HQ.
- 8.7.3. Through the connectivity to the District/State data centers, this network will have access to the various state and central services hosted at District/State/Central data centers.
- 8.7.4. The internet connectivity to this network can be from two sources namely by connecting to an ISP at the state HQ level or connecting to the TSP's at the DHQ level.

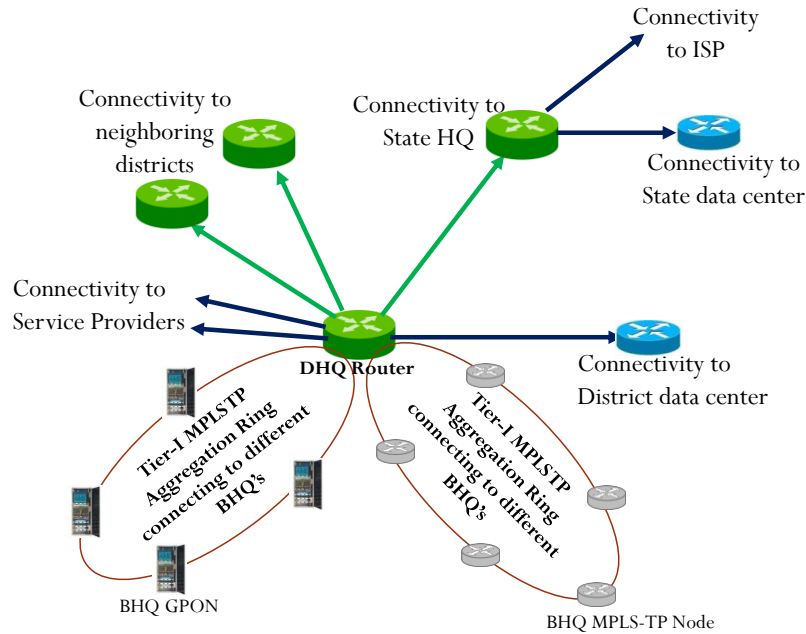


Figure-31: Connectivity to internet & State/District data centers from the proposed network

9.0 TEC Standards and Specifications

This section details the existing TEC standards / specifications in Table 25 below which can be used

Table-25: TEC Specification details

Sl. No	Product	Specification No
1.	MPLS Core Routers	TEC/GR/IT/TCP-004/01 FEB-14
2.	MPLS Edge Routers	TEC/GR/IT/TCP-004/01 FEB-14
3.	MPLS-TP Aggregation Routers	TEC/GR/IT/TCP-004/01 FEB-14
4.	GPON OLT & ONT	GR/PON-01/02 APR.2008
5.	GPON Splitters	TEC/GR/TX/OPT-001/01 APR-12
6.	Ground Based 10/20 Mt Mast	TEC/GR/PI/MST-013/01/AUG-15
7.	Wi-Fi Hotspot	GR/WiFi-01/01 APR 2007
8.	Solar Panel and Charge Controller unit	GR/SPV-02/MAY-2008 TEC/GR/TX/SPV-003/MAR-11
9.	VRLA Battery	TEC/GR/TX/BAT-001/04-JAN 2011 TEC/GR/TX/BAT-002/03-DEC 2013 TEC/GR/TX/BAT-003/02-MAR 2011
10.	Wi-Fi access point for customer access locations	TEC/GR/CP/Wi-Fi-002/01/SEP-11
11.	7GHz IP microwave Radio equipment	TEC/TX/GR/HMR-002/01.SEP-12
12.	13GHz IP microwave Radio equipment	TEC/TX/GR/HMR-003/01.SEP-12
13.	Packet Microwave Radio Equipment (15, 18 & 23GHz)	TEC/TX/GR/PMR-001/01.MAR-13

14.	Point to Point Radio Modem in ISM bands	GR/MOD-009/03 SEP 2012
15.	Dish Antenna for Point-to-point radio systems at 7GHz	GR/ANT-04/04.SEP2006
16.	Content delivery platform	TEC/GR/IT/CDN-001/03 MAR-14
17.	Internet Data center	GR/SA/IDC-001/02 MAR 2010
18.	Cloud Infrastructure	TEC/GR/I/CLI-001/01/Oct12
19.	Servers	TEC/GR/IT/SRV-001/01 FEB-14
20.	Enterprise Storage infrastructure	GR/I/ESI-001/03.MAR.2012
21.	Inverter	GR/INV-01/03 JAN 2001
22.	Dish Antenna for Point-to-point radio systems at 15GHz	TEC/GR/PI/ANT-019/03. NOV-09
23.	Dish Antenna for Point-to-point radio systems at 18GHz	TEC/GR/PI/ANT-009/04. MAR-11
24.	Dish Antenna for Point-to-point radio systems at 23GHz	TEC/GR/PI/ANT-022/01. OCT-13

10.0 Suggestions for the users

10.1. Access and backhaul technologies to be used at subscriber end as well as network end

- 10.1.1. Broadband Access over GPON may be provided to those locations falling in the fiber route planned for Gram Panchayat connectivity.
- 10.1.2. Wi-Fi access may be extended from the Gram Panchayats.
- 10.1.3. Broadband wireless access through TSP's may be provided for those areas where TSP is providing the BWA services.
- 10.1.4. Broadband may be provided through Cable TV access network in those GP's or VP's where cable TV operations are available.
- 10.1.5. Satellite Access may be provided to remote locations which cannot be covered through the Wireline or LOS Radio Backhaul.
- 10.1.6. Backhaul connectivity using Point to Point Radios may be provided to those locations inaccessible over GPON and having clear line of sight.

10.2. General Requirements for the usage of the licensed / unlicensed bands of Radio connectivity

- 10.2.1. There shall be line of sight available between the two stations
- 10.2.2. The contour map of the area is to be taken, the locations of both stations shall be plotted in the map
- 10.2.3. The heights of different locations in the path shall be noted along with the distance from the stations.
- 10.2.4. The distance vs height shall be plotted on a graph paper.
- 10.2.5. Tower height (Including the height of the buildings) shall be marked in the graph such that line of sight is available between the two locations.
- 10.2.6. Additional clearance for the vegetation shall be given to take care of growth of vegetation, available as well as which may come in future. Generally 10mt clearance is given for

vegetation in places with trees etc. However this can change based on the geography of the location. Clearance for the tall buildings if any en-route may also be taken into account.

10.3. Additional Requirements for the Licensed bands of Radio connectivity

- 10.3.1. Approval of the frequency of usage shall be obtained from WPC.
- 10.3.2. There is no limitation in the height of the antenna.
- 10.3.3. Typical reach and bandwidth availability for various frequency bands is given in the Table-26 below.

Table-26: Bandwidth calculations under different connectivity scenarios

Scenario	Frequency GHz	Tx Power dBm	Cable/ Connector Loss dB	Antenna Gain dBi	EIRP	Distance Km	Free Space Loss dB	Fade Margin dB	Rx Power dBm	Modulation	data rate (20MHz Channel) Mbps	data rate (28MHz Channel) Mbps	data rate (40MHz Channel) Mbps
Licensed Band LOS (*)	3.3	30	3	26	53	50	136.76	6	-66.76	16QAM	24		50
	3.3	30	3	26	53	25	130.74	6	-60.74	64QAM	50		80
	7	25.5	3	26	48.5	60	144.87	6	-79.37	16QAM		100	
	7	23	3	26	46	12	130.89	6	-67.89	256QAM		200	
	13	24	3	26	47	25	142.65	6	-78.65	32QAM		100	
	13	23	3	26	46	6	130.25	6	-67.25	256QAM		200	
	15	24	3	26	47	20	141.95	6	-77.95	32QAM		100	
	15	22	3	26	45	5	129.91	6	-67.91	256QAM		200	
	18	23	3	26	46	14	140.44	6	-77.44	32QAM		100	
	18	20	3	26	43	3	127.06	6	-67.06	256QAM		200	
	23	23	3	26	46	9	138.73	6	-75.73	32QAM		100	
23	21	3	26	44	3	129.18	6	-68.18	256QAM		200		

* In the licensed band, LOS, it is possible to achieve around 1.7 times the above bandwidth by using Cross Polarisation Interference Canceller (XPIC)

10.4. Additional Requirements for the De-licensed bands of Radio connectivity

- 10.4.1. It is suggested to use the 5.8GHz frequency band.
- 10.4.2. In radios operating in 5.825-5.875GHz license-free bands, the maximum output power permissible is 30dBm and maximum effective radiated power is 36dBm.
- 10.4.3. The total bandwidth available at the GP location over the Point to Point Radio link calculated under different connectivity scenario is given below in Table-27.

Table-27: Bandwidth calculations under different connectivity scenarios

Frequency GHz	Tx Power dBm	Cable/ Connector Loss dB	Antenna Gain dBi	EIRP	Distance Km	Free Space Loss dB	Fade Margin dB	Rx Power dBm	Modulation	data rate (20MHz Channel) Mbps	data rate (40MHz Channel) Mbps
5.8	20	3	17	34	1.1	108.5	6	-66.5	64QAM	52	81
5.8	20	3	17	34	5	121.66	6	-79.66	BPSK	6.5	13
2.4	22	3	17	36	3.5	110.89	6	-66.89	64QAM	52	81
2.4	22	3	17	36	15	123.53	6	-79.53	BPSK	6.5	13

10.5. Typical Tower Height Requirement for Point to point Radio in a Plain Area

In case of a plain area where clear line of sight is available, (There are no tall buildings or tall vegetation) a typical tower height of 15mt could be used. This is only for giving a general guideline and the tower heights may be calculated using site survey methods.

10.6. Suggestions for the usage of Wi-Fi as an Access Technology

- 10.6.1. 2.4-2.4835GHz is preferred for the broadband access
- 10.6.2. In radios operating in 2.4-2.4835GHz de-licensed band, the maximum output power permissible is 30dBm, maximum effective isotropic radiated power is 36dBm.
- 10.6.3. The maximum height of antenna permissible is 5mt above the roof top of the existing authorized building.
- 10.6.4. The bandwidth available depends upon the Line of Sight conditions and the distance from the Wi-Fi hotspot.
- 10.6.5. Typical Calculations for the total Bandwidth Availability per Wi-Fi Access Point is given in the Table-28 below. The bandwidth per user depends upon the distance of the user from the Access Point and the number of users.

Table-28: Bandwidth available per Wi-Fi Access Point

IEEE Standard	802.11b	802.11g	802.11n
Frequency	2.4 GHz	2.4 GHz	2.4/5 GHz
Max. Data Rate	11 Mbps	54 Mbps	600 Mbps
Typical Range Indoors*	100 ft.	125 ft.	225 ft.
Typical Range Outdoors*	450 ft.	450 ft.	825 ft.

- 10.6.6. Depending upon the adopted Wi-Fi standard the bandwidth availability of minimum 2 Mbps at the edge of coverage range as given in Table below for Omni directional antenna. Sector Antenna as standalone can be used for desired 120° of coverage. By using 3 sectors with 3 Access Points, the number of clients can be tripled in a given area. This increases range, reduces latency, and speeds up network efficiency.
- 10.6.7. *Range estimates are typical and require line of sight. Basically that means you will need a clear unobstructed view of the antenna from the remote point in the link. Keep in mind that walls and obstacles will limit your operating range and could even prevent you from establishing a link. Signals generally will not penetrate metal or concrete walls. Trees and leaves are obstructions to 802.11 frequencies so they will partially or entirely block the signal.
- 10.6.8. Other factors that will reduce range and affect coverage area include metal studs in walls, concrete fiberboard walls, aluminum siding, foil-backed insulation in the walls or under the siding, pipes and electrical wiring, furniture and sources of interference. The primary source of interference in the home will be the microwave oven. Other sources include other wireless equipment, cordless phones, radio transmitters and other electrical equipment.

In case required coverage is not met with one Wi-Fi access point, additional access points can be installed in different locations for the required coverage. The Wi-Fi access points at locations other than the main location can be backhauled to the main location either through Optical Fiber links or through Point-to-Point Radio systems. ONT's with Fiber ports are available for such connectivity.

10.7. Security requirements for access from Wi-Fi:

Open Wi-Fi access is a major security concern. Hence while implementing such Wi-Fi systems, the access shall always be through user access authentication from a centralized server. The guidelines for the same has already been issued by DoT vide letter no. 842-725/2005-VAS dated 23/02/2009.

10.8. Lawful Interception requirements

Proper provision shall be made in the system for the lawful interception requirement

10.9. Calculations for the Solar Panel/Battery/Inverters

10.9.1. For the guidelines for calculations for the battery bank and the SPV power generating systems, Annexure-4 of the GR No. TEC/GR/TX/SPV-003/03.MAR-2011 (Solar Photo Voltaic (SPV) power supply for Telecom Equipments) may be referred.

10.9.2. However one sample calculation for a total power requirement of 100W is given below in Table-29.

Table-29: Calculation for battery bank and power requirement of 100W

Total Power Requirement	100W
Battery Voltage	48V
Continuous current	$100/48 = 2A$
Load per day	$2 \times 24 = 48AH$
Autonomy	3 continuous sunless days
Permissible Battery discharge	0.8 (80%)
Battery capacity slower than C/20 and faster than C/120	1.2 (120%)
Battery reserve required	$= 48 \times 3 / 0.8 / 1.2 = 150AH/48V$
Nearest Battery capacity Available	150AH
Battery conversion Efficiency	0.9 (90%)
Efficiency of the charge controller	0.85 (85%)
Efficiency of the Inverter	0.85 (85%)
Safety factor for SPV power loss	1.25
Full sun isolation availability in India	4Hrs
SPV Voltage of 12V Panel at Peak power point	17V
SPV requirement	$= \{[(48/0.9 \times 0.85 \times 0.85)] \times 1.25\} / 4 \times 17 \times 4$ = 1569 Watts
No of 24Vx300W SPV Panels	= 6 (2 Panels connected in Series to make 48V and 3 such sets connected in parallel)
Inverter Capacity Required	1KVA

10.10. Typical deployment Scenario with a combination of backhaul technologies

10.10.1. A typical deployment scenario with different backhaul (GPON, Point to Multi Point Radio, Point to Point Radio and Satellite) and access technologies (GPON, Direct Ethernet, Wi-Fi) is given in Figure-32 below.

- 10.10.2. As shown, different services like video streaming, surveillance camera, public address system, tele-education, tele-medicine, internet browsing etc., are shown being accessed through the network to get a feel of how the different service access across the network.
- 10.10.3. The bandwidth availability for various services depends upon the backhaul and access technology used and is already indicated under the previous paras of the report. The bandwidth requirement for various services were also tabulated as part of the report.

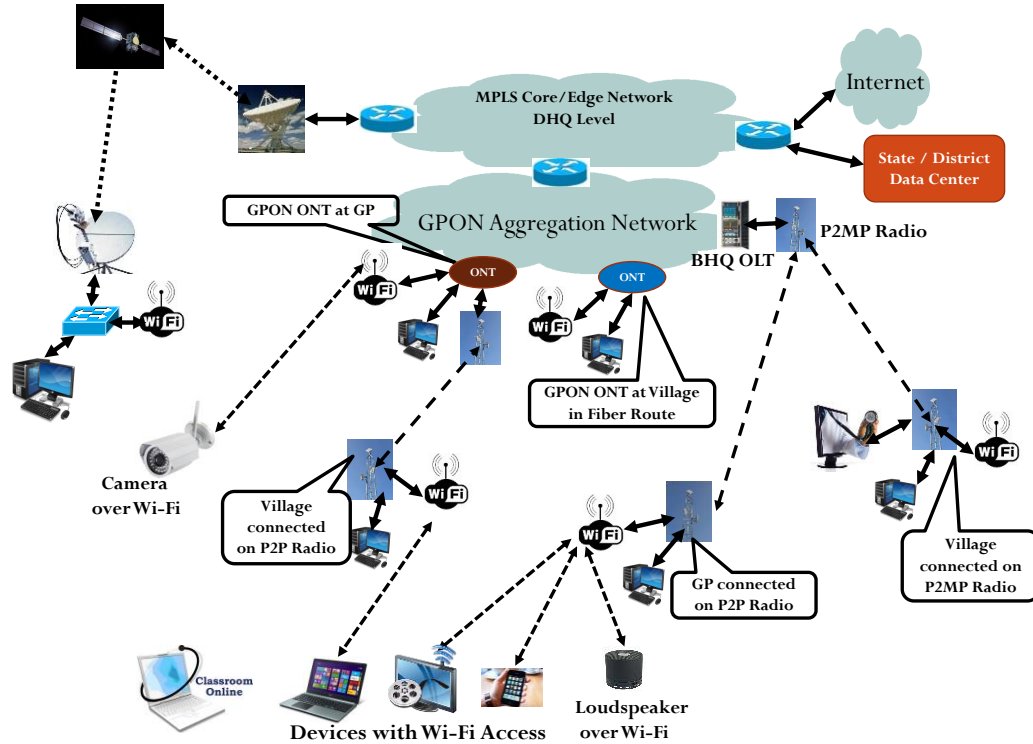


Figure-32: Connectivity in a typical scenario with different access technologies

10.11. Suggestions for the choice of Technology

10.11.1. Choice of Backbone technology for the GP's

- 10.11.1.1. GPON based backbone technology is to be used for those GP's which can be connected over Fiber.
- 10.11.1.2. In case fiber connectivity to the BHQ is not possible, and line of sight is possible with reasonable tower height of say maximum 40mt, such locations may be covered through radio links. Such radio links may use licensed spectrum in case the link distances are more and may use delicensed spectrum in case the link distances are short. The calculations for the link distances and bandwidth which can be made available under different distances are already tabulated in Table-26 and Table-27. In case more than one GP/Village is to be connected from the BHQ point to multi point radio systems may be used.
- 10.11.1.3. Satellite connectivity using VSAT may be used for connectivity of those locations which cannot be connected over Fiber or Radio links.

10.11.2. Choice of Backbone technology for the Villages

- 10.11.2.1. GPON based backbone technology is to be used for those villages which can be connected over Fiber.
- 10.11.2.2. In case fiber connectivity to the GP is not possible, and line of sight is possible with reasonable tower height of say maximum 40mt, such locations may be covered through radio links. Such radio links may use licensed spectrum in case the link distances are more and may use delicensed spectrum in case the link distances are short. The calculations for the link distances and bandwidth which can be made available under different distances are already tabulated in Table-26 and Table-27. In case more than one Village is to be connected from the GP/BHQ point to multi point radio systems may be used.
- 10.11.2.3. Satellite connectivity using VSAT may be used for connectivity of those locations which cannot be connected over Fiber or Radio links.

10.11.3. Choice of the Access technology

- 10.11.3.1. GPON based backbone technology is to be used for those access locations such as schools, village offices, police stations etc., which require higher bandwidth as well as which can be connected on Fiber. Such locations shall either fall in the fiber route or a small extension to such locations can be built from the GPON ONT location in the GP or the village.
- 10.11.3.2. Wi-Fi may be used as an access technology for connecting locations say within one km and where line of sight is available from the access devices. The bandwidth available in the Wi-Fi access location depends upon the distance from the access point, number of simultaneous users as well as the line of sight situations. While using Wi-Fi, necessary security precautions may be taken care of.
- 10.11.3.3. While using Wi-Fi access, in case the location do not have proper coverage or distance is slightly above the requirements, outdoor antenna over poles can be used at the access location.
- 10.11.3.4. Where ever ADSL based copper broadband access is available from telecom service providers, such services can be used. However the bandwidth availability in such locations depends upon the distance from the exchange location.
- 10.11.3.5. Where ever connectivity can be extended over the cable TV network, such possibility may be explored.
- 10.11.3.6. Where ever wireless broadband access is provided by the Telecom Service providers, such access mechanism can be used. However the bandwidth availability in such locations depends upon the distance from the tower location, line of sight conditions and number of simultaneous users.
- 10.11.3.7. Satellite connectivity using VSAT may be used for connectivity of those locations which cannot be connected over Fiber or Wi-Fi or other access technologies.

11.0 Reference

1. Report of the committee formed by Sr. DDG TEC to frame the architecture of an integrated last mile technological solution for delivery of various services in rural areas under digital India program
2. Supplementary report of the committee formed by Sr. DDG TEC to frame the architecture of an integrated last mile technological solution for delivery of various services in rural areas under digital India program.
3. WPC Notification no G.S.R.38(E) dated 19th January, 2007
4. WPC Notification no G.S.R.45(E) dated 28th January, 2005
5. DoT guidelines for providing Wi-Fi service under de-licensed bands vide letter no. 842-725/2005-VAS dated 23/02/2009
6. IEEE standard 802.11 Wireless LAN and IEEE standard 802.16 Wireless MAN specifications
7. State of Broadband 2014: Broadband for all, report by Broadband commission, ITU
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9. ASSOCHAM India, Com First India Report on Broadband for India
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11. Solar Photo Voltaic (SPV) power supply for Telecom Equipments GR No. TEC/GR/TX/SPV-003/03.MAR-2011.