PLANNING FOR
BharatNet PHASE 2

September 2016

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Planning for BharatNet Phase 2

Report on
IIT Bombay BharatNet Planning Tool

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Executive Summary

BharatNet is a project envisioned by the Government of India to digitally connect all the Gram Panchayats (GPs) and Villages of India. In order to achieve the target in the stipulated time, it is necessary to exploit various wired and wireless technologies and design a network topology.

The IIT Bombay BharatNet planning tool has been designed and enhanced for its functionality in order to generate fibre route along with wireless links as well as its feasibility for connectivity of Phase 2 GPs of BharatNet project. The tool takes into account the road data of India that facilitates fibre planning along the road based on GPON architecture. The tool also takes inputs of the Optical Line Terminators (OLTs) present in each block for determining the fibre route from block headquarters to the GPs in the block. The GPs which are not connected through fibre, are then considered for alternate technologies such as 5.8 GHz Wi-Fi technology and satellite.

A thorough fibre link feasibility and wireless link feasibility is undertaken to design a feasible and stable network of fibre and wireless links. Various assumptions have been made for feasibility tests and network topology design.

Based on the new assumptions mentioned in Chapter 8, following is the Pan-India fibre and wireless summary of the results.

State Name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of OLTs as per IITB design	Number of ONTs as per IITB design	Wireless from Phase 1 GP	Wireless from BSNL Towers	Satellite Recommendation	Total number of GPs which are not connected	Total Fibre Route Length (km)	Total Fibre length (km)
ANDAMAN & NICOBAR ISLANDS	0	0	0	0	0	0	0	0	0	0
ANDHRA PRADESH	19303	3065	996	14655	3	4557	42	46	56476.27	63366.37
ARUNACHAL PRADESH	924	86	85	595	26	139	117	47	2972.81	3335.493
ASSAM	33	91	5	7	2	24	0	0	50	56.1
BIHAR	1326	668	98	975	97	239	7	8	4591.78	5151.977
CHANDIGARH	0	0	0	0	0	0	0	0	0	0
CHHATTISGARH	5211	954	105	3596	76	1165	131	243	13248.23	14864.51
DADRA AND NAGAR HAVELI	11	0	1	11	0	0	0	0	66	74.052
DAMAN & DIU	15	0	2	15	0	0	0	0	48	53.856
GOA	0	0	0	0	0	0	0	0	0	0
GUJARAT	7942	1946	169	5513	1	2187	32	209	22092.53	24787.82
HARYANA	0	0	0	0	0	0	0	0	0	0
HIMACHAL PRADESH	2888	474	73	1776	16	737	11	348	8777.42	9848.265
JAMMU & KASHMIR	1807	185	53	1209	39	280	136	143	3180.64	3568.678
JHARKHAND	2545	1058	163	1871	0	582	37	55	9130.54	10244.47
KARNATAKA	0	0	0	0	0	0	0	0	0	0
KERALA	0	0	0	0	0	0	0	0	0	0
LAKSHADWEEP	0	0	0	0	0	0	0	0	0	0
MADHYA PRADESH	6197	2053	85	3393	133	2171	26	474	13449.55	15090.4
MAHARASHTRA	7815	2387	167	6528	108	961	24	194	24082.02	27020.03
MANIPUR	0	0	0	0	0	0	0	0	0	0
MEGHALAYA	0	0	0	0	0	0	0	0	0	0
MIZORAM	438	33	21	274	7	11	17	129	1863.34	2090.667
NAGALAND	249	140	16	95	27	101	20	6	607	681.054

State Name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of OLTs as per IITB design	Number of ONTs as per IITB design	Wireless from Phase 1 GP	Wireless from BSNL Towers	Satellite Recommendation	Total number of GPs which are not connected	Total Fibre Route Length (km)	Total Fibre length (km)
NCT OF DELHI	0	0	0	0	0	0	0	0	0	0
ODISHA	2328	891	142	1503	0	735	67	23	10481.11	11759.81
PUDUCHERRY	0	0	0	0	0	0	0	0	0	0
PUNJAB	6469	2039	77	3745	262	2455	0	7	10564.01	11852.82
RAJASTHAN	2069	2235	104	1240	105	603	1	120	10769.82	12083.74
SIKKIM	0	0	0	0	0	0	0	0	0	0
TAMIL NADU	7982	3599	232	5823	0	2080	0	79	19476.92	21853.1
TRIPURA	19	117	5	6	0	13	0	0	32	35.904
UTTAR PRADESH	33653	2696	338	23824	1315	7014	69	1431	39511.39	44331.78
UTTARAKHAND	5735	743	116	4525	98	634	150	328	15117.1	16961.39
WEST BENGAL	0	0	0	0	0	0	0	0	0	0
TOTAL	114959	25460	3053	81179	2315	26688	887	3890	266588.48	299112.3
UNPROCESSED GPs	35041	-	-	-	-	-	-	-	140164	157264
GRAND TOTAL	150000	25460	3053	81179	2315	26688	887	3890	406752.5	456376.3

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Chapter 1
Overview of BharatNet Phase 2

1.1. Introduction

India has a very large rural-urban digital divide. While urban India is almost completely covered both through voice and internet, rural India still suffers from inadequate connectivity with approximately 50,000 villages which do not even have voice connectivity. Rural India has 2,50,000 village offices named as Gram Panchayats. Each Gram Panchayat serves roughly about 2.56 villages on an average thus totalling approximately 6,40,000 villages. Connectivity in urban India is mostly provided by private entities. For these private operators, there is little incentive in extending their network to the rural areas mainly on account of factors such as (i) need to cover a large area with low population density, thus limiting their return on investments (ii) high capital investments for setting up the infrastructure and (iii) high operational costs for mainly security and power. Hence, bridging the digital divide needs to be an initiative by the government as internet connectivity can play a significant role not only in making administration efficient and transparent but also in generating employment and rapid dissemination of information.

The Government of India has been very ambitious about bridging this digital divide. The BharatNet (formerly National Optical Fibre Network (NOFN)) has been one such digital plan of the Government of India that aims to digitally connect all of India's villages and Gram Panchayats by broadband Internet connectivity. According to this plan, by the year 2019, it has been envisaged that all two lakh fifty thousand Gram Panchayats in India will enjoy broadband connectivity. Within BharatNet, which is being implemented in two phases, point of presence (PoP) with optical connectivity at all Gram Panchayat (GP) will be provided by 2019. This will enable key services like administration, education, health, banking and agriculture in becoming efficient and transparent. It is also proposed to provide Gram Panchayat kiosks for rural India to access the internet. Further, connectivity to individual households is expected to be established by local players under enabling employment and entrepreneurship options for village youth.

For the success of BharatNet project in the desired time frame and its sustainability over a long period of time, careful planning of the network by understanding various trade-offs is essential. The technologies that can be considered for connecting the GPs include underground/overhead fibre optic cables, wireless in unlicensed bands and satellite connections. Connectivity using optical fibre provides high bandwidth, low maintenance and a scalable network. However, the downside of it is that, deployment of fibre optic network may be time consuming on account of various requirements for laying cables. Comparatively, deploying wireless links can be used to increase deployment speed, but they may need maintenance periodically and careful planning to account for factors that include redundancy, terrain, weather conditions and interference. In addition to easy deployment, wireless links can be made self-sustaining with the use of renewable energy sources. This is useful in areas where power availability is unreliable. Satellite connections can also be used to connect locations that are difficult to reach using both optical fibres and wireless. However, it is worth

noting that satellite resource is scarce and expensive, and it should be proposed as the last resort.

Our aim is to explore all the above technologies, their respective advantages and limitations, and propose a network topology that can be deployed within the prescribed time-frame that meets the throughput requirements of individual Gram Panchayats.

1.2. Planning Objectives

Out of two lakh fifty thousand Gram Panchayats (GPs), one lakh GPs are expected to be connected with fibre in Phase-I of BharatNet by March 2016 [1].The remaining one lakh fifty thousand GPs is to be connected in the Phase 2 of the project. The aim of this project is to provide Internet connectivity infrastructure to one lakh fifty thousand Gram Panchayats for which there has been no planning done as yet. It is also termed as backhaul planning. The backhaul network has high bandwidth requirements. Thus, the technology in designing the backhaul network should support the same.

The broad objective of this report is to provide backhaul planning for one lakh fifty thousand Gram Panchayats.
The key steps are:

- Design topology to decide which of the GPs should be fibre connected and which can be connected via wireless,
- Propose the design parameters for the wireless links like tower heights, transmit power, antenna parameters etc.
- Establish the reliability of the proposed fibre and wireless links,
- Ensure that the throughput requirement at each GP is met,
- To estimate bill of quantity for fibre and wireless links enabling further creation of bill of materials.

1.3. IIT Bombay BharatNet Planning Tool

In order to design Phase 2 of BharatNet project, a planning tool is extremely important. Tools for comparing various options are not commercially available or need to be customized for specific objectives of BharatNet. The IIT Bombay BharatNet Planning tool has been designed by IIT Bombay which will decide the technology and the optimum network topology on the basis of distance, terrain and population. This tool will propose fibre topology for GP along with wireless and satellite links where necessary.

Chapter 2
IITB BharatNet Planning Tool

2.1. Introduction

IITB BharatNet Planning Tool has been designed with an objective to present technologically feasible and sustainable network topology to connect Phase 2 GPs fulfilling the throughput requirement based on population of each GP of India. This tool takes into account various technologies such as optical fibre and wireless technologies for the topology planning.

2.2. Features

The tool primarily features the following:

1. Throughput requirement calculations

   For each GP, the tool obtains its population from the census data by considering the populations for the GP village and the villages associated with the GP. From the population, the tool computes the throughput requirements for each GP. The throughput requirements are being used for planning both fibre and optical links.

2. Fibre and Wireless Link Feasibility test and reliability test

   The tool checks link feasibility of both fibre and wireless links, based on GP to GP route length, terrain profile, maximum tower height, population and throughput demand of a GP. The reliability for wireless links is ensured by making sure that enough fade margin is accounted for to compensate potential losses due to various factors such as shadowing, equipment installation and weather conditions.

3. Frequency Reuse Planning

   To avoid interference among wireless links, frequency reuse planning has been carried out. In 5.8 GHz frequency band, there are 8 channels of 80MHz bandwidth. These channels can be used for data transmission in a region with no or minimal interference. Other physical solutions that are considered in the tool includes use of directional antenna and positioning the antennas at different altitudes on a tower to avoid interference.

2.3. Advantages

- The tool can plan at any level of aggregation, e.g. at block level, district level, state level etc.
- Many key design parameters can be given as input and various scenarios can be developed, e.g. maximum route length, distance between first and last ONTs, frequency band to be used for the wireless links, maximum tower height allowed, average transmit power etc.
- Tool can be used for online planning, i.e., if during the physical site survey certain proposed link cannot be formed, then the tool can suggest alternate wireless links that are feasible. Similarly, during fibre planning phase it is discovered that it is convenient to connect only the certain GPs using fibre, then tool can propose a wireless topology to connect the remaining from these.

2.4. Limitations

- The tool heavily depends on the data provided to it. Accuracy of the data has a great influence on the accuracy of the tool output. For example, if the terrain data is not correct, then the link feasibility may result in erroneous prediction. Similarly, the error in GP locations can have impact on the final calculations.

Chapter 3
Design Methodology

3.1. Introduction

The design methodology refers to the development of a system by forming a comprehensive set of specific engineering rules, methods, and procedures along with design parameters.

3.2. Design parameters and its features

Based on the approach, various design parameters that are needed to be determined and quantified are as follows:

- **Throughput requirement**
  We determine what would be the throughput requirement at each GP. This depends on the population size of the GP, contention ratio, an average number of members in a household and minimum throughput requirement per household. Estimation of throughput requirement is taken as an input parameter for link feasibility analysis of wireless links.
- **Recommendation for technology**
  Wired and wireless technologies have been taken into account for internet connectivity across GPs. In Phase I of BharatNet Planning, fibre laying was the important agenda for connecting GPs. However, fibre deployment has a number of issues associated with it. Laying fibre in difficult terrain is not only time-consuming but also increases the capital investment. Wireless technologies, which can be taken as an alternative of fibre, includes licensed and unlicensed systems. Each technology has its advantages and limitations which helps in selecting most appropriate one for the present scenario.
- **Maximum length of a fibre and wireless link**
  The maximum length of route is (along the road) from OLT to any GP considered to be 50km.
  The length of a wireless link depends on the required and the received SNR. The received SNR should be greater than the required SNR by a substantial margin so as to account for the losses due to free space path, cable/connector or shadowing. The longer the link, the smaller the SNR at the receiver end.
- **Backhaul/Fibre point of presence**
  Every wireless link requires a fibre point of presence as backhaul. In IITB BharatNet Planning tool, the block headquarters and Phase I GPs are considered as fibre point of presence from where the wired and wireless links grow.
- **Bill of Quantities**
  Bill of Quantities is an itemized list of materials and equipments required for estimating the total expenditure of the project. It includes both wired and wireless components.

Following questions can be answered to determine the key design parameters considered for planning tool.

- What is the throughput requirement at each GP?
- What is the maximum allowable length of the wired and wireless link?

- How many GPs can be connected from point of origination of the link? How many hops can the wireless network have?
- What should be the criteria adopted for satellite connectivity?

Each of these questions is discussed in detail in the following chapters.

Chapter 4
Wireless Technology Choice and Constraints

4.1. Introduction

Determining the maximum wireless link length is a challenging problem as it depends on the devices used at both ends for communication.

In order to ensure scalability and fast deployment, technologies that have a high spectral efficiency and an ability to handle long distance communication are needed to be considered. These also need to be matured technologies as opposed to experimental ones. Moreover, these devices should be readily and easily available in India at reasonable price.

4.2. Technology Choice

Various Licensed and Unlicensed wireless technologies can be used to provide Internet in rural environment. As per the current scope of the design, only unlicensed frequency band of 2.4 GHz or 5 GHz has been considered. The 2.4 GHz band is a more popular choice for hotspots and indoor networks hence it is more prone to interference.

Furthermore, 5 GHz frequency can easily propagate up to 25 km and provides high throughput of around 200 Mbps for Point-to-Point (PtP) links and 30 Mbps for 5 GPs in Point-to-MultiPoint (PtMP) links as mentioned in the table below (*Reference: Report of the Committee on NOFN)*. IIT Bombay has tested 802.11ac devices in P2P configuration and experimental results have shown a throughput of 110 Mbps over a link of about 7.2 Km in rural environment.

Table 1: Features of Unlicensed Band Radio Spectrum Backhaul
Courtesy: Report of the Committee on NOFN 2015

Key factors	Features of Unlicensed Band Radio Spectrum Backhaul
Service	Point-to-point, Multipoint-to-Point and Multipoint-to-Multipoint Backhaul
Spectrum	5.48 GHz (unlicensed spectrum)
Capacity	P2MP of 150 Mbps (i.e. 5GPs of 30 Mbps each), or P2P of 200 Mbps
Reach	P2MP: up to 6 km; P2P: up to 25 km
Performance	Medium due to possibilities of spectrum interference.
Maintenance	Maintenance costs are higher than optical fibre.
Physical Infrastructure requirements	Towers Mast at Block and GP lower than that required for Licensed Band Radio network due to better propagation characteristics of spectrum. GP Pole: 9 m Block Mast: 20 m.
Power requirements	8.5 W
Architecture	All outdoor; no rack space required; powered over Ethernet
Cost	Rs 1.1 lakhs per hop

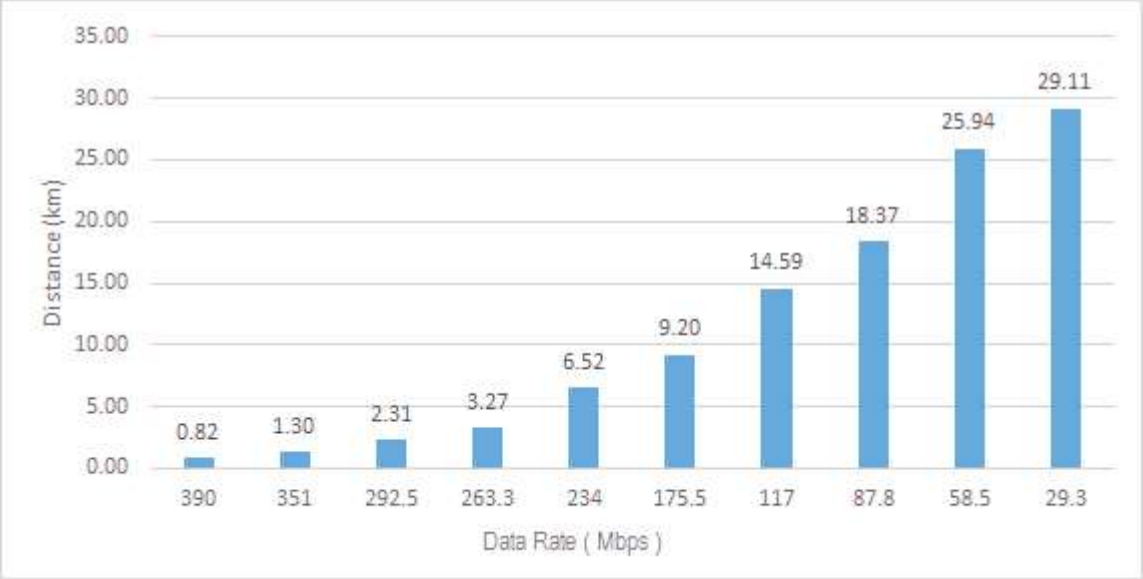
The following table demonstrates the maximum distance covered corresponding to the various Physical data rates available in IEEE 802.11ac, assuming a flat terrain without any

obstruction. Here, 20 dB fade margin has been provisioned to account for factors that include shadowing, losses due to inaccuracy in installation and rain. Since line of sight links are considered in the rural environment, losses due to shadowing are expected to be minimal, at any given point.

Data rate for 80 MHz channel for 802.11ac devices
Noise: -100 dB, Desired fade Margin: 20 dB and transmit power: 4W

Table 2: Data rate for 80 MHz channel for 802.11ac devices

Data rate (Mbps)	Sensitivity (dB)	Required SNR (dB) at receiver	Distance (km)
390	-65	55	0.82
351	-69	51	1.30
292.5	-74	46	2.31
263.3	-77	43	3.27
234	-83	37	6.52
175.5	-86	34	9.20
117	-90	30	14.59
87.8	-92	28	18.37
58.5	-95	25	25.94
29.3	-96	24	29.11



Graph 1 : Graph showing distance versus data rate for 80MHz channel

Note: - The graph plotted above illustrates that the Physical data rates of around 175 Mbps can be achieved for a distance of up to 9 km. However, on account of various losses at MAC layer and above (as high as 40%), throughput for 9 km can be expected to be over 100 Mbps. It has been experimentally confirmed that 100 Mbps throughput can actually be achieved on a link of 7.2 km. Hence, in the design, the links have maximum allowable length as 5-7 km.

4.3. Deciding Topology Constraints

It is notable that communication in 5.8 GHz band requires line of sight (LoS) links. To establish a LoS, antennas should be positioned high on towers. Types and structural complexities of tower are out of scope of this report. However, the height of the towers to be used for wireless connectivity has been restricted to 3m, 6m, 9m and 15m respectively. Towers of height below 9m can be rooftop or wall mounted structures on GP building and 9m towers can be ground rooted pole structures. The 15m towers can be erected near GP office.

It is worth considering that the cost, construction time and space requirement increases exponentially with an increase in tower height. Thus the tool design strives to reduce the tower height as much as possible. The existing BSNL towers can be also utilised to restrict the expenditure on towers. After the GPs are connected with fibre, the existing towers can potentially be used to connect villages in the GP wirelessly.

The next step is to determine the number of links to be formed from the fibre point of presence.

It is proposed to use highly directional antennas (beam width of the order of 20 degrees) as they can establish long distance links with transmit power within regulatory constraints. However, significant interference can be caused by the side lobes of the directional antenna to the links in close vicinity. To avoid interference, it is recommended to make at most three links from fibre PoP and appropriately position antennas (depending on radiation pattern) at different heights on a tower. The above discussed parameter is heuristic and can be revisited upon further detailed experimental investigations.

The number of GPs connected by forming 3 links from a fibre PoP is minimal. Considering the scenario, a multi-hop network can be a feature of the network architecture to connect more GPs wirelessly. However, multi-hops network has its own drawbacks including increased delay, decreased throughput in each hop and reduction in reliability. Therefore, the current architecture design is limited to single hop networks.

Summary of design constraints are as follows:

- Tower height at any GP should not be more than 15m,
- No tower should have more than 3 antennas (3 links),
- Single hop network is to be established,
- Required throughput requirements must be met on each link.

4.4. Power Availability

According to the progress report of village electrification as on May 2015 [2], an average of 95% of villages are electrified in India.

Table 3: Percentage of Villages electrified as on 31-05-2015

States/UTs	Percentage of villages electrified as on 31-05-2015
Andhra Pradesh	100
Arunachal Pradesh	73.3
Assam	96.8
Bihar	95.5
Chhattisgarh	97.7
Goa	100
Gujarat	100
Haryana	100
Himachal Pradesh	99.7
Jammu & Kashmir	98.2
Jharkhand	92.9
Karnataka	99.9
Kerala	100
Madhya Pradesh	97.2
Maharashtra	99.9
Manipur	86.6
Meghalaya	80.1
Mizoram	93.6
Nagaland	90.8
Odisha	91.9
Punjab	100
Rajasthan	90.4
Sikkim	100
Tamil Nadu	100
Tripura	97
Telangana	100
Uttar Pradesh	98.7
Uttarakhand	99.3
West Bengal	99.99
Total(States)	96.7
A & N Islands	77.8
Chandigarh	100
D & N Haveli	100
Daman & Diu	100
Delhi	100

Lakshadweep	100
Pondicherry	100
Total(UTs)	87.1
Average	95.74

A village would be declared as electrified if:
1) Basic infrastructure such as Distribution Transformer and Distribution lines are provided in the inhabited locality as well as the Dalit Basti/ hamlet where it exists.
2) Electricity is provided to public places like Schools, Panchayat Office, Health Centres, Dispensaries and Community centres etc. and
3) The number of households electrified should be at least 10% of the total number of households in the village.
In spite of the overwhelming figures of electrified villages, availability of grid electricity in these villages is unreliable and periodic. The short or long-term loss of the electric power, also known as power outage, is still a huge concern in India. Since continuous supply of power is necessary for the wireless equipments, an alternative of electric power is important.

Solar panel is one of the solutions which can be employed in BharatNet project. The power essentially required by the equipments is 24 Watt/50 Ampere which can be easily served by a photovoltaic (PV) module, a packaged, connected assembly of typically 6×10 solar cells which has been rated by its DC output power under standard test conditions, and typically ranges from 100 to 365 watts.

Chapter 5
Wireless Link Feasibility

In this chapter, the key steps of the wireless link feasibility are described in detail.

5.1. Estimation of Throughput

Estimation of throughput is a 2-step procedure.

The first step is to obtain GP wise population data in terms of number of households and the second step involves calculation of throughput as a function of GP population.

5.1.1. Methodology for obtaining GP Population

The population data for the tool is gathered from the data provided by BBNL. The data contains population statistics of every village in India. To calculate the population of GP, the following methodology is undertaken.

- The villages are mapped to their respective GP,
- GP population is then taken as a sum of population of all the villages mapped to a GP,
- The population of all the villages of a particular GP are summed to obtain the population of the GP under-consideration.

The above steps results in the calculation of GP population.

5.1.2. Calculating throughput based on the population

The throughput requirements for the GPs are calculated using the GP population in the following steps.

Step 1 - Assume a Gram Panchayat has total population to be T.

Step 2 - Let the average number of members in a household to be 5, then the number of households becomes $(\frac{T}{5})$.

Step 3 - Let the contention ratio for rural India) to be 1:25.
On applying the contention ratio, the number of active household turns to be $(\frac{T}{5} * \frac{1}{25})$ at any given point of time.

Step 4 - As mentioned in (*Report of the Committee on NOFN, 2015*)(page 10), the throughput requirement of each active household is 2 Mbps. Thus the total bandwidth required for the GP is $(\frac{T}{5} * \frac{1}{25} * 2)$ Mbps.

Step 5 - Hence, the minimum total throughput requirement at a GP with 'T' number of people can be calculated as
$\left(\frac{T}{62.5}\right)$Mbps.

Note: - These calculations are simplistic in comparison to the calculations recommended in Report of the Committee on NOFN (Section 2, page 31) as following parameters are not considered:

(i) Estimation of future requirements on account of technology penetration, and

(ii) Socio-economic status of the population.

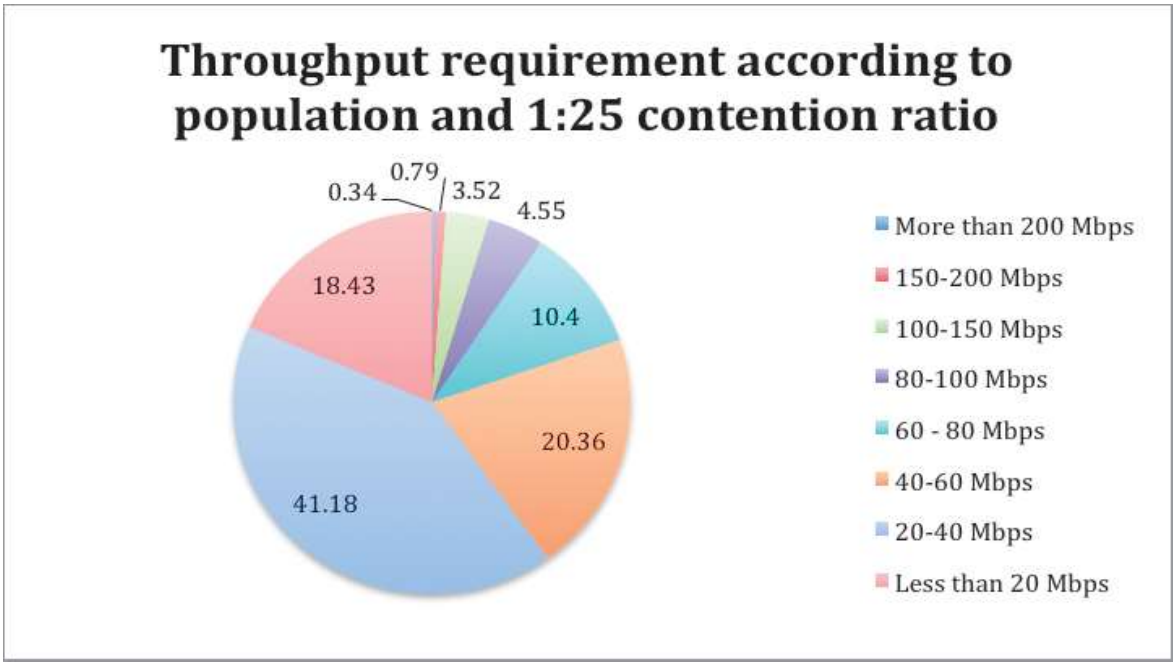


Figure 1: Throughput requirement according to population and 1:25 contention ratio

From Figure 2, it can be noted that about 60% of GPs require less than 40 Mbps throughput while only 20% GPs have a requirement of above 60 Mbps. This shows that wireless links can be used to connect most of the GPs while satisfying their throughput requirements.

The throughput requirement thus calculated, can be further used to propose the wireless network.

5.2. Determining the Distance based Link Feasibility

As stated in Section 4.2 [1], wireless links of 5-7 km length can be considered. A conservative choice of 5 km is made.

Following inputs are required for determination of distance based on link feasibility:

- Locations (Latitude and Longitude) of Phase-I and Phase-II GP offices
- BSNL tower locations

Given the locations of the entities mentioned above, it can be assumed that a link between entities X and Y can potentially be considered for link feasibility if the distance between them is less than 5 km. The output of the step is to provide set of links that satisfy the distance criteria and hence can be considered for further processing.

5.3. RF Planning, Tower Heights and Achievable Throughputs

In this step, the following parameters are determined:

- **Wireless link feasibility** between two given geo-locations,
- **Required tower heights** if the link is feasible,
- **Throughput** of the feasible link.

Inputs to this step are two geo-locations, corresponding to the two end points of a proposed wireless link.

5.3.1. Obtaining terrain data

The path is defined as an array of two or more comma-separated coordinate text strings separated using the pipe ('|') character:

$$\text{path} = 40.714728, -73.998672| - 34.397,150.644$$

The number of samples of the elevation profile can be specified along the path of the link. With 512 samples for a distance of about 5 km, accuracy of 10 m can be achieved. Thus, the sample size is set to 512. The elevation profile, obtained along the path, is then compared to the Fresnel zone (calculated along the path) to check whether the wireless link is established or is obstructed by any topographical elevations.

5.3.2. Calculating received signal strength

For the calculation of the received signal strength, parameters such as i) transmit power ii) transmitter and receiver antenna heights iii) transmitter and receiver antenna gains and iv) propagation model need to be considered.

As per the regulations, **Equivalent Isotropically Radiated Power** (**EIRP**) cannot be more than 36 dBm for 5 GHz frequency band. For an antenna with transmitter antenna gain as 25 dBi, the allowable output transmit power should not be greater than 11 dBm, considering no losses are incurred.

$$EIRP = P_{TX} + G_{TX} - L \tag{1}$$

where,

$EIRP$ =Equivalent isotropically radiated power
P_{TX} = Output Transmit Power
G_{TX} = Transmitter Antenna Gain
L = Losses

Maximum transmitter and receiver antenna heights are set according to the available tower infrastructure. This will be considered in further calculations.

The propagation model gives an empirical formula which provides a method to predict the received signal strength based upon the path loss.

The propagation model used in the current tool is Free Space Path Loss Model.

5.3.2.1. Free space path loss

- Free Space Path Loss is the loss in signal strength of an electromagnetic wave of a line-of-sight path through free space with no obstacles nearby to cause reflection or diffraction.
- It is directly proportional to the square of the distance between transmitter antenna and receiving antenna and to the square of frequency of the radio signal.

$$FSPL = \left(\frac{4\pi df}{c}\right)^2 \tag{2}$$

where,

f =Signal frequency (in hertz),
d =Distance from the transmitter (in metres),
c = Speed of light in a vacuum, 2.99792458×10^8 metres per second

This equation can be expressed in terms of decibel as below:

$$FSPL\ (dB) = 20\ log_{10}(d) + 20\ log_{10}(f) - 147.55 \quad (3)$$

For different units of the parameters, the constant of the equations changes as follows:

- For d, f in kilometres and gigahertz, respectively, the constant becomes 92.45.
- For d, f in meters and megahertz, respectively, the constant becomes -27.55.
- For d, f in kilometres and megahertz, respectively, the constant becomes 32.45.
- For d, f in meters and kilohertz, respectively, the constant becomes -87.55.

5.3.2.2. Fresnel zones

Fresnel Zone is taken into account to check the link feasibility. A Fresnel zone is a cylindrical ellipse drawn between transmitter and receiver. There are an infinite number of Fresnel zones, however, only the first 3 have significant effect on radio propagation. These are numbered and are called 'F1', 'F2' and 'F3' etc. as shown in below figure. These are used to calculate reflections and diffraction loss between a transmitter and receiver. The net result is that even numbered Fresnel zones incur a 180° signal reflection. These are detrimental to radio propagation. Odd numbered Fresnel zones incur a 360° phase shift and will add constructively at the receiver.

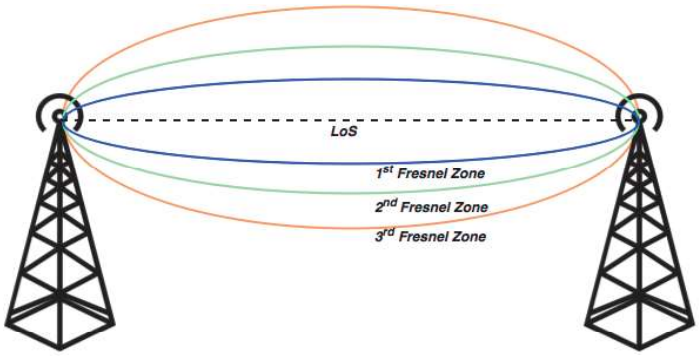


Figure 2: Fresnel Zone

For a stable and strong signal at the receiver end, antenna heights are often selected so that F1 is an unobstructed path and F2 is obstructed by a hill or the earth bulge along the path as any 180° reflected signals along the F2 zone can interfere and cancel the main received signal.

'60% of the first Fresnel zone' means a narrower ellipsoid with a radius that is 60% of the radius of the first Fresnel zone. For LoS links, the first Fresnel zone must have at least 60% clearance of any obstructions in order for the radio wave propagation to behave as if it is in 'free space'.

The scenarios shown below depict the manner in which Fresnel zone clearance is used to decide the height of the transmitter and receiver antenna considering various factors such as throughput, distance and tower cost.

In the first scenario, the transmitter and receiver antenna heights are set at 9m. Though LoS is clear, 60% Fresnel zone is obstructed by elevated terrain between transmitter and receiver. Hence the received signal strength will be less than the desired signal strength.

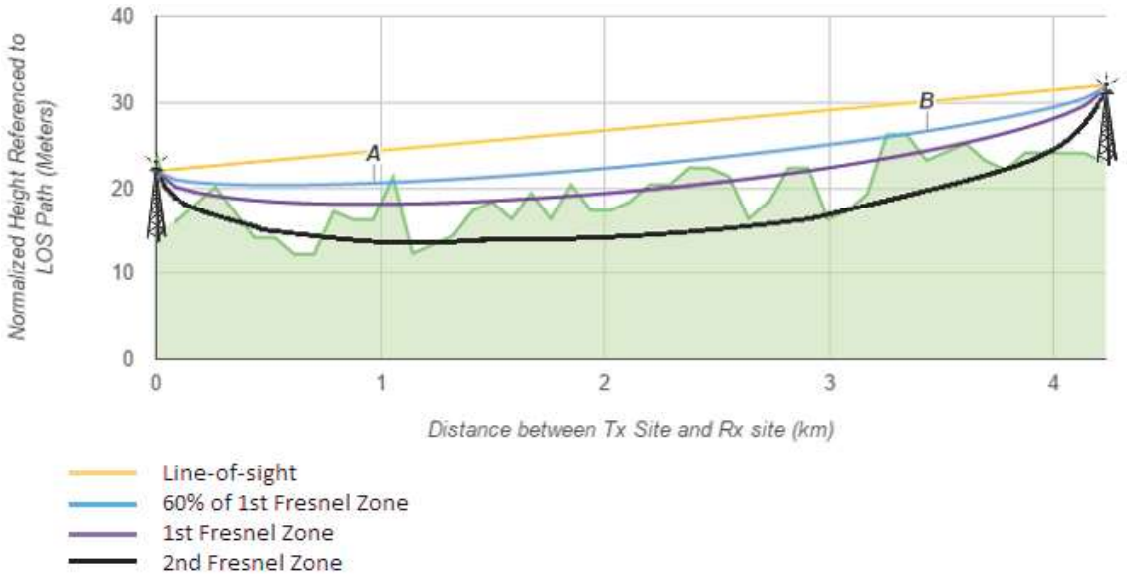


Figure 3: Fresnel Zones created with Tx Antenna at 9m height and Rx Antenna at 9m height

In the second scenario depicted below, the transmitter and receiver antenna heights are set at 15m. In this case, LoS along with 60% Fresnel zone and 1st Fresnel zone is clear. Hence the received signal strength will be equal or more than desired signal strength as reflections from 1st Fresnel zone will add constructively with LoS received signal.

Figure 4: Fresnel Zones created with Tx Antenna at 15m height and Rx Antenna at 15m height

In the third scenario, the transmitter and receiver antenna heights are set at 9m and 30m respectively. In this case, LoS along with 60% Fresnel zone and 1st Fresnel zone are clear. Hence the received signal strength will be equal or more than desired signal strength as

reflections from 1st Fresnel zone will add constructively with LoS received signal. However, construction of a 30m tall tower involves more monetary investment as well as time.

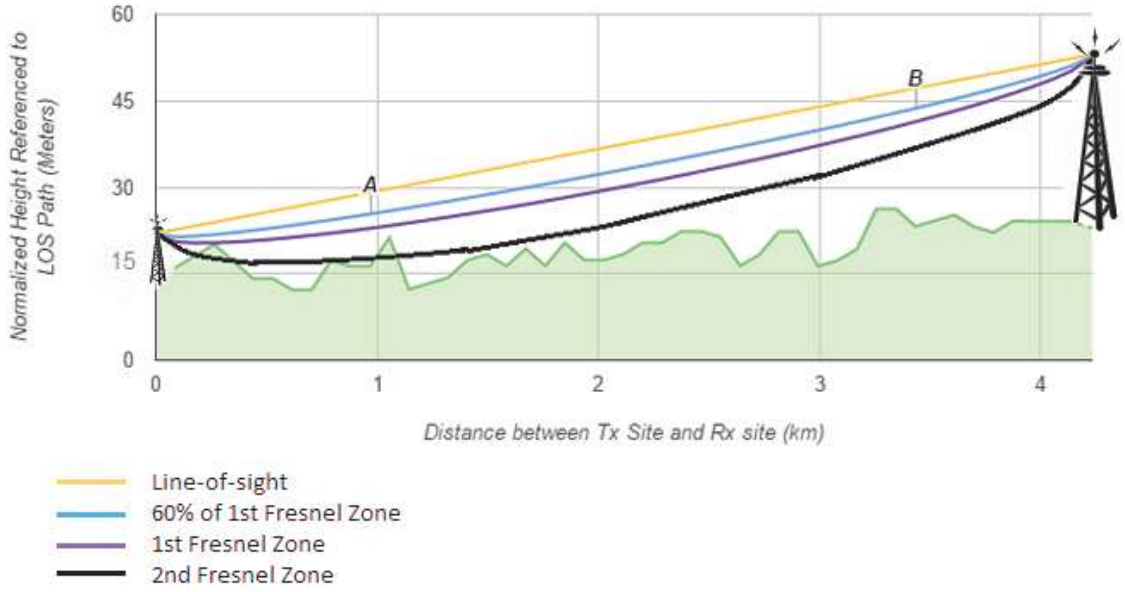


Figure 5: Fresnel Zones created with Tx Antenna at 9m height and Rx Antenna at 30m height

Considering various scenarios as above, it becomes important to choose the most feasible link which not only gives desired signal strength at the receiving end but is also cost effective.

5.3.2.3. Deciding tower heights

The tower height determination should comply with following criteria:

1. 60% Fresnel zone should be clear for all the links originating or terminating at a location at maximum height of the tower.
2. The maximum height of tower should be 15 m.

5.3.3. Translating Received Signal Power to achievable throughput

The received signal power is theoretically calculated by taking into account the transmitter power, the transmitter and receiver antenna gains and the path loss. The received signal power should be equal to or greater than Receiver Sensitivity (RS) for the signal to be detected. The RS is dependent on the Modulation and Coding Scheme (MCS) used at the transmitter. For instance, the RS of QPSK will be different from the RS of 64-QAM. Hence, for the signal to be detected, the received signal power should be greater than the RS of the MCS at which the signal was coded.

To account for the fading losses, fade margin is also included. The fade margin is required to ensure that the signal is received even if the channel quality is bad. The better the fade margin, more stable is the link.

Taking into account the fade margin and the received signal power, the highest possible MCS is decided. This will then be used to calculate the Physical Layer Data Rate achievable by that link. The Transport Layer throughput can be calculated after taking into account the overhead of the lower layers.

5.3.4. Algorithm involving RF planning calculations

5.3.4.1. Inputs

Following are the inputs to the program:

1. Latitude and longitude of the Transmitter (Tx) (x1,y1) and Receiver (Rx) (x2,y2)
   Transmitter is fibre point of presence and Receiver is phase 2 GP
2. Maximum Possible heights of Tx Antenna (h1) and Rx Antenna (h2)
   Maximum Transmitter height is 40 m and maximum receiver antenna height is 15 m
3. Required throughput of the receiver end
4. Elevation profile between the Tx and Rx
   a. Height Above Mean Sea Level (AMSL) of Tx and Rx
   b. Height (AMSL) of all points (at interval of 5m) between Tx and Rx

5.3.4.2. Assumptions

1. Tx and Rx positions are in terms of latitude/longitude pairs.
2. The upper limit of the transmitter antenna height and receiver antenna height are restricted by maximum possible heights of the Tx and Rx antennas (tower heights).
3. 512 samples of elevation profile are considered.
4. EIRP is taken as 4 W.
5. Receiver Antenna Gain is 25 dBi.
6. Fade Margin is taken as 20 dB.

5.3.4.3. Link Feasibility Code Details

The code is divided into two parts:

1. Fresnel zone clearance -
   A link is said to be LoS if it clears 60% of F1 (first Fresnel Zone) and the F2 (second Fresnel zone) is blocked. The objective of the tool is to check whether 60% of F1 is cleared for the maximum height of Tx and Rx antennas.
   The Fresnel zone calculations consider earth curvature, diffraction and atmospheric refraction.

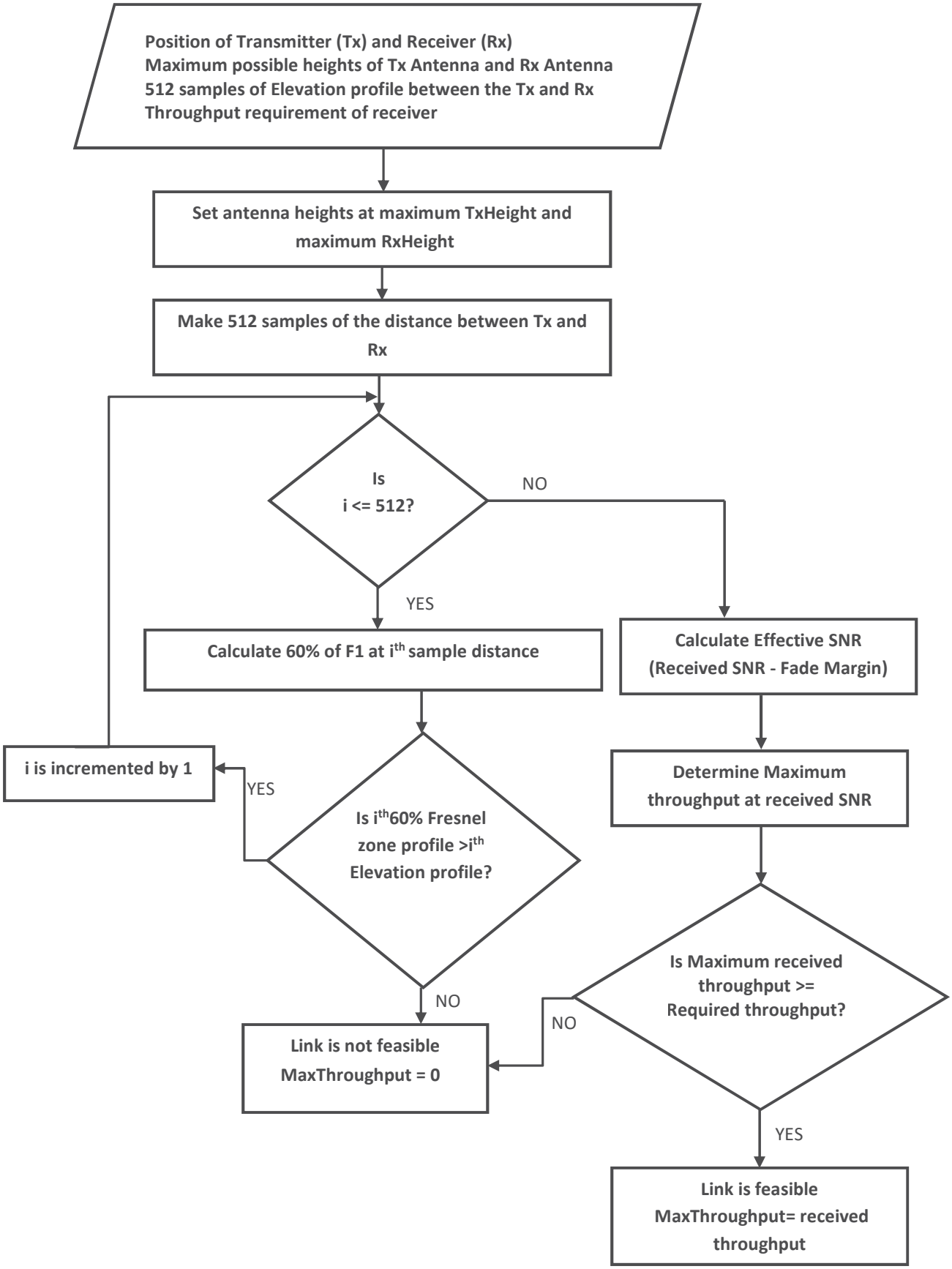
2. Fade margin calculations -
   Once the link is feasible, the propagation loss model can be used to calculate the fade margin of the link. The fade margin is directly proportional to the stability of the link i.e. higher the fade margin, more stable is the link.
   WiFi Technology in frequency band 5.8 GHz is considered. The propagation loss model used for 5.8 GHz band is ITU terrain model in addition to free space path loss.

5.3.4.4. Output

After calculating the above two parameters, the output will be a matrix of maximum throughput, optimum transmitter antenna height and optimum receiver antenna height at which desired fade margin is obtained**:**

$$\begin{bmatrix} \text{MaxThroughput} \\ \text{TxHeight} \\ \text{RxHeight} \end{bmatrix}$$

5.3.5. Flowchart of Wireless Link feasibility



Chapter 6
Fibre Link Feasibility and Planning

Fibre is, certainly a permanent solution to connect all the Gram Panchayats of India. A near to accurate estimation of the fibre route is necessary for optimal deployment in later stages of Phase 2. For estimating the fibre network, a planning tool design connects the block headquarters/ Phase 1 GPs to unconnected Phase 2 GPs.

6.1. GPON architecture

Gigabit-capable Passive Optical Network (GPON) architecture has been implemented to design the fibre route. GPON is a type of PON standardized in the ITU-T G.9 84 series of recommendations, which can transport not only Ethernet, but also Asynchronous Transfer Multiplexing (ATM) and Time Division Multiplexing (TDM) (PSTN, ISDN, E1 and E3) traffic. GPON network consists of mainly two active transmission equipments, namely- Optical Line Termination (OLT) and Optical Network Unit (ONU) or Optical Network Termination (ONT). It supports triple-play services, high-bandwidth, long reach, etc.

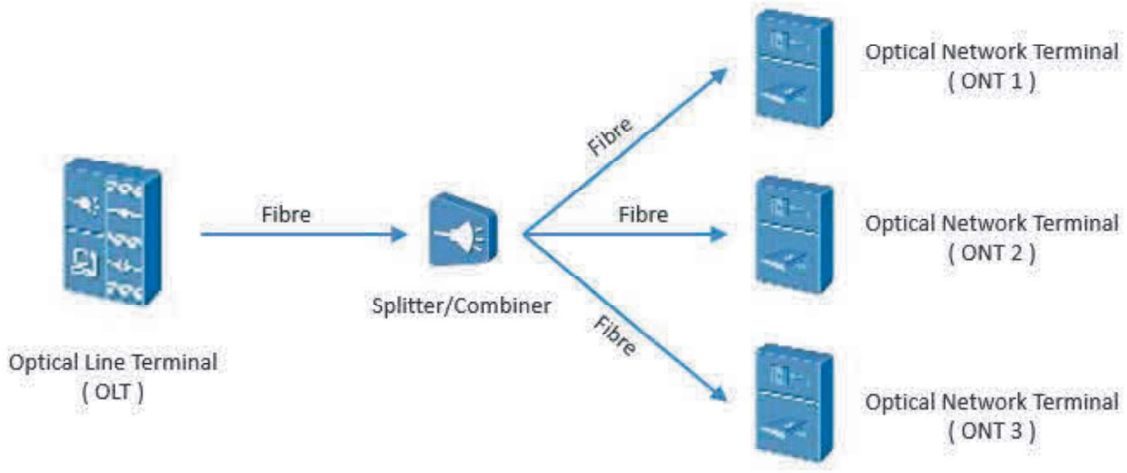


Figure 6: GPON Architecture

GPON adopts Wavelength Division Multiplexing (WDM) technology, facilitating bi-directional communication over a single fibre. To separate upstream and downstream signals of multiple users over a single fibre, GPON employs two multiplexing mechanisms:

- In upstream direction, data packets are transmitted in a Time Division Multiplexing Access (TDMA) manner with a capacity of 1.244 Gbps.
- In downstream direction, data packets are transmitted in a Broadcast manner with a capacity of 2.488 Gbps.

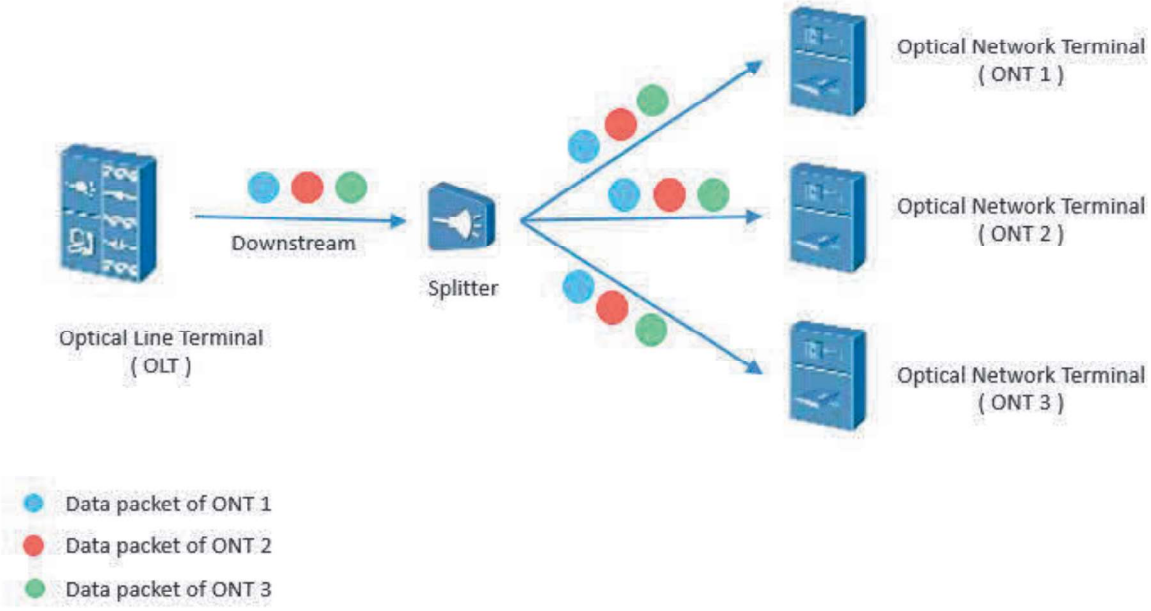


Figure 7: Data transfer in downstream direction

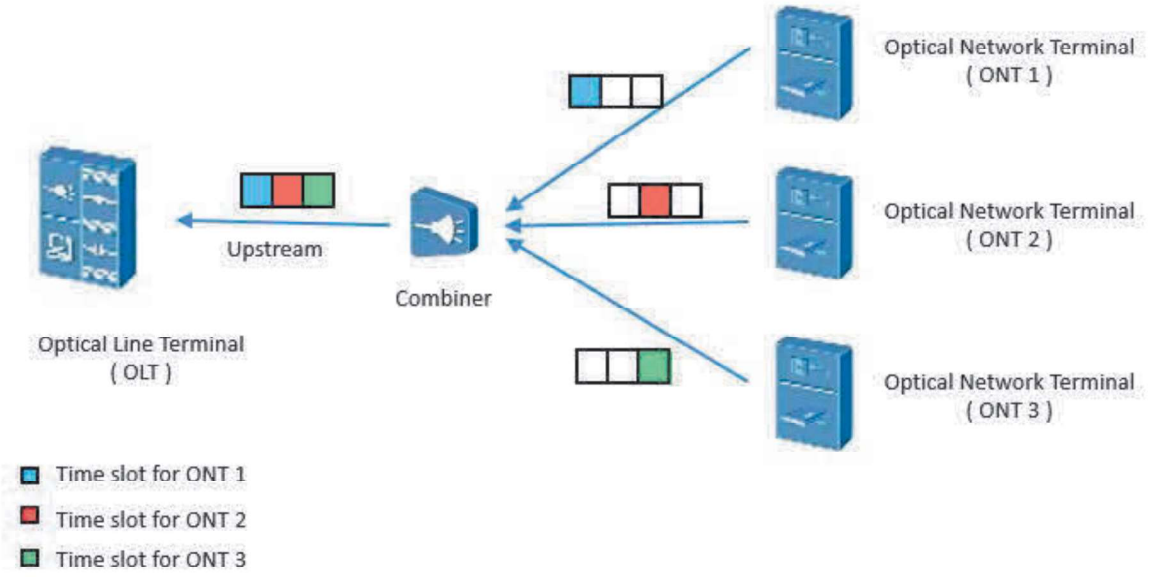


Figure 8: Data transfer in upstream direction

Clock synchronisation is critical for GPON architecture. It is required for smooth transmission of services over broadband networks. Since a large number of users share the available bandwidth of the split fibre, there are chances of collisions in the upstream traffic. To maintain clock synchronisation Time Division Multiple Access is incorporated in the architecture. Moreover, with each node, the clock synchronisation is disturbed. In spite of a good distance of 100 km which can be achieved if splitters are not used in a fibre link from OLT to ONT, the distance is restricted to 60 km. The reduction in distance and hence decrease in the number of nodes helps in synchronising the clock easily.

6.2. Power Link Budget

To ensure that fibre connections have sufficient power for correct operation, calculation of power link budget is essential. The power budget refers to the amount of loss that a datalink

from transmitter to receiver can tolerate in order to operate properly. It is the difference between the output power of the transmitter and the receiver sensitivity.

$$P_B = P_T - P_R \tag{4}$$

where,

P_B = Power budget
P_T = Output Transmit Power
P_R = Receiver Sensitivity

Table 4: Power Link Budget

Key factors	Estimated Values
Splicing and Propagation Loss	0.4 dB per km
Splitter Loss	1:2 splitter – 3.4 dB 1:4 splitter – 7.8 dB
Connector Loss	0.5 dB (0.25 per connector)
OLT Transmit Power	0-3 dBm
Receiver Sensitivity	-28 dBm
Power Budget	20 – 22 dB

6.3. Estimating the fibre distance

The estimation of fibre length can be done, provided power budget and number of connectors and splicers are known for a link.

The maximum distance up to which the optical power does not dissipate below the receiver sensitivity, can be calculated by the following formula.

$$Fibre\ Length = \frac{Power\ budget - link\ loss}{fibre\ loss\ per\ km} \tag{5}$$

$$Fibre\ Length = \frac{(P_T - P_R) - (L_S * N_S) - (L_C * N_C) - (Safety\ Margin)}{fibre\ loss\ per\ km} \tag{6}$$

where,

P_T = Output Transmit Power
P_R =Receiver Sensitivity
L_S = Splicer Loss
N_S = Number of splicers in a link
L_C = Connector Loss

N_C = Number of connectors in a link

This tool has two parts. The first part designs a network of fibre only. It does not consider wireless technologies for connecting GPs. The second part is a combination of both fibre and wireless technologies with fibre network at the base.

This tool is based on the concept of Minimum Spanning Tree. A spanning tree of a graph is a subgraph that contains and connects all the vertices and is a tree. A minimum spanning tree is to find the shortest path that visits each point at least once.

6.3.1. Algorithm involving Fibre route planning

Below is the algorithm used in fibre network planning tool.

6.3.1.1. Inputs

Phase 1 and Phase 2 GP locations in latitude longitude pairs
BSNL Tower locations in latitude longitude pairs
Road distance
BSNL Rural Exchange

6.3.1.2. Processing

Part A: only Fibre network

Step 1 - Calculate the road distance for each GP from Block Exchange.
Step 2 - For GPs without any road data, those are suggested for satellite connectivity.
Step 3 - Minimum Spanning Tree is created for all the GPs in a block along the road.
Step 4 - GPON feasibility of each link is checked from a Block OLT to GP.
Step 5 - The GPs with unfeasible link as in step 4 are checked for GPON feasibility with the next OLT.
Step 6 - Step 4 and 5 are repeated until all the GPs are checked for GPON feasibility from all the OLTs present in the block.
Step 7 - GPON verified Minimum spanning tree is obtained.

Part B: Fibre and Wireless network

Step 1 - Perform Step 1 to Step 4 of Part A processing.
Step 2 - The leaf nodes outside the route of fibre network are identified.
Step 3 - The throughput requirements of identified leaf nodes are calculated.
Step 4 - If the throughput requirement is more than 100 Mbps, then it is suggested for fibre connectivity.
Step 5 - If the throughput requirement is less than 100 Mbps, then wireless link feasibility following Chapter 2 for links from block headquarter and Phase 1 GP to the leaf node is checked.
Step 6 - If the wireless link is feasible from block headquarter and Phase 1 GP to the leaf node, the leaf node is connected wirelessly and the parent node of the leaf node becomes the leaf node.
Step 7 - Repeat Step 5 and Step 6 until no further wireless link can be established from block headquarter and Phase 1 GP to the leaf node.

6.3.1.3. Output

Part A:

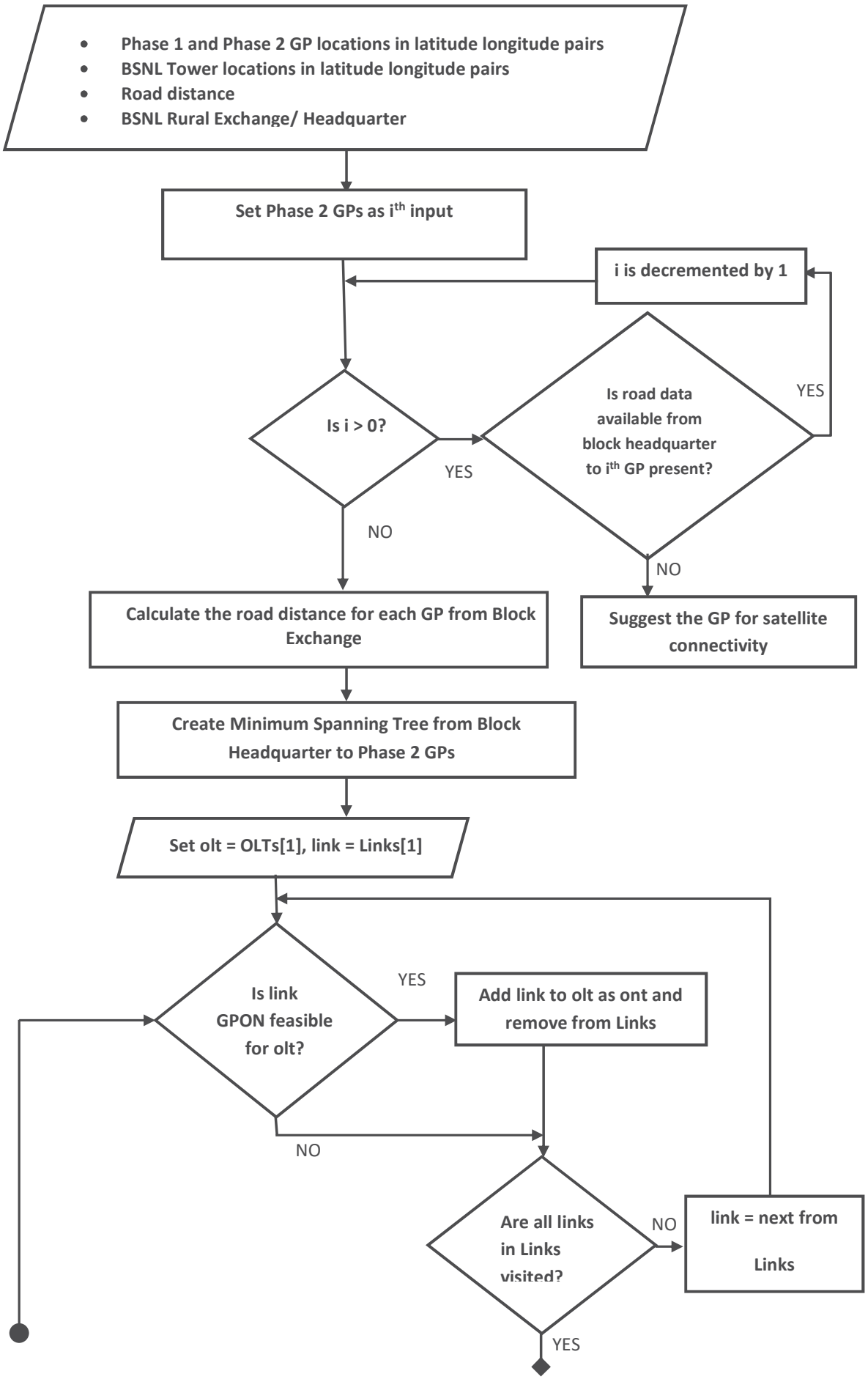
The output is the fibre route plan only.

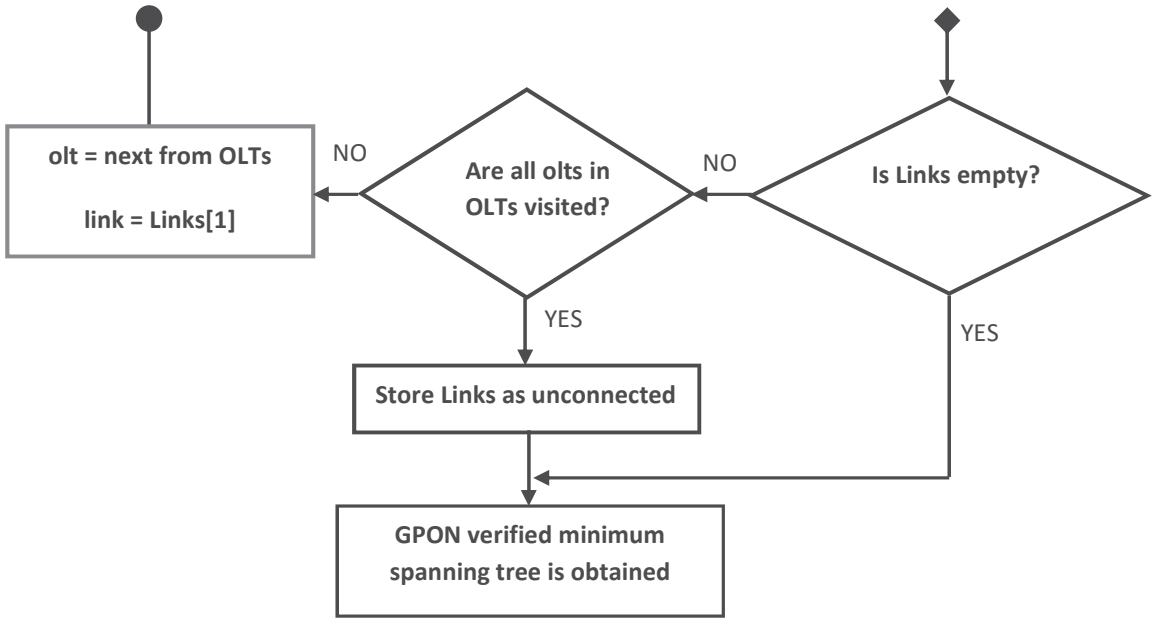
Part B:

The output is fibre and wireless links.

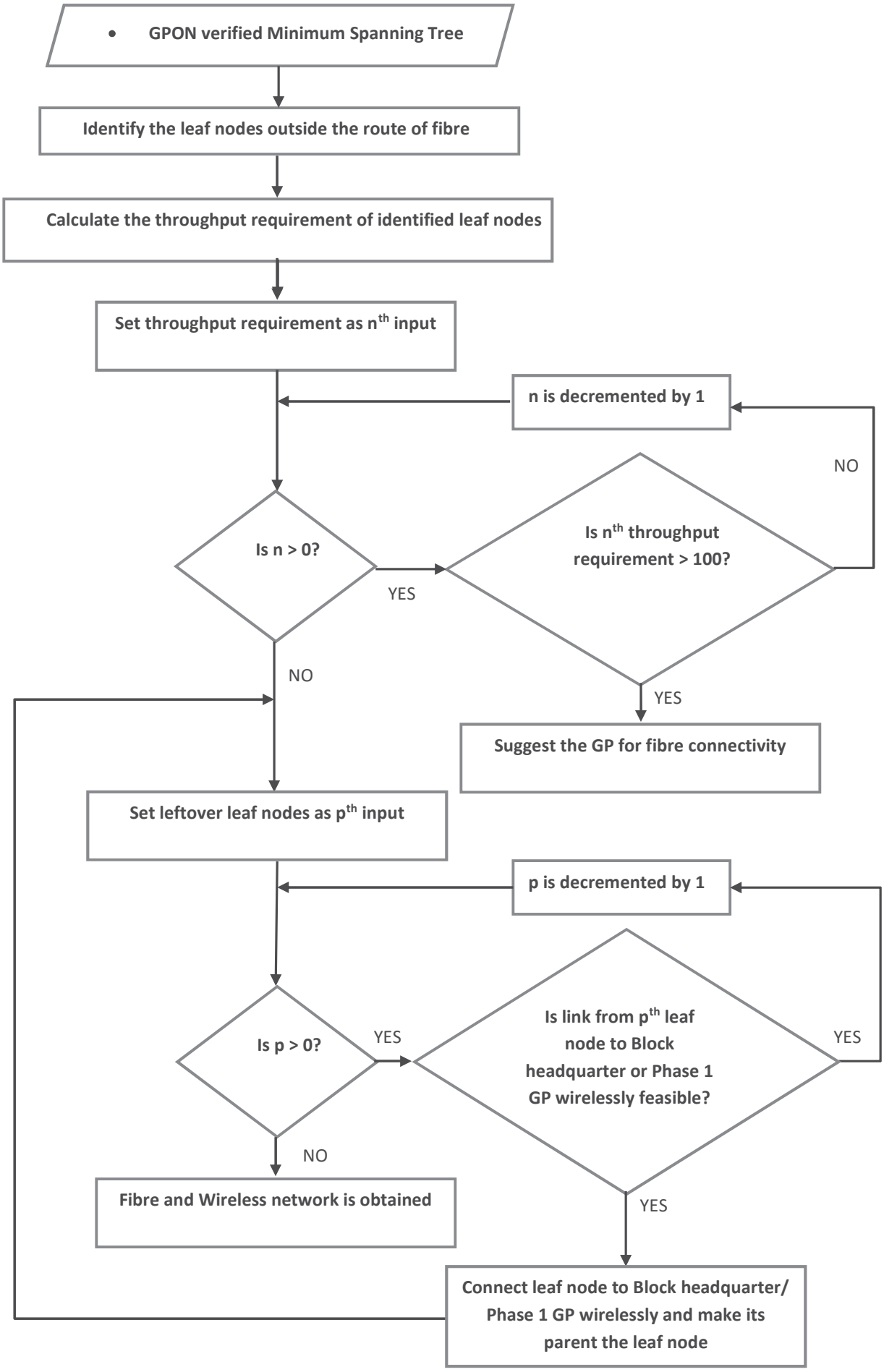
6.3.2. Flowchart of Fibre Route Planning

Part A




olt = next from OLTs
link = Links[1]
NO
Are all olts in OLTs visited?
NO
Is Links empty?
YES
YES
Store Links as unconnected
GPON verified minimum spanning tree is obtained

Part B


GPON verified Minimum Spanning Tree
Identify the leaf nodes outside the route of fibre
Calculate the throughput requirement of identified leaf nodes
Set throughput requirement as n^th input
n is decremented by 1
Is n > 0?
YES
Is n^th throughput requirement > 100?
NO
YES
NO
Suggest the GP for fibre connectivity
Set leftover leaf nodes as p^th input
p is decremented by 1
Is p > 0?
YES
Is link from p^th leaf node to Block headquarter or Phase 1 GP wirelessly feasible?
YES
NO
Fibre and Wireless network is obtained
YES
Connect leaf node to Block headquarter/ Phase 1 GP wirelessly and make its parent the leaf node

Chapter 7
Results and Conclusion

7.1. Summary of all fibre network

State Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Total number of OLTs as per IITB design	Total number of ONTs as per IITB design	Total number of GPs which are not connected**	Total Fibre Length(km)
CHHATTISGARH	5211	287	112	4594	617	15540.88
DAMAN & DIU	15	2	2	15	0	46.38
HIMACHAL PRADESH	2888	79	73	2393	495	11089.94
JAMMU AND KASHMIR	1807	74	57	1463	344	3807.95
ANDHRA PRADESH	19303	2217	999	19161	142	69885.73
DADRA AND NAGAR HAVELI	11	1	1	11	0	87.57
GUJARAT	7942	877	181	7370	572	27893.17
BIHAR	1326	539	98	1306	20	6267.29
ASSAM	33	40	5	33	0	138.38
PUNJAB	6469	1451	85	6440	29	14759.36
JHARKHAND	2545	244	165	2402	143	11082.65
ARUNACHAL PRADESH	924	107	85	687	237	3216.85
TRIPURA	19	24	5	19	0	77.38
MAHARASHTRA	7815	2219	176	7485	330	27146.28
UTTARAKHAND	5735	386	117	5017	718	16300.85
NAGALAND	249	68	16	205	44	899.29
MADHYA PRADESH	6197	171	87	4604	1593	17091.16
MIZORAM	438	28	21	273	165	1841.66
RAJASTHAN	2069	1112	103	1870	199	12642.86
TAMILNADU	7982	292	241	7753	229	25770.38
ODISHA	2328	393	135	2143	185	13458.04
UTTAR PRADESH	33653	1701	335	30605	3048	45575.07
Total	114959	12312	3099	105849	9110	324619.1

** - GPs for which road data is not available and are situated more than 60 km away from all the OLTs of the block

7.2. Summary of fibre and wireless network

State Name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of OLTs as per IITB design	Number of ONTs as per IITB design	Wireless from Phase 1 GP	Wireless from BSNL Towers	Satellite recommendation	Total number of GPs which are not connected**	Total Fibre Length(km)	Total Fibre Reduction(km)
CHHATTISGARH	5211	954	112	3411	85	1232	194	289	12283.23	3257.65
DAMAN & DIU	15	0	2	15	0	0	0	0	46.38	0
HIMACHAL PRADESH	2888	474	73	1832	14	664	13	365	9041.42	2022.48
JAMMU AND KASHMIR	1807	185	57	1212	34	265	143	153	3204.64	603.31
ANDHRA PRADESH	19303	3065	999	14552	3	4646	50	52	55954.27	13322.63
DADRA AND NAGAR HAVELI	11	0	1	11	0	0	0	0	87.57	0
GUJARAT	7942	1946	181	5371	1	2206	32	332	21371.53	6510.83
BIHAR	1326	668	98	950	102	258	7	9	4463.78	1654.49
ASSAM	33	91	5	12	1	20	0	0	60.6	46.95
PUNJAB	6469	2039	85	3477	277	2708	0	7	9223.01	5536.19
JHARKHAND	2545	1058	165	1832	0	606	49	58	8934.54	2004.67
ARUNACHAL PRADESH	924	86	85	544	27	144	158	51	2710.81	347.05
TRIPURA	19	117	5	12	0	7	0	0	40.69	36.69
MAHARASHTRA	7815	2387	176	6452	113	987	24	239	23690.02	3456.27
UTTARAKHAND	5735	743	117	4487	92	649	153	354	14926.1	1374.75
NAGALAND	249	140	16	118	21	81	23	6	540.47	358.82
MADHYA PRADESH	6197	2053	87	3074	132	2211	30	750	11851.55	5239.62
MIZORAM	438	33	21	269	7	9	17	136	1836.34	5.33
RAJASTHAN	2069	2235	103	1519	59	343	4	144	10732.98	1909.88
TAMILNADU	7982	3599	241	5746	0	2118	0	118	19091.92	6582.08
ODISHA	2328	891	135	1508	0	685	110	25	10501.11	2956.92
UTTAR PRADESH	33653	2696	335	22828	1392	7339	194	1900	34462.39	11015.7
Total	114959	25460	3099	79232	2360	27178	1201	4988	255055.4	68242.31

7.3. State-wise output of all fibre network

Andhra Pradesh

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
532	ADILABAD	624	57	38	620	7	2276.57
533	NIZAMABAD	696	84	35	692	6	2445.39
534	KARIMNAGAR	1186	104	59	1186	4	3886.22
535	MEDAK	1035	92	46	1034	2	3682.61
538	MAHABUBNAGAR	1306	124	63	1303	5	5220.32
539	NALGONDA	1162	130	60	1161	2	4736.40
540	WARANGAL	892	52	50	555	32	3230.18
541	KHAMMAM	79	94	6	64	2	386.19
542	SRIKAKULAM	1088	73	38	437	3	2943.00
543	VIZIANAGARAM	916	123	34	395	9	2879.59
544	VISHAKHAPATNAM	813	72	38	562	20	3153.55
545	EAST GODAVARI	941	111	55	625	15	3110.25
546	WEST GODAVARI	866	121	46	497	5	2623.18
547	KRISHNA	962	128	49	507	3	3060.50
548	GUNTUR	984	127	56	696	0	2725.95
549	PRAKASAM	940	112	51	940	2	3660.30
550	SPSR NELLORE	909	65	46	583	15	3985.11
551	YSR KADAPA	780	107	50	578	2	3317.17
552	KURNOOL	828	183	52	542	2	3225.28
553	ANANTAPUR	948	116	62	767	3	4906.79
554	CHITTOOR	1296	142	65	808	3	4431.17

Arunachal Pradesh

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
245	TAWANG	77	6	6	17	34	241.09
246	WEST KAMENG	14	10	1	6	7	57.69
247	EAST KAMENG	102	10	10	73	29	304.21
249	LOWER SUBANSIRI	72	16	7	29	0	333.62
250	KURUNG KUMEY	149	13	13	73	67	262.84
251	UPPER SUBANSIRI	83	9	9	44	37	216.99
254	UPPER SIANG	51	4	4	41	18	301.65
255	DIBANG VALLEY	18	3	3	18	1	161.13
256	LOWER DIBANG VALLEY	20	6	2	17	1	68.04
257	LOHIT	132	8	8	104	0	408.59
259	CHANGLANG	82	7	7	61	22	339.50
260	TIRAP	73	15	15	61	21	521.50

Assam

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
305	NAGAON	33	40	5	12	0	138.38

Bihar

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
203	PASHCHIM CHAMPARAN	66	29	5	47	5	362.65
204	PURBI CHAMPARAN	141	55	11	101	2	752.32
207	MADHUBANI	126	58	7	81	1	571.11
209	ARARIA	126	15	6	101	3	574.04
212	KATIHAR	36	32	4	21	0	189.42
213	MADHEPURA	35	29	3	16	2	157.61
215	DARBHANGA	111	55	9	69	2	534.62
217	GOPALGANJ	153	28	11	140	0	615.54
221	SAMASTIPUR	28	59	2	16	0	99.10
224	BHAGALPUR	9	33	1	7	0	24.55
229	NALANDA	120	40	11	76	0	583.83
230	PATNA	70	34	6	48	0	367.03
231	BHOJPUR	52	24	3	31	1	193.68
235	JEHANABAD	17	12	2	11	0	69.69
236	ARWAL	26	5	2	17	0	102.87
238	GAYA	201	31	15	168	4	1069.24

Chhattisgarh

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
400	KORIYA	65	5	2	50	20	178.67

401	SURGUJA	275	13	7	226	3	818.83
402	JASHPUR	312	20	8	250	39	1120.11
403	RAIGARH	518	28	10	351	46	1494.54
404	KORBA	269	15	5	214	50	1046.93
405	JANJGIR-CHAMPA	392	24	8	266	25	1082.14
406	BILASPUR	507	37	10	318	79	1373.59
407	KABIRDHAM	195	6	4	121	37	605.41
408	RAJNANDGAON	594	27	15	398	47	2190.37
409	DURG	165	23	4	96	0	566.47
410	RAIPUR	274	19	5	190	24	860.92
411	MAHASAMUND	389	15	6	327	6	1117.00
412	DHAMTARI	232	18	7	171	6	882.62
413	KANKER	281	9	6	109	135	454.91
414	BASTAR	269	17	8	204	33	1078.73
415	NARAYANPUR	16	2	1	5	18	56.91
416	DANTEWADA	82	5	3	44	13	214.10
417	BIJAPUR	87	4	3	71	36	398.63

Dadar and Nagar Haveli

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
496	DADAR AND NAGAR HAVELI	11	1	1	11	0	87.57

Daman and Diu

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
494	DIU	4	1	1	4	0	13.15
495	DAMAN	11	1	1	11	0	33.23

Gujarat

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
469	BANASKANTHA	804	142	18	500	0	3152.08
472	SABAR KANTHA	259	122	6	131	0	993.87
474	AHMEDABAD	504	110	18	329	86	2174.26
475	SURENDRANAGAR	646	94	19	470	1	2958.07
476	RAJKOT	573	15	15	573	250	2268.79
477	JAMNAGAR	661	77	19	478	7	2996.42
479	JUNAGADH	823	139	17	823	0	2705.30
484	PANCHMAHAL	630	13	11	279	132	1664.48
485	DAHOD	409	7	7	263	21	1231.19
486	VADODARA	865	36	20	490	5	2990.01
487	NARMADA	217	24	6	152	1	834.84
489	DANGS	44	4	2	44	21	264.95
491	VALSAD	364	21	6	363	10	1209.62
492	SURAT	560	57	11	316	1	1671.27

493	TAPI	251	16	6	160	37	778.04

Himachal Pradesh

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
23	CHAMBA	221	7	7	184	77	1016.95
24	KANGRA	731	15	15	480	32	2295.34
25	LAHAUL AND SPITI	26	2	2	12	21	174.74
26	KULLU	185	5	5	141	16	826.27
27	MANDI	349	11	10	258	92	1656.04
28	HAMIRPUR	54	6	2	22	0	172.75
29	UNA	218	5	5	146	12	605.15
30	BILASPUR	136	4	4	110	15	651.74
31	SOLAN	130	5	4	104	16	731.54
32	SIRMAUR	158	6	6	136	77	1010.32
33	SHIMLA	260	10	10	195	128	1579.03
34	KINNAUR	55	3	3	44	9	370.06

Jammu & Kashmir

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
1	KUPWARA	280	10	9	244	8	384.98
2	BADGAM	236	8	7	214	4	489.38
7	KATHUA (HIRANAGAR)	138	7	6	128	21	541.63
8	BARAMULLA	211	12	8	139	29	587.07

9	BANDIPORA	29	5	3	18	49	59.90
11	GANDERBAL	76	4	3	53	5	162.46
12	PULWAMA	153	5	5	44	118	249.38
14	ANANTNAG	203	6	5	128	57	295.70
15	KULGAM	146	5	4	117	1	305.75
21	KATHUA	104	8	4	91	50	426.25
22	SAMBA	78	4	3	36	2	305.46

Jharkhand

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
346	GARHWA	193	19	19	157	7	914.85
347	CHATRA	148	12	12	120	2	681.71
348	KODERMA	0	6	0	0	0	0.00
349	GIRIDIH	171	7	7	112	31	593.35
350	DEOGHAR	0	11	1	0	0	0.00
351	GODDA	181	10	10	112	23	756.13
352	SAHEBGANJ	0	10	0	0	0	0.00
353	PAKUR	127	6	6	113	1	525.37
354	DHANBAD	247	8	8	124	2	772.23
355	BOKARO	0	9	1	0	0	0.00
356	LOHARDAGA	57	7	7	33	0	259.77
357	EAST SINGHBUM	220	12	11	133	9	852.51
358	PALAMU	279	20	20	217	8	997.89
359	LATEHAR	108	9	9	97	3	667.39

360	HAZARIBAGH	0	16	0	0	0	0.00
361	RAMGARH	0	6	0	0	0	0.00
362	DUMKA	191	11	11	165	17	1069.14
363	JAMTARA	111	6	6	95	14	515.62
364	RANCHI	0	19	0	0	0	0.00
365	KHUNTI	76	6	6	66	2	424.63
366	GUMLA	154	13	12	117	12	738.26
367	SIMDEGA	90	10	10	74	9	652.88
369	SARAIKELAKHARSAWAN	134	11	9	97	3	660.92

Punjab

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
35	GURDASPUR	991	138	16	638	8	1917.70
36	KAPURTHALA	374	83	3	199	0	815.11
37	JALANDHAR	433	143	6	218	0	994.55
38	HOSHIARPUR	700	127	5	296	0	1200.72
39	NAWANSHAHR	264	53	3	119	0	598.80
40	FATEHGARH SAHIB	166	71	4	86	0	493.10
41	LUDHIANA	388	118	6	230	0	1054.00
42	MOGA	297	66	4	183	0	806.78
43	FIROZPUR	634	67	6	377	0	1221.55
44	MUKTSAR	168	66	3	110	1	664.80
45	FARIDKOT	88	42	1	65	0	286.85

46	BATHINDA	184	71	5	115	0	686.95
47	MANSA	38	56	1	22	0	154.07
48	PATIALA	639	124	6	305	0	1416.00
49	AMRITSAR	503	23	6	219	12	874.88
50	TARN TARAN	301	12	4	112	6	670.53
52	S.A.S NAGAR	144	31	2	88	2	335.38
53	SANGRUR	88	115	2	53	0	287.59
54	BARNALA	62	45	2	42	0	280.00

Maharashtra

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
497	NANDURBAR	252	40	5	233	8	727.24
498	DHULE	305	74	6	291	4	1039.45
499	JALGAON	623	190	13	479	11	1934.00
501	AKOLA	240	37	4	215	6	827.68
503	AMRAVATI	59	69	3	58	0	236.19
516	NASHIK	618	114	11	531	23	1644.74
517	THANE	495	98	14	363	9	1928.61
520	RAIGAD	371	71	8	266	148	1034.21
521	PUNE	659	198	13	601	58	2167.85
522	AHMEDNAGAR	898	310	24	836	5	3520.10
523	BEED	685	83	15	615	8	2423.79
526	SOLAPUR	546	146	20	386	4	3205.22
527	SATARA	745	163	13	691	27	2376.61

528	RATNAGIRI	460	106	12	401	6	1732.94
529	SINDHUDURG	68	24	3	60	6	374.36
530	KOLHAPUR	383	215	8	295	6	1180.85
531	SANGLI	169	281	4	131	1	792.45

Mizoram

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
281	MAMIT	36	3	3	34	41	283.81
282	KOLASIB	27	2	2	22	19	201.61
283	AIZAWL	67	5	5	58	33	358.54
284	CHAMPHAI	54	5	4	54	32	457.12
285	SERCHHIP	0	2	0	0	0	0.00
286	LUNGLEI	30	4	2	23	15	172.12
287	LAWNGTLAI	27	5	3	18	13	143.02
288	SAIHA	61	2	2	60	12	225.44

Madhya Pradesh

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
418	SHEOPUR	102	3	2	41	72	340.35
419	MORENA	357	7	6	189	132	995.72
420	BHIND	350	6	5	182	118	1078.91
421	GWALIOR	78	11	1	47	0	302.71
422	DATIA	109	3	2	65	67	330.35
423	SHIVPURI	335	8	5	158	133	1107.51

425	CHHATARPUR	135	10	3	68	51	475.55
429	SATNA	422	8	5	175	133	1165.77
430	REWA	75	1	1	71	1	217.89
431	UMARIA	140	3	2	53	112	286.90
432	NEEMUCH	71	3	1	29	15	208.07
433	MANDSAUR	217	5	3	83	80	428.37
434	RATLAM	140	6	2	96	28	449.42
436	SHAJAPUR	146	7	3	57	73	437.72
441	BARWANI	161	5	3	93	1	437.37
446	RAISEN	183	5	3	112	65	592.56
450	KATNI	277	6	4	153	34	936.74
451	JABALPUR	264	7	4	155	52	775.11
452	NARSINGHPUR	0	13	1	0	0	0.00
454	MANDLA	0	3	1	0	0	0.00
455	CHHINDWARA	549	11	8	376	78	2098.67
456	SEONI	298	8	5	187	84	955.85
457	BALAGHAT	332	10	6	235	52	1179.04
458	GUNA	170	3	2	92	13	441.57
460	SHAHDOL	253	5	4	147	113	878.52
461	ANUPPUR	96	4	1	84	27	317.98
465	ALIRAJPUR	39	2	1	31	0	141.04
466	KHANDWA (EAST NIMAR)	89	6	2	61	15	364.00
467	BURHANPUR	59	2	1	34	44	147.50

Nagaland

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
261	MON	13	7	1	9	4	31.96
262	TUENSANG	22	9	3	15	8	59.49
263	LONGLENG	15	2	1	14	0	57.17
264	KIPHIRE	0	3	0	0	0	0.00
265	MOKOKCHUNG	41	8	4	33	0	247.03
266	ZUNHEBOTO	17	10	1	2	0	31.47
267	WOKHA	11	5	1	5	1	44.78
268	DIMAPUR	65	6	1	19	6	187.80
269	KOHIMA	48	7	3	17	25	122.77
270	PEREN	0	5	0	0	0	0.00
271	PHEK	11	6	1	4	0	116.82

Odisha

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
370	BARGARH	246	34	12	179	7	1595.98
371	JHARSUGUDA	72	20	8	42	2	515.01
372	SAMBALPUR	143	31	9	75	23	846.67
373	DEOGARH	0	10	0	0	0	0.00
374	SUNDARGARH	255	49	19	154	40	1571.98
378	BHADRAK	193	36	8	93	4	1051.19

382	JAJPUR	279	65	10	121	6	1492.01
384	ANUGUL	208	28	9	144	8	1121.87
393	BALANGIR	277	38	15	201	18	1457.34
396	RAYAGADA	168	23	11	122	23	955.17
397	NABARANGPUR	148	12	9	135	2	816.09
398	KORAPUT	217	35	16	169	32	1373.88
399	MALKANGIRI	97	12	9	73	20	660.85

Puducherry

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
635	PONDICHERRY	0	2	0	0	0	0
637	KARAIKAL	0	1	0	0	0	0

Rajasthan

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
100	HANUMANGARH	34	76	3	33	0	302.61
102	CHURU	48	96	5	42	0	478.86
104	ALWAR	96	91	4	78	0	521.63
105	BHARATPUR	77	40	3	46	0	436.24
106	DHOLPUR	60	6	3	53	5	327.64
107	KARAULI	73	6	2	46	40	298.42
108	SAWAI MADHOPUR	36	16	1	23	0	208.62
111	SIKAR	73	93	5	53	0	549.52

112	NAGAUR	152	87	12	127	0	1238.70
113	JODHPUR	86	14	5	64	35	593.22
114	JAISALMER	35	27	4	33	15	505.34
115	BARMER	144	57	11	114	62	1282.52
116	JALORE	117	49	5	99	3	771.11
118	PALI	66	23	4	48	17	560.14
119	AJMER	30	57	2	20	0	188.89
120	TONK	31	37	2	27	0	223.96
122	BHILWARA	95	39	4	71	0	528.56
123	RAJSAMAND	20	50	1	18	0	155.52
124	DUNGARPUR	89	33	2	70	7	340.92
125	BANSWARA	102	22	4	83	0	402.93
126	CHITTORGARH	61	45	4	45	4	397.02
128	BARAN	61	31	4	48	0	385.25
129	JHALAWAR	84	27	3	70	0	517.42
130	UDAIPUR	160	73	6	130	4	872.98
131	PRATAPGARH	95	17	4	78	7	554.84

Tamil Nadu

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
602	THIRUVALLUR	522	41	15	519	0	1503.85
604	KANCHIPURAM	633	40	15	621	1	2023.39
606	DHARMAPURI	241	8	8	145	1	991.97
607	KRISHNAGIRI	317	10	10	185	17	1226.12

608	TIRUVANNAMALAI	817	18	18	587	43	2277.58
613	KOTAGIRI	25	3	3	15	2	174.84
614	COIMBATORE	195	11	11	127	2	764.00
616	DINDIGUL	295	14	14	188	9	1300.11
617	KARUR	148	8	8	95	5	705.32
618	TIRUCHIRAPPALLI	340	12	12	254	7	1153.33
619	PERAMBALUR	156	7	7	114	7	582.02
620	ARIYALUR	192	6	6	152	0	658.04
621	CUDDALORE	664	13	13	404	11	1691.92
623	THIRUVARUR	418	10	10	262	0	1150.42
624	THANJAVUR	558	14	14	465	22	1549.98
625	PUDUKKOTTAI	473	13	13	324	28	1719.81
627	MADURAI	415	13	13	265	3	1266.06
628	THENI	124	8	8	82	0	454.67
629	VIRUDHUNAGAR	445	11	11	399	1	1480.04
630	RAMANATHAPURAM	393	11	11	236	70	1342.36
631	TUTICORIN	401	12	12	267	0	1423.62
633	KANNIYAKUMARI	92	9	9	40	0	330.94

Tripura

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
289	WEST TRIPURA	0	6	0	0	0	0.00
290	SOUTH TRIPURA	0	4	2	0	0	0.00

291	DHALAI	0	7	0	0	0	0.00
292	NORTH TRIPURA	19	7	3	12	0	77.38

Uttarakhand

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)
56	UTTAR KASHI	397	22	11	340	35	1250.03
57	CHAMOLI	579	37	13	529	38	1800.02
58	RUDRA PRAYAG	311	27	8	276	29	1126.32
59	TEHRI GARHWAL	776	57	18	621	133	2325.12
60	DEHRADUN	139	23	3	109	74	367.96
61	PAURI GARHWAL	894	78	23	804	50	3541.43
62	PITHORAGARH	513	28	8	405	120	1283.84
63	BAGESHWAR	198	15	3	141	60	437.08
64	ALMORA	1038	52	17	917	35	2443.42
65	CHAMPAWAT	213	12	5	156	32	766.19
66	NAINITAL	239	23	6	175	56	813.43
67	UDHAMSINGH NAGAR	84	12	2	14	56	146.02

Uttar Pradesh

District Code	District Name	Number of GPs in Phase 2	Number of BSNL Rural Exchanges	Number of OLTs as per IITB design	Number of ONTs as per IITB design	Number of GPs are not connected GPs	Total Fibre Length(km)

133	MUZAFFARNAGAR	288	48	6	209	79	776.7882
134	BIJNOR	279	45	4	278	1	657.033
135	MORADABAD	435	24	6	431	4	655.1702
136	RAMPUR	166	19	1	166	0	247.633
137	JYOTIBA PHULE NAGAR	364	16	5	267	97	649.2865
138	MEERUT	244	24	7	178	66	740.6047
139	BAGHPAT	65	16	2	63	2	201.293
140	GHAZIABAD	113	6	2	91	22	238.212
142	BULANDSHAHR	409	30	7	409	0	914.5361
143	ALIGARH	433	31	6	430	3	1131.371
144	MAHAMAYA NAGAR	152	23	3	151	1	405.703
145	MATHURA	206	29	5	200	6	704.1052
146	AGRA	331	35	10	322	9	1082.862
147	FIROZABAD	214	26	4	211	3	546.891
148	MAINPURI	161	23	3	161	0	463.024
149	BUDAUN	460	44	8	453	7	1091.84
150	BAREILLY	527	27	8	429	98	1134.419
151	PILIBHIT	284	7	3	247	37	600.1431
152	SHAHJAHANPUR	377	24	3	355	22	316.1668
153	KHERI	1037	58	10	981	56	1589.287
156	UNNAO	935	46	8	909	26	1308.098
158	RAE BARELI	114	39	1	114	0	111.6687
159	FARRUKHABAD	435	26	3	433	2	544.1767
160	KANNAUJ	726	27	9	692	34	1096.728

161	ETAWAH	36	19	1	32	4	93.179
162	AURAIYA	334	19	5	323	11	811.4101
163	KANPUR DEHAT	682	33	8	336	346	988.3179
164	KANPUR NAGAR	392	21	4	152	240	478.2417
165	JALAUN	404	27	5	388	16	784.3164
166	JHANSI	564	17	6	510	54	992.7345
167	LALITPUR	364	20	4	344	20	767.6372
169	MAHOBA	112	12	1	110	2	231.0695
170	BANDA	152	50	2	134	18	255.9067
171	CHITRAKOOT	114	22	2	114	0	244.0387
172	FATEHPUR	933	45	7	859	74	1085.401
173	PRATAPGARH	1129	61	8	1123	6	1173.412
174	KAUSHAMBI	551	19	5	545	6	724.9193
175	ALLAHABAD	87	25	1	87	0	139.1514
176	BARABANKI	506	51	4	474	32	552.3012
178	AMBEDKAR NAGAR	363	35	1	361	2	247.9178
180	BAHRAICH	1147	33	10	1125	22	1484.361
181	SHRAVASTI	386	11	3	380	6	449.4531
182	BALRAMPUR	1024	14	7	682	342	842.0836
183	GONDA	1579	31	12	1519	60	1695.291
185	BASTI	1689	29	11	1689	0	1231.037
186	SANT KABEERNAGAR	778	25	5	772	6	644.6447
189	KUSHI NAGAR	1804	29	14	1798	6	1754.797
191	DEORIA	2349	70	18	2143	206	1957.873

193	BALLIA	730	43	7	590	140	568.7217
194	JAUNPUR	1335	59	9	1169	166	761.4672
195	GHAZIPUR	1340	37	13	1118	222	1706.304
196	CHANDAULI	1079	20	8	1063	16	1275.745
198	SANT RAVIDAS NAGAR	699	24	4	693	6	759.2489
199	MIRZAPUR	939	53	9	711	228	976.5555
200	SONBHADRA	900	13	10	690	210	1577.63
201	ETAH	168	26	3	168	0	509.356
202	KANSHIRAM NAGAR	229	15	4	223	6	603.506

7.4. State-wise output of fibre and wireless network

Andhra Pradesh

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
532	ADILABAD	624	0	620	38	0	0	4	2276.57	0.00	3
533	NIZAMABAD	696	0	692	35	0	0	4	2445.39	0.00	1
534	KARIMNAGAR	1186	0	1186	59	0	0	0	3886.22	0.00	4
535	MEDAK	1035	0	1034	46	0	0	1	3682.61	0.00	1
538	MAHABUBNAGAR	1306	0	1303	63	0	0	3	5220.32	0.00	2
539	NALGONDA	1162	0	1161	60	0	0	1	4736.40	0.00	1
540	WARANGAL	892	197	555	50	0	337	0	2131.40	1050.14	11
541	KHAMMAM	79	202	64	6	3	10	2	309.28	76.92	0
542	SRIKAKULAM	1088	186	437	38	0	651	0	1280.61	1480.75	1
543	VIZIANAGARAM	916	214	395	34	0	514	7	1481.79	1234.92	2
544	VISHAKHAPATNAM	813	150	562	38	0	240	11	2426.54	685.03	9
545	EAST GODAVARI	941	246	625	55	0	309	7	2179.12	931.13	7

546	WEST GODAVARI	866	235	497	46	0	364	5	1560.28	1062.90	0
547	KRISHNA	962	279	507	49	0	455	0	1730.35	1260.20	1
548	GUNTUR	984	278	696	56	0	288	0	2048.34	677.61	0
549	PRAKASAM	940	0	940	51	0	0	0	3660.30	0.00	2
550	SPSR NELLORE	909	176	583	46	0	325	1	2671.71	1276.46	5
551	YSR KADAPA	780	136	578	50	0	201	1	2560.21	756.96	0
552	KURNOOL	828	252	542	52	0	285	1	2484.29	740.99	1
553	ANANTAPUR	948	242	767	62	0	179	2	4137.26	769.53	0
554	CHITTOOR	1296	272	808	65	0	488	0	3045.27	1319.08	1

Arunachal Pradesh

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
245	TAWANG	77	9	0	17	6	49	11	112.26	40.16	0
246	WEST KAMENG	14	25	0	6	1	2	6	22.26	35.43	0
247	EAST KAMENG	102	2	0	73	10	0	29	304.21	0.00	0

249	LOWER SUBANSIRI	72	11	25	29	7	18	0	226.27	37.03	0
250	KURUNG KUMEY	149	4	0	73	13	13	63	206.65	56.19	4
251	UPPER SUBANSIRI	83	6	0	44	9	5	34	208.31	8.68	2
254	UPPER SIANG	51	4	0	41	4	4	6	299.92	1.73	10
255	DIBANG VALLEY	18	0	0	18	3	0	0	161.13	0.00	1
256	LOWER DIBANG VALLEY	20	2	2	17	2	1	0	58.75	9.29	0
257	LOHIT	132	8	0	104	8	28	0	355.02	53.57	0
259	CHANGLANG	82	7	0	61	7	17	4	270.83	68.67	18
260	TIRAP	73	8	0	61	15	7	5	485.20	36.29	16

Assam

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
305	NAGAON	33	91	12	5	1	20	0	60.605	46.945	0

Bihar

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
203	PASHCHIM CHAMPARAN	66	33	47	5	6	9	4	17.39	7.16	1
204	PURBI CHAMPARAN	141	57	101	11	8	32	0	94.78	24.28	2
207	MADHUBANI	126	61	81	7	4	41	0	38.54	31.15	1
209	ARARIA	126	16	101	6	18	6	1	60.05	39.05	0
212	KATIHAR	36	45	21	4	4	11	0	52.89	49.98	0
213	MADHEPURA	35	30	16	3	1	18	0	83.27	50.57	0
215	DARBHANGA	111	66	69	9	10	31	1	560.08	55.46	1
217	GOPALGANJ	153	18	140	11	3	10	0	120.87	68.55	0
221	SAMASTIPUR	28	72	16	2	0	12	0	261.46	81.03	0
224	BHAGALPUR	9	59	7	1	0	2	0	266.91	95.74	0
229	NALANDA	120	28	76	11	14	30	0	431.71	142.34	0
230	PATNA	70	114	48	6	7	15	0	913.95	155.29	0

231	BHOJPUR	52	27	31	3	13	8	0	328.75	205.87	1
235	JEHANABAD	17	10	11	2	3	3	0	517.01	209.21	0
236	ARWAL	26	7	17	2	0	9	0	368.04	215.79	0
238	GAYA	201	25	168	15	11	21	1	348.08	223.03	3

Chattisgarh

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
400	KORIYA	65	20	50	2	0	11	4	173.31	5.36	11
401	SURGUJA	275	44	226	7	2	45	2	695.64	123.19	1
402	JASHPUR	312	63	250	8	0	48	14	991.59	128.52	23
403	RAIGARH	518	94	351	10	2	155	10	1193.23	301.31	30
404	KORBA	269	60	214	5	7	41	7	908.79	138.14	32
405	JANJGIR-CHAMPA	392	56	266	8	17	109	0	730.15	351.99	17
406	BILASPUR	507	88	318	10	3	157	29	1070.07	303.52	4
407	KABIRDHAM	195	39	121	4	2	72	0	418.64	186.77	17

408	RAJNANDGAON	594	94	398	15	0	192	4	1615.41	574.96	30
409	DURG	165	107	96	4	0	69	0	360.91	205.56	0
410	RAIPUR	274	102	190	5	3	81	0	624.25	236.68	18
411	MAHASAMUND	389	28	327	6	10	47	5	922.30	194.70	1
412	DHAMTARI	232	45	171	7	25	36	0	748.88	133.75	2
413	KANKER	281	44	109	6	4	85	83	291.40	163.51	49
414	BASTAR	269	38	204	8	5	53	7	932.94	145.79	22
415	NARAYANPUR	16	6	5	1	3	0	8	56.91	0.00	7
416	DANTEWADA	82	14	44	3	2	29	7	156.46	57.64	3
417	BIJAPUR	87	12	71	3	0	2	14	392.36	6.27	22

Dadra and Nagar Haveli

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
496	Dadra and Nagar Haveli	11	0	11	1	0	0	0	87.57	0	0

Daman and Diu

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
494	DIU	4	0	4	1	0	0	0	13.15	0	0
495	DAMAN	11	0	11	1	0	0	0	33.23	0	0

Gujarat

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
469	BANASKANTHA	804	252	500	18	0	304	0	2201.57	950.51	0
472	SABAR KANTHA	259	235	131	6	1	127	0	540.60	453.27	0
474	AHMEDABAD	504	290	329	18	0	148	27	1830.03	344.22	0
475	SURENDRANAGAR	646	166	470	19	0	175	1	2299.69	658.38	0
476	RAJKOT	573	0	573	15	0	0	0	2268.79	0.00	250
477	JAMNAGAR	661	165	478	19	0	180	3	2258.15	738.26	2
479	JUNAGADH	823	0	823	17	0	0	0	2705.30	0.00	0
484	PANCHMAHAL	630	158	279	11	0	351	0	910.99	753.49	21

485	DAHOD	409	82	263	7	0	146	0	853.52	377.67	11
486	VADODARA	865	267	490	20	0	375	0	1797.38	1192.63	0
487	NARMADA	217	36	152	6	0	65	0	634.15	200.69	1
489	DANGS	44	4	44	2	0	0	0	264.95	0.00	21
491	VALSAD	364	0	363	6	0	0	1	1209.62	0.00	9
492	SURAT	560	248	316	11	0	244	0	1043.76	616.71	1
493	TAPI	251	43	160	6	0	91	0	553.04	224.99	16

Himachal Pradesh

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
23	CHAMBA	221	17	184	7	0	34	3	943.07	73.88	55
24	KANGRA	731	86	480	15	0	250	1	1580.75	688.55	15
25	LAHAUL AND SPITI	26	8	12	2	0	14	0	148.15	26.59	13
26	KULLU	185	58	141	5	0	44	0	672.64	153.64	12
27	MANDI	349	59	258	10	2	88	1	1356.63	299.41	70

28	HAMIRPUR	54	35	22	2	8	24	0	69.25	103.50	0
29	UNA	218	28	146	5	0	72	0	442.81	162.34	12
30	BILASPUR	136	20	110	4	0	26	0	549.26	102.48	11
31	SOLAN	130	42	104	4	4	22	0	614.94	116.61	8
32	SIRMAUR	158	22	136	6	0	21	1	959.55	50.77	63
33	SHIMLA	260	88	195	10	0	63	2	1355.36	223.67	102
34	KINNAUR	55	11	44	3	0	6	5	349.00	21.06	4

Jharkhand

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
346	GARHWA	193	22	0	157	19	30	6	796.02	118.83	1
347	CHATRA	148	33	0	120	12	28	0	594.94	65.98	2
348	KODERMA	0	25	0	0	0	0	0	0.00	0.00	0
349	GIRIDIH	171	28	0	112	7	45	14	515.54	77.81	1
350	DEOGHAR	0	34	0	0	1	0	0	0.00	0.00	0

351	GODDA	181	24	0	112	10	69	0	483.14	219.64	18
352	SAHEBGANJ	0	18	0	0	0	0	0	0.00	0.00	0
353	PAKUR	127	8	0	113	6	14	0	483.34	42.03	1
354	DHANBAD	247	119	0	124	8	121	2	386.39	358.50	0
355	BOKARO	0	88	0	0	1	0	0	0.00	0.00	0
356	LOHARDAGA	57	17	0	33	7	24	0	144.20	73.60	0
357	EAST SINGHBUM	220	112	0	133	11	79	8	607.48	245.03	0
358	PALAMU	279	41	0	217	20	62	0	793.55	204.35	5
359	LATEHAR	108	18	0	97	9	11	0	606.41	60.98	3
360	HAZARIBAGH	0	73	0	0	0	0	0	0.00	0.00	0
361	RAMGARH	0	31	0	0	0	0	0	0.00	0.00	0
362	DUMKA	191	34	0	165	11	26	0	920.08	149.06	14
363	JAMTARA	111	11	0	95	6	16	0	468.10	47.52	7
364	RANCHI	0	171	0	0	0	0	0	0.00	0.00	0
365	KHUNTI	76	16	0	66	6	8	2	388.71	35.93	0

366	GUMLA	154	32	0	117	12	26	11	660.80	77.47	1
367	SIMDEGA	90	13	0	74	10	12	4	583.02	69.87	5
369	SARAIKELA KHARSAWAN	134	90	0	97	9	35	2	502.83	158.09	0

Jammu and Kashmir

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
1	KUPWARA	280	4	244	9	1	28	7	365.80	19.18	1
2	BADGAM	236	23	214	7	4	16	2	439.90	49.48	2
7	KATHUA (HIRANAGAR)	138	9	128	6	0	4	6	535.61	6.02	15
8	BARAMULLA	211	16	139	8	9	61	2	400.10	186.97	23
9	BANDIPORA	29	9	18	3	0	11	0	59.90	0.00	38
11	GANDERBAL	76	8	53	3	6	13	4	122.08	40.38	1
12	PULWAMA	153	7	44	5	0	27	82	201.25	48.13	28
14	ANANTNAG	203	11	128	5	5	37	33	244.52	51.18	2

15	KULGAM	146	3	117	4	9	19	1	254.72	51.03	0
21	KATHUA	104	65	91	4	0	7	6	414.03	12.22	41
22	SAMBA	78	30	36	3	0	42	0	166.73	138.73	2

Punjab

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
35	GURDASPUR	991	33	16	638	227	126	0	1159.57	757.98	4
36	KAPURTHALA	374	122	3	199	0	175	0	506.03	309.08	0
37	JALANDHAR	433	217	6	218	3	212	0	613.10	381.45	0
38	HOSHIARPUR	700	171	5	296	0	404	0	629.29	571.43	0
39	NAWANSHAHR	264	98	3	119	0	145	0	369.94	228.85	0
40	FATEHGARH SAHIB	166	133	4	86	0	80	0	353.60	139.50	0
41	LUDHIANA	388	164	6	230	17	141	0	740.90	313.11	0
42	MOGA	297	65	4	183	0	114	0	589.86	216.92	0
43	FIROZPUR	634	69	6	377	7	250	0	801.12	420.43	0

44	MUKTSAR	168	66	3	110	4	54	0	497.05	167.74	1
45	FARIDKOT	88	51	1	65	2	21	0	232.78	54.07	0
46	BATHINDA	184	136	5	115	0	69	0	470.02	216.93	0
47	MANSA	38	74	1	22	0	16	0	118.37	35.71	0
48	PATIALA	639	168	6	305	3	331	0	806.90	609.10	0
49	AMRITSAR	503	106	6	219	7	277	0	392.01	482.87	0
50	TARN TARAN	301	63	4	112	5	184	0	282.80	387.73	1
52	S.A.S NAGAR	144	106	2	88	1	55	0	226.39	108.99	1
53	SANGRUR	88	138	2	53	1	34	0	210.57	77.02	0
54	BARNALA	62	59	2	42	0	20	0	222.71	57.28	0

Maharashtra

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
497	NANDURBAR	252	50	233	5	0	15	4	656.42	70.81	4
498	DHULE	305	70	291	6	3	11	0	955.45	84.00	4

499	JALGAON	623	180	479	13	21	120	3	1516.51	417.49	4
501	AKOLA	240	41	215	4	6	19	0	735.68	92.00	6
503	AMRAVATI	59	83	58	3	0	1	0	233.59	2.60	0
516	NASHIK	618	180	531	11	8	79	0	1345.95	298.79	23
517	THANE	495	172	363	14	12	119	1	1483.51	445.10	7
520	RAIGAD	371	116	266	8	36	64	5	891.65	142.56	96
521	PUNE	659	214	601	13	2	56	0	1935.25	232.60	48
522	AHMEDNAGAR	898	148	836	24	1	61	0	3322.34	197.76	5
523	BEED	685	82	615	15	2	68	0	2202.88	220.91	6
526	SOLAPUR	546	233	386	20	0	158	2	2652.70	552.52	2
527	SATARA	745	164	691	13	8	44	2	2240.48	136.13	24
528	RATNAGIRI	460	134	401	12	6	52	1	1541.86	191.08	4
529	SINDHUDURG	68	33	60	3	0	4	4	358.80	15.57	1
530	KOLHAPUR	383	242	295	8	4	82	2	952.42	228.43	4
531	SANGLI	169	245	131	4	4	34	0	664.52	127.93	1

Mizoram

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
281	MAMIT	36	5	34	3	0	1	1	283.81	0.00	39
282	KOLASIB	27	1	22	2	0	5	0	201.61	0.00	14
283	AIZAWL	67	27	58	5	0	3	6	353.73	4.81	26
284	CHAMPHAI	54	0	54	4	0	0	0	457.12	0.00	32
285	SERCHHIP	0	0	0	0	0	0	0	0.00	0.00	0
286	LUNGLEI	30	0	23	2	0	0	7	172.12	0.00	8
287	LAWNGTLAI	27	0	18	3	7	0	2	142.51	0.51	6
288	SAIHA	61	0	60	2	0	0	1	225.44	0.00	11

Madhya Pradesh

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
418	SHEOPUR	102	37	41	2	6	52	3	270.42	69.93	27
419	MORENA	357	70	189	6	13	153	2	639.14	356.58	58

420	BHIND	350	73	182	5	5	163	0	679.41	399.50	52
421	GWALIOR	78	110	47	1	0	31	0	183.04	119.66	0
422	DATIA	109	35	65	2	15	29	0	272.12	58.23	44
423	SHIVPURI	335	173	158	5	3	174	0	694.56	412.95	59
425	CHHATARPUR	135	86	68	3	2	63	2	305.83	169.73	26
429	SATNA	422	116	175	5	5	242	0	699.39	466.38	40
430	REWA	75	8	71	1	0	4	0	207.84	10.05	0
431	UMARIA	140	69	53	2	4	83	0	216.73	70.17	48
432	NEEMUCH	71	60	29	1	0	42	0	108.35	99.72	3
433	MANDSAUR	217	99	83	3	2	132	0	256.34	172.03	23
434	RATLAM	140	99	96	2	3	39	2	354.99	94.43	12
436	SHAJAPUR	146	117	57	3	2	87	0	276.62	161.11	26
441	BARWANI	161	47	93	3	3	65	0	269.80	167.57	0
446	RAISEN	183	68	112	3	4	66	1	468.82	123.75	22
450	KATNI	277	78	153	4	2	121	1	595.75	340.99	15

451	JABALPUR	264	137	155	4	8	101	0	525.56	249.54	25
452	NARSINGHPUR	0	65	0	1	0	0	0	0.00	0.00	0
454	MANDLA	0	23	0	1	0	0	0	0.00	0.00	0
455	CHHINDWARA	549	139	376	8	5	160	8	1590.43	508.24	48
456	SEONI	298	72	187	5	7	101	3	687.06	268.80	50
457	BALAGHAT	332	56	235	6	24	73	0	859.83	319.21	45
458	GUNA	170	58	92	2	0	74	4	236.21	205.36	4
460	SHAHDOL	253	57	147	4	3	99	4	661.34	217.18	61
461	ANUPPUR	96	50	84	1	0	12	0	298.69	19.29	23
465	ALIRAJPUR	39	7	31	1	2	6	0	117.13	23.91	0
466	KHANDWA (EAST NIMAR)	89	36	61	2	9	19	0	259.38	104.61	11
467	BURHANPUR	59	8	34	1	5	20	0	116.79	30.70	28

Nagaland

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
261	MON	13	7	9	1	0	0	4	31.96	0.00	0
262	TUENSANG	22	6	15	3	4	1	2	51.66	7.84	3
263	LONGLENG	15	3	14	1	0	1	0	52.05	5.12	0
264	KIPHIRE	0	2	0	0	0	0	0	0.00	0.00	0
265	MOKOKCHUNG	41	17	33	4	0	8	0	211.22	35.81	0
266	ZUNHEBOTO	17	13	2	1	7	8	0	4.62	26.85	0
267	WOKHA	11	13	5	1	2	3	1	13.54	31.23	0
268	DIMAPUR	65	36	19	1	2	44	0	71.01	116.79	3
269	KOHIMA	48	19	17	3	4	11	16	88.68	34.09	0
270	PEREN	0	13	0	0	0	0	0	0.00	0.00	0
271	PHEK	11	11	4	1	2	5	0	15.73	101.09	0

Odisha

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
370	BARGARH	246	61	179	12	0	63	4	1313.08	282.90	0
371	JHARSUGUDA	72	40	42	8	0	28	2	377.65	137.37	0
372	SAMBALPUR	143	90	75	9	0	56	12	603.97	242.71	4
373	DEOGARH	0	18	0	0	0	0	0	0.00	0.00	0
374	SUNDARGARH	255	172	154	19	0	86	15	1166.38	405.60	5
378	BHADRAK	193	86	93	8	0	98	2	652.98	398.21	1
382	JAJPUR	279	121	121	10	0	158	0	877.76	614.25	0
384	ANUGUL	208	90	144	9	0	58	6	883.38	238.49	0
393	BALANGIR	277	71	201	15	0	66	10	1146.05	311.29	4
396	RAYAGADA	168	43	122	11	0	26	20	819.50	135.67	2
397	NABARANGPUR	148	20	135	9	0	12	1	782.98	33.11	1
398	KORAPUT	217	62	169	16	0	26	22	1274.50	99.38	5
399	MALKANGIRI	97	17	73	9	0	8	16	602.89	57.96	3

Puducherry

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
635	PONDICHERRY	0	0	0	0	0	0	0	0	0	0
637	KARAIKAL	0	0	0	0	0	0	0	0	0	0

Rajasthan

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
100	HANUMANGARH	34	88	33	3	0	1	0	296.05	6.56	0
102	CHURU	48	93	42	5	0	6	0	421.92	56.94	0
104	ALWAR	96	168	78	4	2	16	0	447.22	74.41	0
105	BHARATPUR	77	79	46	3	6	25	0	296.15	140.09	0
106	DHOLPUR	60	16	53	3	2	4	1	297.79	29.86	4
107	KARAULI	73	68	46	2	2	24	1	223.63	74.79	27
108	SAWAI MADHOPUR	36	84	23	1	1	12	0	129.70	78.92	0

111	SIKAR	73	127	53	5	2	18	0	446.50	103.02	0
112	NAGAUR	152	153	127	12	3	22	0	1081.48	157.23	0
113	JODHPUR	86	186	64	5	0	22	0	520.80	72.43	23
114	JAISALMER	35	52	33	4	0	2	0	486.68	18.66	14
115	BARMER	144	115	114	11	0	30	0	1156.33	126.19	47
116	JALORE	117	60	99	5	4	14	0	667.89	103.22	3
118	PALI	66	107	48	4	4	14	0	469.34	90.80	13
119	AJMER	30	175	20	2	3	7	0	133.42	55.47	0
120	TONK	31	71	27	2	0	4	0	201.17	22.79	0
122	BHILWARA	95	95	71	4	5	19	0	397.54	131.02	0
123	RAJSAMAND	20	60	18	1	0	2	0	147.33	8.19	0
124	DUNGARPUR	89	39	70	2	3	16	0	283.99	56.92	4
125	BANSWARA	102	40	83	4	3	16	0	310.02	92.92	0
126	CHITTORGARH	61	80	45	4	1	15	0	352.42	44.60	0
128	BARAN	61	67	48	4	6	7	0	296.99	88.26	0

129	JHALAWAR	84	50	70	3	9	5	0	422.78	94.64	0
130	UDAIPUR	160	136	130	6	3	25	2	760.63	112.35	2
131	PRATAPGARH	95	26	78	4	0	17	0	485.21	69.63	7

Tamil Nadu

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
602	THIRUVALLUR	522	14	519	15	0	3	0	1497.69	6.16	0
604	KANCHIPURAM	633	19	621	15	0	12	0	1991.95	31.44	1
606	DHARMAPURI	241	128	145	8	0	96	0	621.09	370.88	0
607	KRISHNAGIRI	317	166	185	10	0	132	0	721.68	504.44	7
608	TIRUVANNAMALAI	817	136	587	18	0	230	0	1697.10	580.48	15
613	KOTAGIRI	25	63	15	3	0	10	0	106.22	68.62	1
614	COIMBATORE	195	319	127	11	0	68	0	496.05	267.95	2
616	DINDIGUL	295	179	188	14	0	107	0	885.66	414.45	8
617	KARUR	148	171	95	8	0	53	0	463.22	242.09	3

618	TIRUCHIRAPPALLI	340	227	254	12	0	86	0	897.92	255.41	3
619	PERAMBALUR	156	183	114	7	0	42	0	431.76	150.26	3
620	ARIYALUR	192	104	152	6	0	40	0	525.20	132.84	0
621	CUDDALORE	664	282	404	13	0	260	0	1014.63	677.28	2
623	THIRUVARUR	418	200	262	10	0	156	0	709.05	441.38	0
624	THANJAVUR	558	273	465	14	0	93	0	1308.84	241.13	16
625	PUDUKKOTTAI	473	249	324	13	0	149	0	1198.50	521.31	11
627	MADURAI	415	193	265	13	0	150	0	849.73	416.33	3
628	THENI	124	61	82	8	0	42	0	327.27	112.99	0
629	VIRUDHUNAGAR	445	141	399	11	0	46	0	1329.57	150.48	1
630	RAMANATHAPURAM	393	100	236	11	0	157	0	903.42	438.94	42
631	TUTICORIN	401	192	267	12	0	134	0	977.36	446.26	0
633	KANNIYAKUMARI	92	199	40	9	0	52	0	138.00	110.97	0

Tripura

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
289	WEST TRIPURA	0	49	0	0	0	0	0	0	0	0
290	SOUTH TRIPURA	0	22	0	2	0	0	0	0	0	0
291	DHALAI	0	23	0	0	0	0	0	0	0	0
292	NORTH TRIPURA	19	23	12	3	0	7	0	40.68	36.68	0

Uttarakhand

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
56	UTTAR KASHI	397	54	340	11	0	41	16	1174.79	75.24	14
57	CHAMOLI	579	37	529	13	0	22	28	1743.58	56.44	8
58	RUDRA PRAYAG	311	33	276	8	0	17	18	1084.17	42.15	11
59	TEHRI GARHWAL	776	96	621	18	35	116	4	1993.77	331.35	65
60	DEHRADUN	139	107	109	3	0	26	4	335.63	32.33	55

61	PAURI GARHWAL	894	95	804	23	26	54	10	3366.17	175.25	31
62	PITHORAGARH	513	42	405	8	7	82	19	1172.45	111.39	67
63	BAGESHWAR	198	33	141	3	2	22	33	412.57	24.51	17
64	ALMORA	1038	83	917	17	3	115	3	2237.08	206.33	19
65	CHAMPAWAT	213	26	156	5	10	35	12	673.38	92.81	11
66	NAINITAL	239	79	175	6	6	52	6	675.39	138.04	41
67	UDHAMSINGH NAGAR	84	58	14	2	3	67	0	57.11	88.90	15

Uttar Pradesh

District Code	District name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of ONTs as per IITB design	Number of OLTs as per IITB design	Connected from Phase 1 GP	Connected from BSNL towers	Satellite recommendation	Total Fibre Length(km)	Fibre length reduced(km)	Problem Cases
133	MUZAFFARNAGAR	215	102	165	6	6	41	3	414.52	63.72	73
134	BIJNOR	279	92	191	4	6	82	0	1234.42	460.87	0
135	MORADABAD	433	82	416	6	12	5	0	83.24	9.94	2
136	RAMPUR	166	61	136	1	1	29	0	1534.43	43.2	0

137	JYOTIBA PHULE NAGAR	333	18	233	5	8	51	41	450.63	206.4	31
138	MEERUT	193	68	119	7	0	74	0	686.61	81.03	51
139	BAGHPAT	63	34	43	2	3	17	0	821.16	167.16	2
140	GHAZIABAD	103	21	73	2	12	18	0	264.62	338.89	10
142	BULANDSHAHR	409	79	267	7	16	126	0	119.94	127.98	0
143	ALIGARH	433	96	286	6	50	97	0	333.5	218.8	0
144	MAHAMAYA NAGAR	152	37	88	3	16	47	1	615.1	144.15	0
145	MATHURA	201	62	128	5	14	59	0	907.7	85.03	5
146	AGRA	326	93	273	10	13	36	4	311.93	137.52	5
147	FIROZABAD	211	47	166	4	8	37	0	633.39	91.53	3
148	MAINPURI	161	54	81	3	25	55	0	900.52	182.34	0
149	BUDAUN	457	131	261	8	53	142	1	911.26	65.3	3
150	BAREILLY	452	98	298	8	40	113	1	162.85	68.22	75
151	PILIBHIT	252	36	198	3	11	43	0	539.25	375.29	32
152	SHAHJAHANPUR	359	50	230	3	36	93	0	194.52	121.65	18

153	KHERI	993	56	719	10	83	179	12	798.28	43.8	44
156	UNNAO	917	98	458	8	46	413	0	685.08	91.71	18
158	RAE BARELI	114	68	114	1	0	0	0	576.59	515.25	0
159	FARRUKHABAD	435	35	298	3	10	127	0	234.65	9.39	0
160	KANNAUJ	700	11	610	9	24	58	8	674.23	633.87	26
161	ETAWAH	34	42	27	1	2	5	0	295.38	248.8	2
162	AURAIYA	328	23	218	5	13	97	0	111.67	0	6
163	KANPUR DEHAT	520	32	253	8	50	217	0	511.48	57.24	162
164	KANPUR NAGAR	262	23	128	4	25	109	0	229.73	26.17	130
165	JALAUN	400	30	331	5	25	40	4	255.31	53.41	4
166	JHANSI	538	39	471	6	15	28	24	455.98	90.91	26
167	LALITPUR	346	18	304	4	25	17	0	1645.56	109.23	18
169	MAHOBA	112	35	81	1	15	16	0	612.66	148.81	0
170	BANDA	140	54	104	2	11	21	4	447.02	257.08	12
171	CHITRAKOOT	114	29	99	2	4	11	0	1289.19	417.11	0

172	FATEHPUR	871	40	718	7	36	115	2	907.24	178.16	62
173	PRATAPGARH	1125	73	368	8	61	696	0	617	167.31	4
174	KAUSHAMBI	545	18	466	5	5	74	0	969.86	988.01	6
175	ALLAHABAD	87	49	85	1	0	2	0	542.06	102.58	0
176	BARABANKI	474	62	259	4	6	209	0	748.2	383.17	32
178	AMBEDKAR NAGAR	361	49	257	1	2	102	0	645.16	10.01	2
180	BAHRAICH	1141	23	962	10	74	105	0	459.78	140.37	6
181	SHRAVASTI	384	13	283	3	47	52	2	1284.53	199.83	2
182	BALRAMPUR	802	10	640	7	62	46	54	1107.38	168.37	222
183	GONDA	1521	33	1166	12	66	287	2	438.44	734.97	58
185	BASTI	1689	19	1212	11	94	383	0	161.54	86.09	0
186	SANT KABEERNAGAR	778	21	581	5	15	182	0	1167.76	421.53	0
189	KUSHI NAGAR	1800	8	1693	14	16	89	2	139.89	61.4	4
191	DEORIA	2293	89	936	18	56	1299	2	195.21	43	56
193	BALLIA	620	50	588	7	0	32	0	805.65	328.77	110

194	JAUNPUR	1241	61	927	9	0	314	0	126.26	12.9	94
195	GHAZIPUR	1272	35	850	13	86	336	0	564.22	85.07	68
196	CHANDAULI	1069	14	924	8	9	134	2	586.08	225.33	10
198	SANT RAVIDAS NAGAR	699	19	552	4	0	147	0	266.93	242.42	0
199	MIRZAPUR	727	48	630	9	8	83	6	1003.96	92.77	212
200	SONBHADRA	708	4	668	10	14	8	18	231.88	231.15	192
201	ETAH	168	69	88	3	16	64	0	593.1	147.5	0
202	KANSHIRAM NAGAR	227	35	108	4	41	77	1	957.85	273.19	2

Chapter 8
Modified Fibre Route Planning

8.1. Assumptions

As suggested by BBNL, new assumptions have been taken into account for fibre planning. Following are the assumptions which have been incorporated into the tool along with the results.

- Maximum route length (along the road) from OLT to any GP is 50 km.
- Maximum number of GPs connected wirelessly from an existing BSNL tower is 4.
- Recommendation for satellite are based on the elevation profile between GPs.
- For estimating total fibre length following calculations have been performed:
  - All unprocessed GPs are connected by fibre with an average fibre route length of 4 km per GP.

  Total number of unprocessed GPs = 35041

  The total of fibre route length of unprocessed GPs= 35041 * 4 = 140164

  For Pan-India,
  - Total fibre route length of processed and unprocessed GPs(L_F) = 140164 + 266588.5

    = 406752.5 km
  - Total Duct length (L_D) = $L_F + 2\ \%\ of L_F$

    = 406752.5 + 8135 = 414887.5 km

    where,

    L_F = Total fibre route length of processed and unprocessed GPs
  - Total fibre length = $L_D + 10\ \%\ of L_D$

    = 414887.5 + 41488.75= 456376.25 km

    where,

    L_D = Total Duct length

8.2. Algorithm involving Fibre route planning with new assumptions

Below is the algorithm used in fibre network planning tool.

8.2.1. Inputs

- Phase 1 and Phase 2 GP locations in latitude longitude pairs of a block
- BSNL Tower locations in latitude longitude pairs
- Road distance
- Direction along the road
- BSNL Rural Exchange

8.2.2. Processing

Part A: only Fibre network

Step 1 - Obtain the way-points* and distance along the road between each pair of GPs within the block.
Step 2 - GPs without any road data are suggested for satellite connectivity.
Step 3 - Minimum Spanning Tree is created for the remaining GPs in a block along the road.
Step 4 - GPON feasibility of each link is checked from a Block OLT to GP.
Step 5 - The GPs with unfeasible link as in step 4 are checked for GPON feasibility with the next OLT.
Step 6 - Step 4 and 5 are repeated until all the GPs are checked for GPON feasibility from all the OLTs present in the block.
Step 7 - GPON verified Minimum spanning tree is obtained.

Part B: Fibre and Wireless network

Step 1 - Perform Step 1 to Step 3 of Part A processing.
Step 2 - The GPs in the minimum spanning tree are connected wirelessly after checking the following 2 conditions:
    a. If the throughput requirement is less than 100 Mbps.
    b. If wireless link is feasible from BSNL towers and Phase 1 GP to the GP.
Step3 - Repeat Step 2 until no further wireless link can be established from BSNL towers and Phase 1 GPs.

Way-points: Way-points are the intermediate points along the road, which help in identifying the turns and directions along the road.

New algorithm is incorporated in the tool to generate state-wise results. Detailed district wise results will produced after fine tuning the code.

Based on the assumptions mentioned above, following is the Pan-India fibre and wireless summary of the results.

State Name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of OLTs as per IITB design	Number of ONTs as per IITB design	Wireless from Phase 1 GP	Wireless from BSNL Towers	Satellite Recommendation	Total number of GPs which are not connected	Total Fibre Route Length (km)	Total Fibre length (km)
ANDAMAN & NICOBAR ISLANDS	0	0	0	0	0	0	0	0	0	0
ANDHRA PRADESH	19303	3065	996	14655	3	4557	42	46	56476.27	63366.37
ARUNACHAL PRADESH	924	86	85	595	26	139	117	47	2972.81	3335.493
ASSAM	33	91	5	7	2	24	0	0	50	56.1
BIHAR	1326	668	98	975	97	239	7	8	4591.78	5151.977
CHANDIGARH	0	0	0	0	0	0	0	0	0	0
CHHATTISGARH	5211	954	105	3596	76	1165	131	243	13248.23	14864.51
DADRA AND NAGAR HAVELI	11	0	1	11	0	0	0	0	66	74.052
DAMAN & DIU	15	0	2	15	0	0	0	0	48	53.856
GOA	0	0	0	0	0	0	0	0	0	0
GUJARAT	7942	1946	169	5513	1	2187	32	209	22092.53	24787.82
HARYANA	0	0	0	0	0	0	0	0	0	0
HIMACHAL PRADESH	2888	474	73	1776	16	737	11	348	8777.42	9848.265
JAMMU & KASHMIR	1807	185	53	1209	39	280	136	143	3180.64	3568.678
JHARKHAND	2545	1058	163	1871	0	582	37	55	9130.54	10244.47
KARNATAKA	0	0	0	0	0	0	0	0	0	0
KERALA	0	0	0	0	0	0	0	0	0	0
LAKSHADWEEP	0	0	0	0	0	0	0	0	0	0
MADHYA PRADESH	6197	2053	85	3393	133	2171	26	474	13449.55	15090.4
MAHARASHTRA	7815	2387	167	6528	108	961	24	194	24082.02	27020.03
MANIPUR	0	0	0	0	0	0	0	0	0	0
MEGHALAYA	0	0	0	0	0	0	0	0	0	0
MIZORAM	438	33	21	274	7	11	17	129	1863.34	2090.667
NAGALAND	249	140	16	95	27	101	20	6	607	681.054

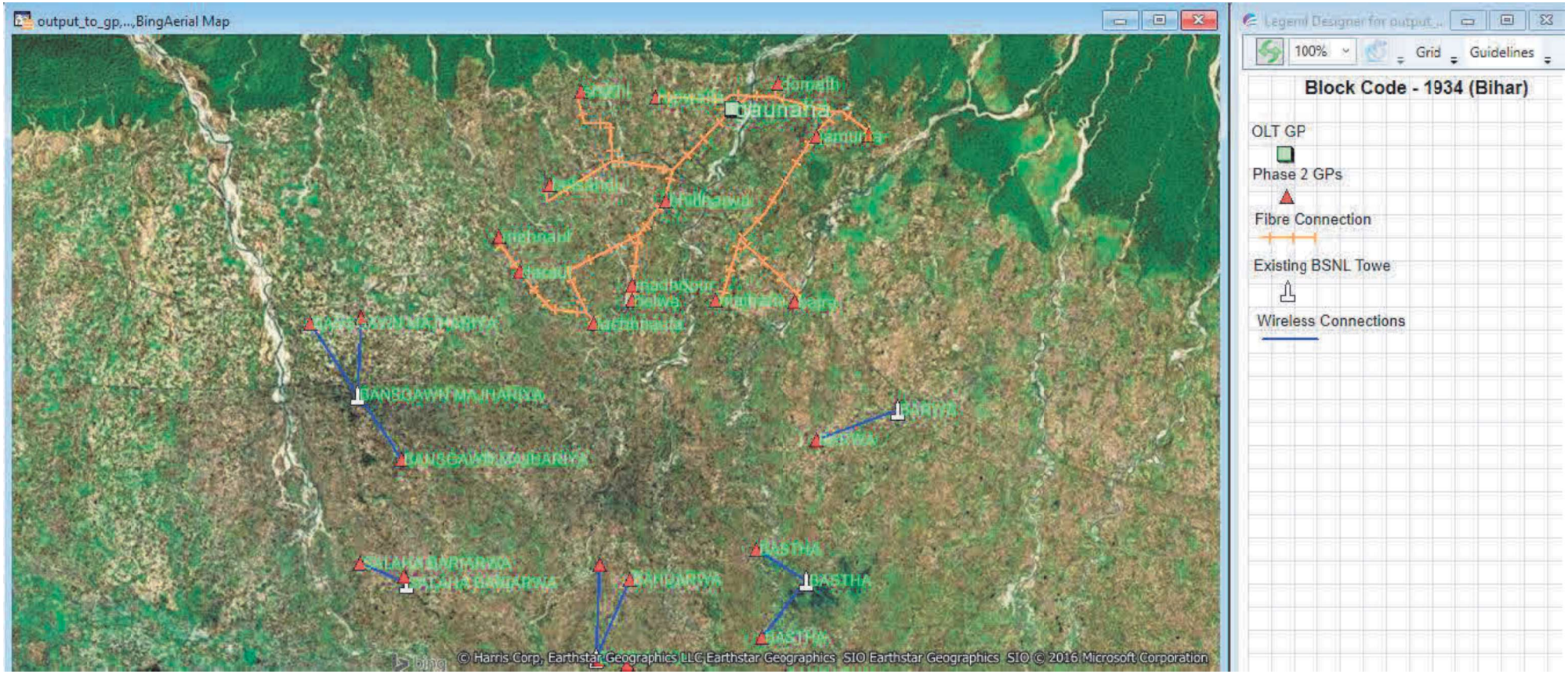
State Name	Number of GPs in Phase 2	Number of existing BSNL Towers	Number of OLTs as per IITB design	Number of ONTs as per IITB design	Wireless from Phase 1 GP	Wireless from BSNL Towers	Satellite Recommendation	Total number of GPs which are not connected	Total Fibre Route Length (km)	Total Fibre length (km)
NCT OF DELHI	0	0	0	0	0	0	0	0	0	0
ODISHA	2328	891	142	1503	0	735	67	23	10481.11	11759.81
PUDUCHERRY	0	0	0	0	0	0	0	0	0	0
PUNJAB	6469	2039	77	3745	262	2455	0	7	10564.01	11852.82
RAJASTHAN	2069	2235	104	1240	105	603	1	120	10769.82	12083.74
SIKKIM	0	0	0	0	0	0	0	0	0	0
TAMIL NADU	7982	3599	232	5823	0	2080	0	79	19476.92	21853.1
TRIPURA	19	117	5	6	0	13	0	0	32	35.904
UTTAR PRADESH	33653	2696	338	23824	1315	7014	69	1431	39511.39	44331.78
UTTARAKHAND	5735	743	116	4525	98	634	150	328	15117.1	16961.39
WEST BENGAL	0	0	0	0	0	0	0	0	0	0
TOTAL	114959	25460	3053	81179	2315	26688	887	3890	266588.48	299112.3
UNPROCESSED GPs	35041	-	-	-	-	-	-	-	140164	157264
GRAND TOTAL	150000	25460	3053	81179	2315	26688	887	3890	406752.5	456376.3

8.3. Plot of fibre and wireless network on MapInfo Pro

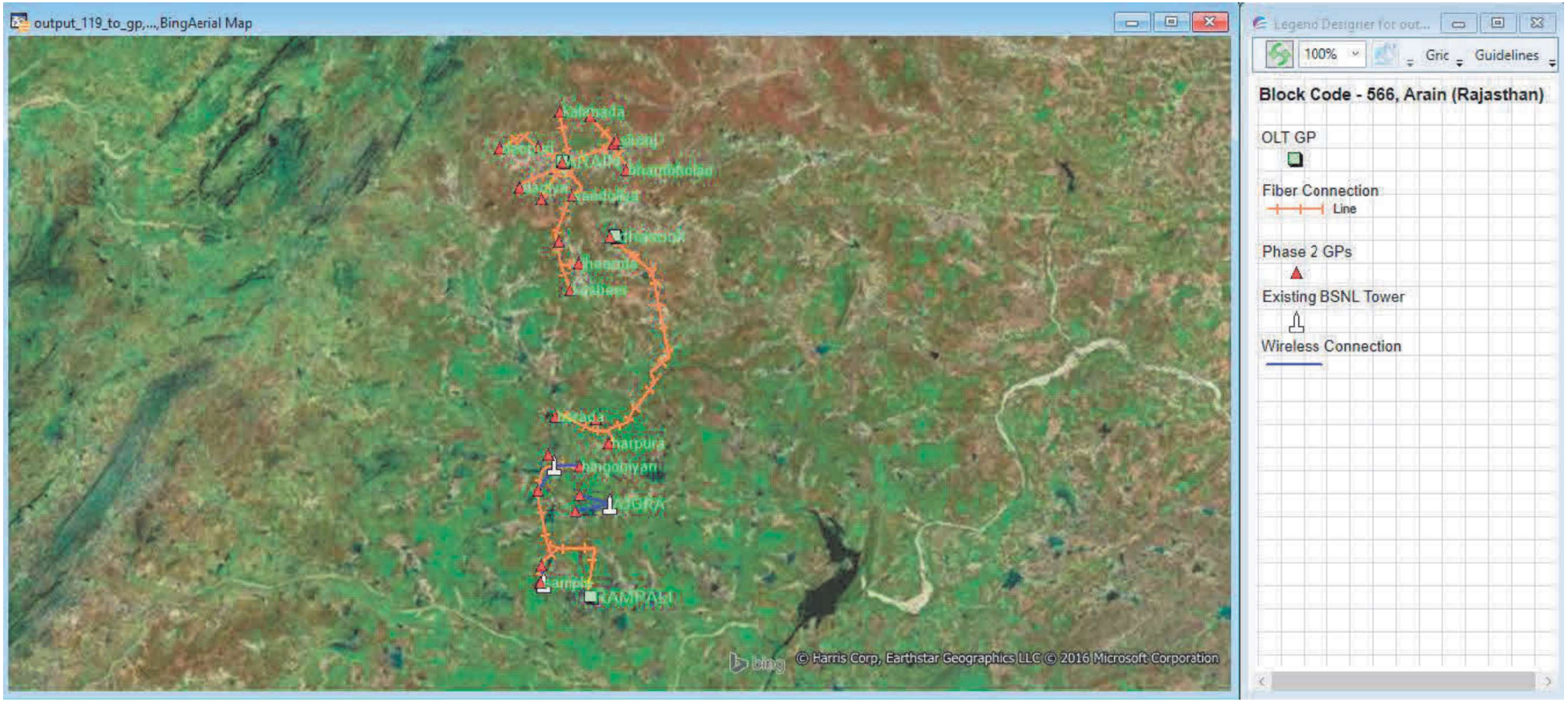
State – Bihar

District Code – 203

Block Code – 1934



State – Rajasthan
District Code – 119
Block Code – 566



State – Odisha
District Code – 307
Block Code – 3311

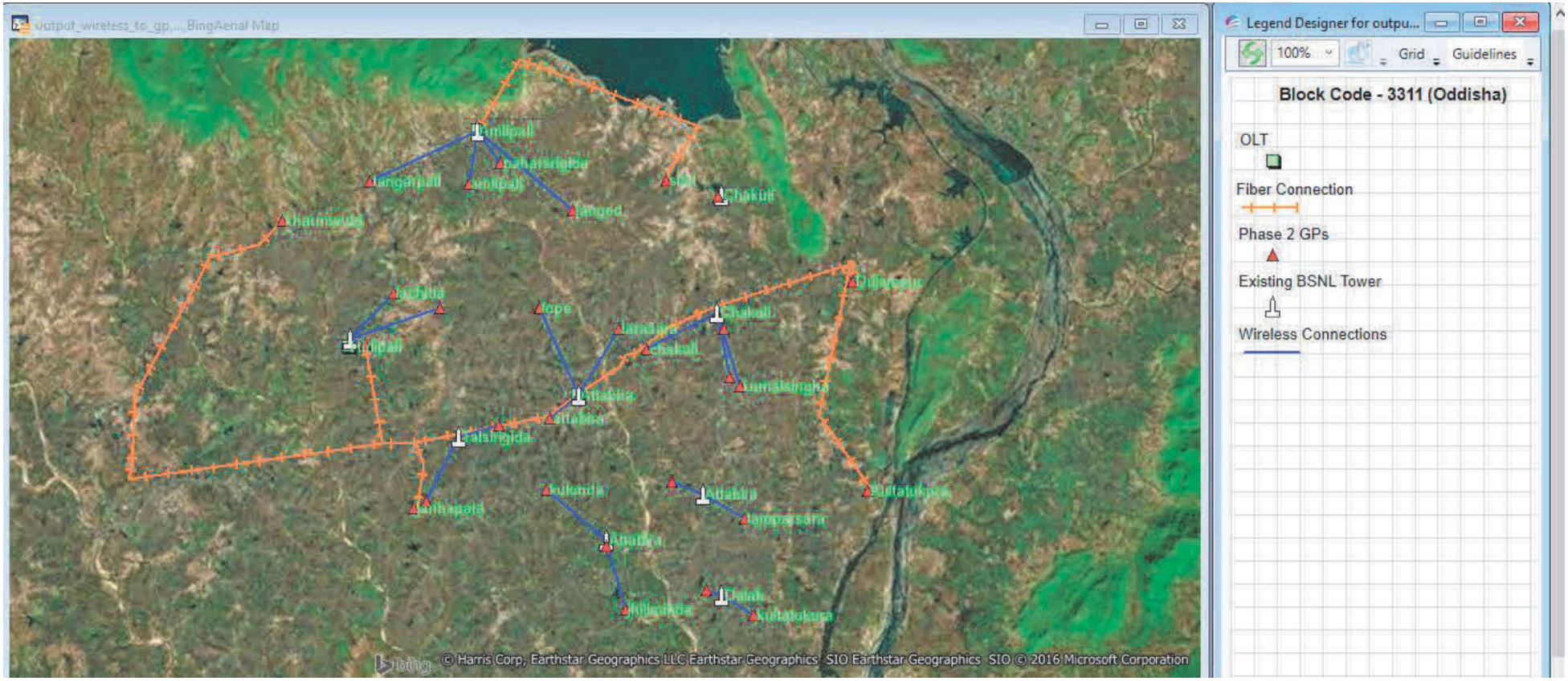
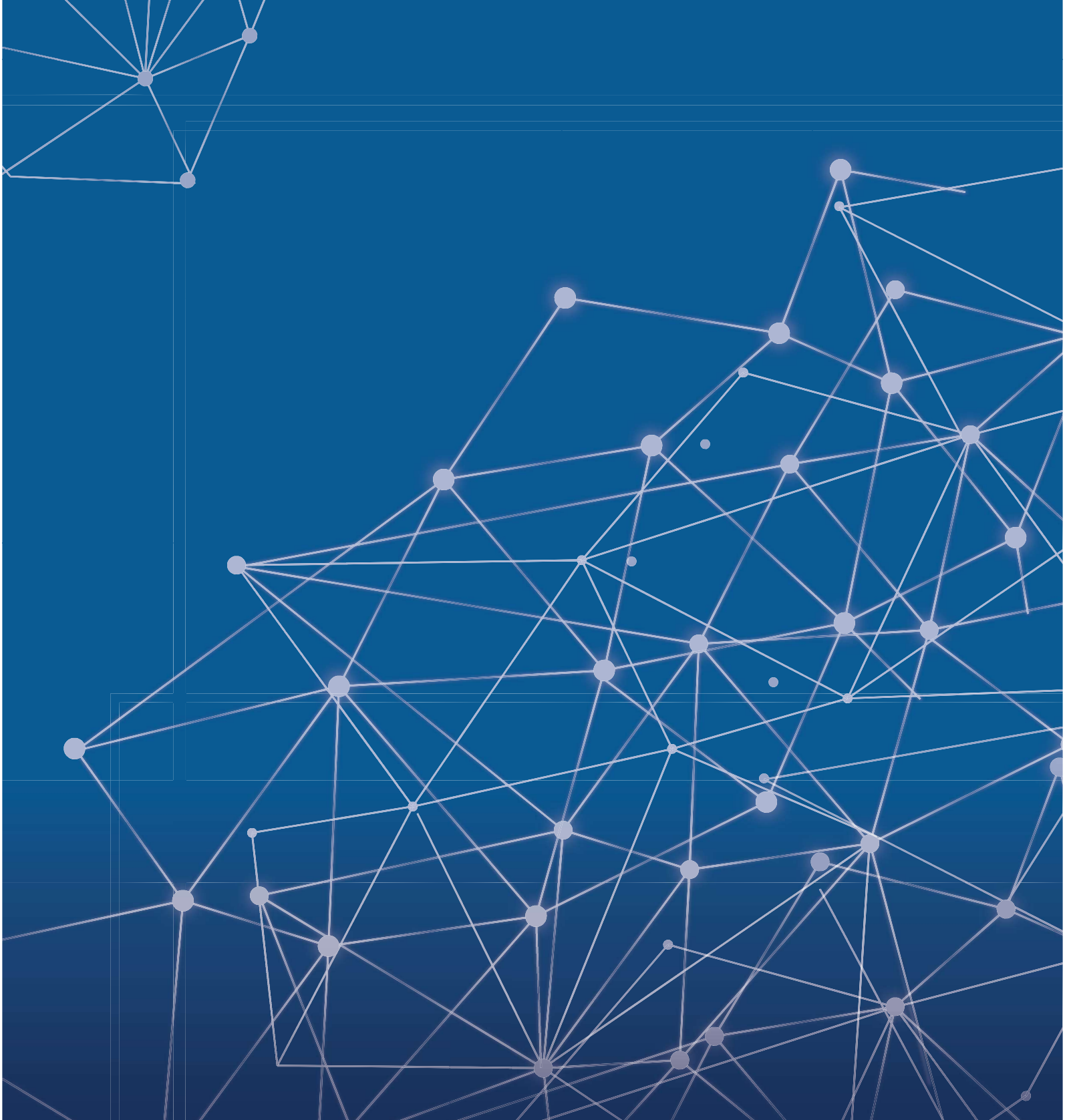


Table of figures

References

[1] Planning for BharatNet Phase 2, 'Report on IITB Bharatnet Planning Tool', July, 2016.



About the Report

This report is a planning document for Phase 2 deployment of BharatNet. Here we are designing the network topology of fibre and wireless links. The planning will help to expedite deployment as near-to-accurate overview of links and materials has been generated by the tool.

We have also provided recommendations for GPs to be connected via satellite. State-wise and district-wise results have been provided with an account of all the assumptions taken into consideration.