PLANNING FOR BharatNet PHASE 2

July 2016

Indian Institute of Technology Bombay

Contributors from IIT Bombay:

Prof Abhay Karandikar

Prof Prasanna Chaporkar

Dr Sarbani Banerjee Belur

Mahak Arora

Jaspreet Singh

Annapurna

Vivek Yogi

Arindam Bhattacharyya

Vinooth Kulkarni

Shubham Sharma

Meghna Khaturia

Shubham Saha

Akshay Bajpai

Planning for BharatNet Phase 2

Report on

IIT Bombay BharatNet Planning Tool

July 2016

Indian Institute of Technology Bombay

Table of Contents

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 for 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 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, an RF 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 suggest radio/wireless network for areas of difficult terrain and will propose fibre topology for GP with population more than a standard range set.

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. Wireless Link Feasibility test and reliability test

   The tool checks link feasibility based on terrain profile, maximum tower height, population and throughput demand of a GP. The reliability 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, 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 the interference.

4. Improving deployment speed

   The tool separately gives the list of GPs that can be connected wirelessly from either the existing BSNL tower or the Phase 1 GP. Note that since the connections are drawn from the fibre PoP, the wireless connections can be made immediately after the Phase 1 completion. Thus, wireless and fibre connectivity for Phase 2 GPs can start simultaneously in parallel.

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. 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 of 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.
- Currently, the tool does not provide the detailed planning of fibre network. This planning needs additional data like road maps, electricity poles and existing fibre routes. Availability of these data sets can be used to plan fibre and wireless network together and further optimize the output.

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, include licensed and unlicensed systems. Each technology has its advantages and limitations which help in selecting most appropriate one for the present scenario.
- **Maximum length of a wireless link**
  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 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 wireless link?
- How many GPs can be connected from point of origination of the link? How many hops can the 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
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 of2.4 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 lakh per hop

The following table demonstrates the maximum distance covered corresponding to the various Physical data rates available in IEEE 802.11 ac, 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

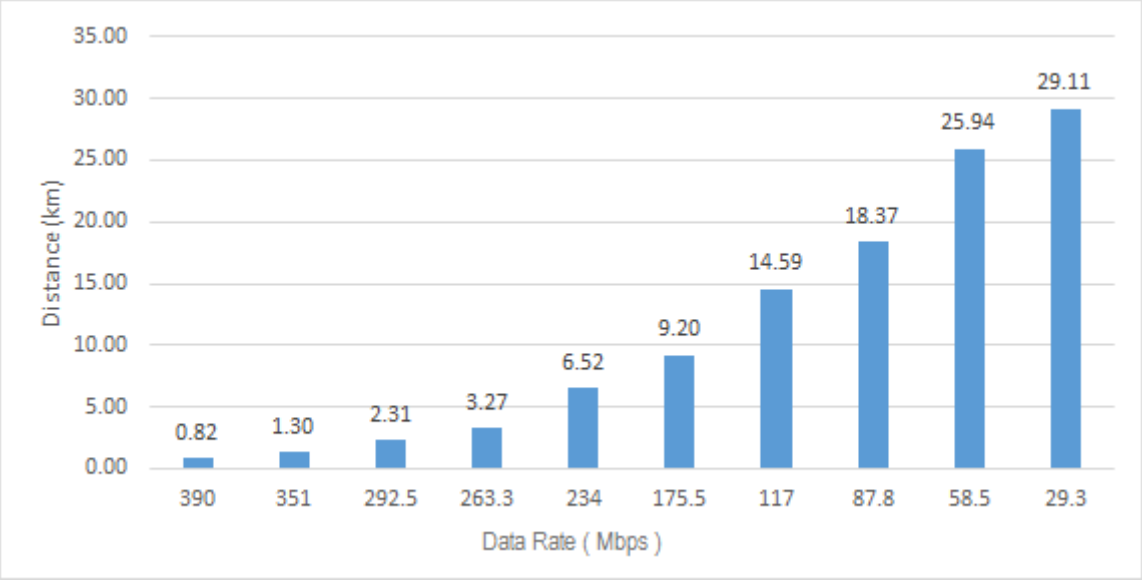


Figure 1 : Graph showing distance versus data rate for 80MHz channel

Note: - The figure 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 is 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.
Inspite 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 section, the key steps of the proposed algorithm 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 its GP,
- GP population is the 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 - A Gram Panchayat has total number of households as H.

Step 2 - The average number of members in a household is 5, hence number of households becomes$(\frac{H}{5})$.

Step 3 - The contention ratio for rural India (as proposed by BBNL) is 1:25.
On applying the contention ration, the number of active household turns to be $(\frac{H}{5} * \frac{1}{25})$ at any given point of time.

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

Step 5 - Hence, the minimum total throughput requirement at a GP with 'H' number of households can be calculated as
$\left(\frac{2H}{125}\right)$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 consider:

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

(ii) Socio-economic status of the population.

However, when wireless connectivity infrastructure will be replaced by fibre, these factors will be taken into consideration.

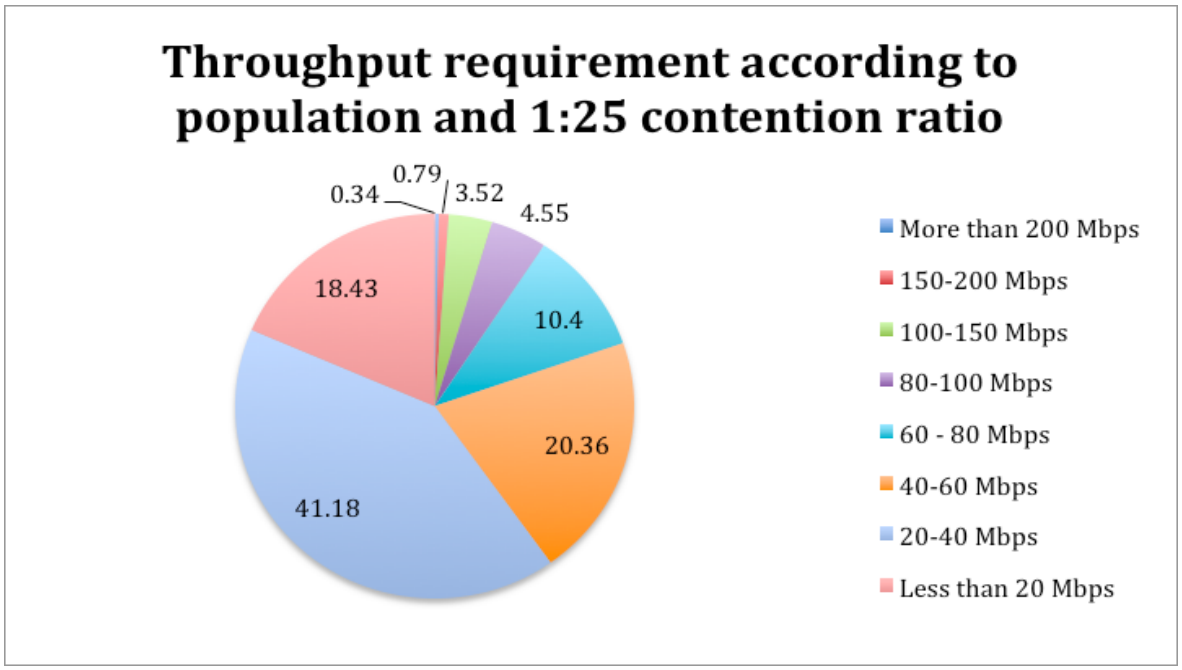


Figure 2: Throughput requirement according to population and 1:25 contention ratio

From Figure 2, it can be noted that about 60% of GPs require less than 40 Mbps throughput while only 20% GPs have 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, wireless links of 5-7 km length can be considered. For this report, a conservative choice of 5 km is made.

Inputs 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, following parameters are determined:

- **Wireless link feasibility** between two given geo-locations,

- **Required tower heights** if 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

Currently Google Maps Elevation API is used for obtaining the elevation profile of the path. 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 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 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 36dBm for 5GHz frequency band. For an antenna with transmitter antenna gain as 25 dBi, the allowable output transmit power should not be greater than 11dBm, 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 the 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.

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

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.

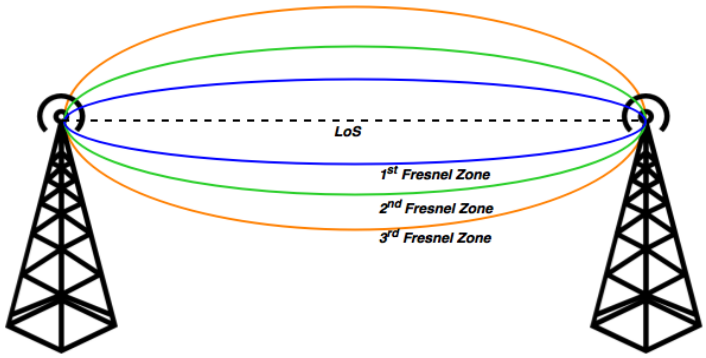


Figure 3: Fresnel Zone

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.

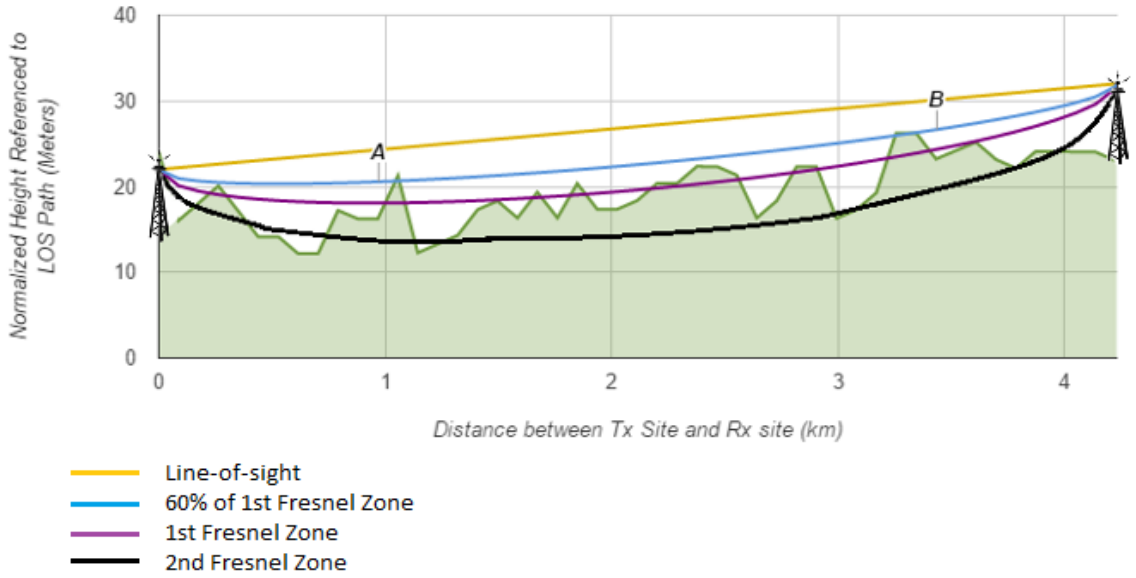


Figure 4: Fresnel Zones created with Tx Antenna at 9m height and Rx Antenna at 9m height

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.

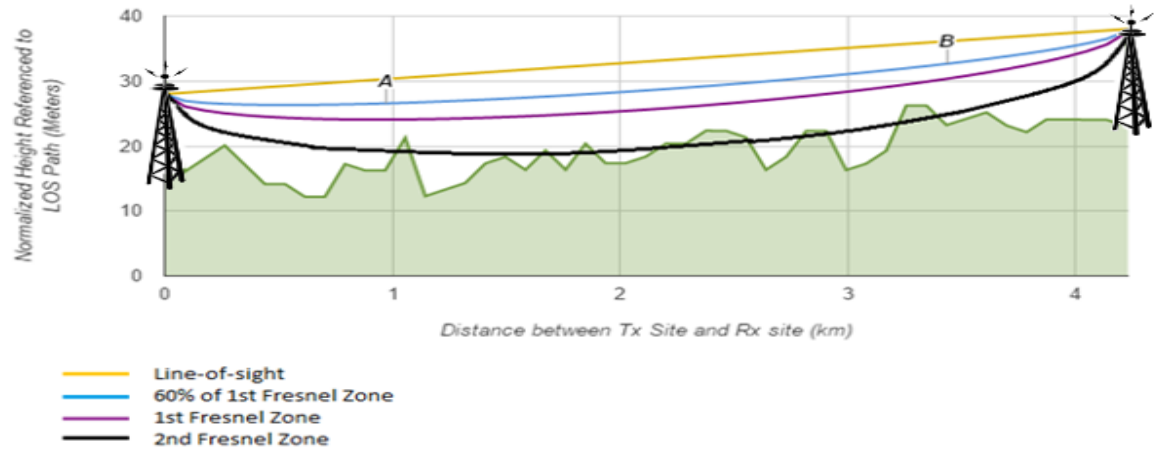


Figure 5: Fresnel Zones created with Tx Antenna at 15m height and Rx Antenna at 15m height

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 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. However, construction of a 30m tall tower involves more monetary investment as well as time.

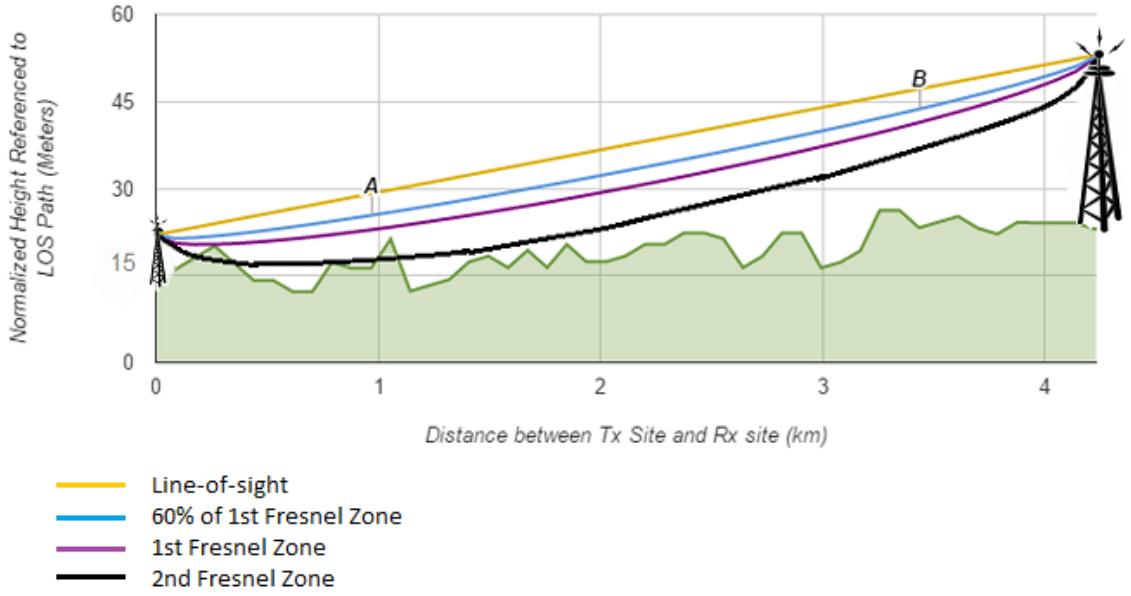


Figure 6: Fresnel Zones created with Tx Antenna at 9m height and Rx Antenna at 30m height

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 taken from Google. However, elevation profile data from other sources such as *National Remote Sensing Centre (NRSC), Hyderabad,* can also be included as and when available.
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:

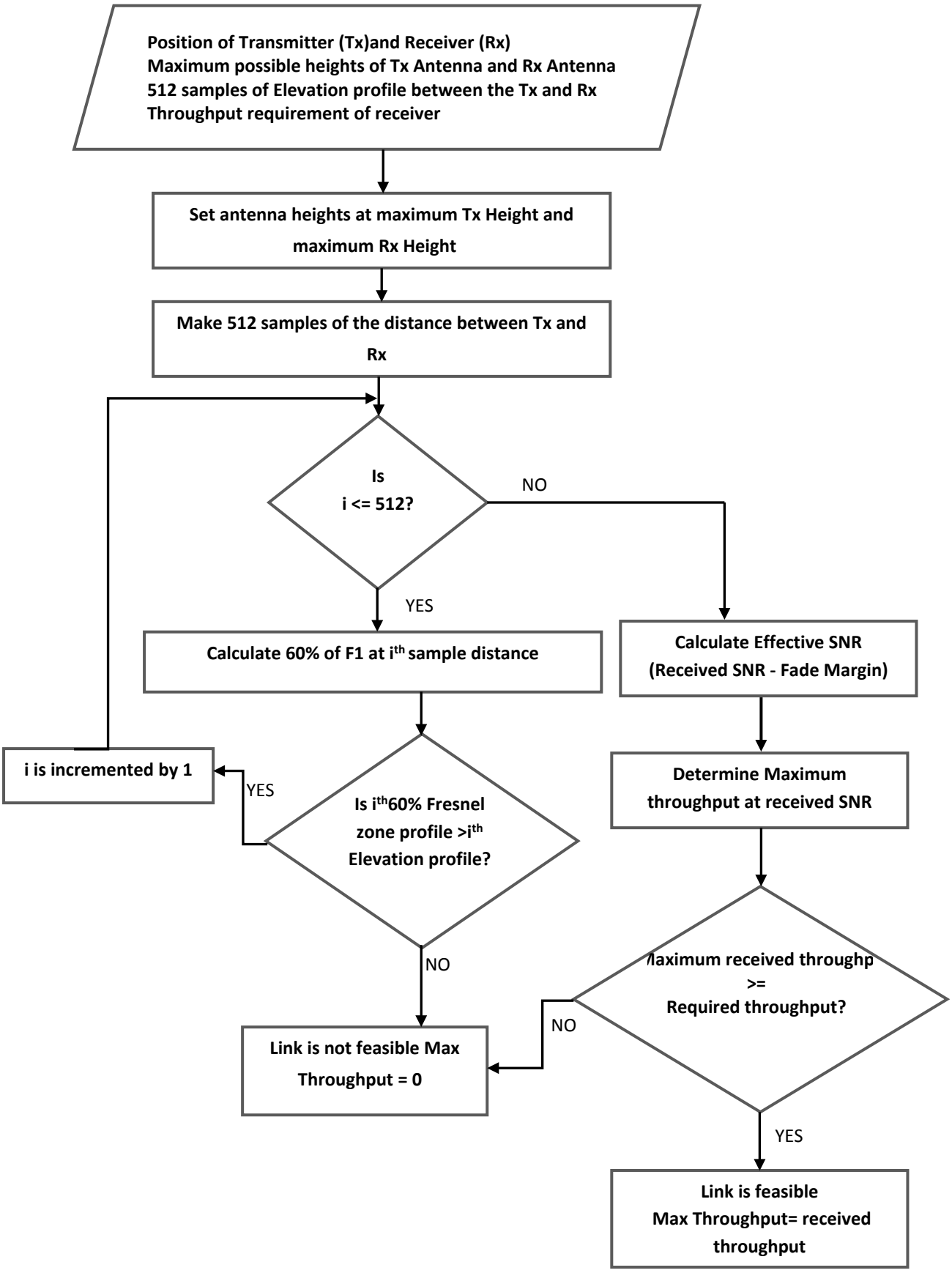
1. Fresnel zone clearance -
   A link is said to be LoS if it clears 60% of F1 (first Fresnel Zone) and the F2 (second Fresnel zone) is blocked. The objective of the code is to check whether 60% of F1 is cleared for the maximum the height of Tx and Rx antennas.
   The Fresnel zone calculations consider 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.
   Technology in frequency band Wi-Fi (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



5.4 Pre-processing and Outer Loop

Inputs –

Phase 1 and Phase 2 GP locations in latitude longitude pairs
BSNL Tower locations in latitude longitude pairs
GP throughput requirement (calculated from GP population)

Processing –

Step 1 - Identify GPs with throughput requirement greater than 100 Mbps and suggest fibre connectivity for such GPs.

Step 2 - GPs within 300 m radius of a BSNL tower are considered to be fibre connected.

Step 3 - For remaining GPs, perform Distance based filtering.
The maximum length of wireless link should be of 5 km from existing BSNL tower to unconnected Phase 2 GP.

Step 4 - For GPs filtered in step 2, perform RF filtering.
Wireless link feasibility of all the links obtained from step 2 are done.

Step 5 - For GPs which are filtered out in distance based filtering or RF filtering are recommended for satellite connectivity. (However, these GPs are considered for minimum fibre length calculations)

Step 6 - For all the wirelessly feasible links, run Greedy Algorithm.
Choose a tower and connect 3 closest unconnected Phase 2 GPs for which:

1. The link length from tower is 5 km and
2. Throughput requirement is met

Step 7 - Repeat step 6 until all towers are exhausted.

Step 8 - If all the BSNL towers are exhausted, choose a Phase 1 GP and connect at most 2 unconnected GPs where the connection is feasible and the throughput requirements are met.

Step 9 - Repeat step 8 until all possible links from connected Phase 1 GP are exhausted.

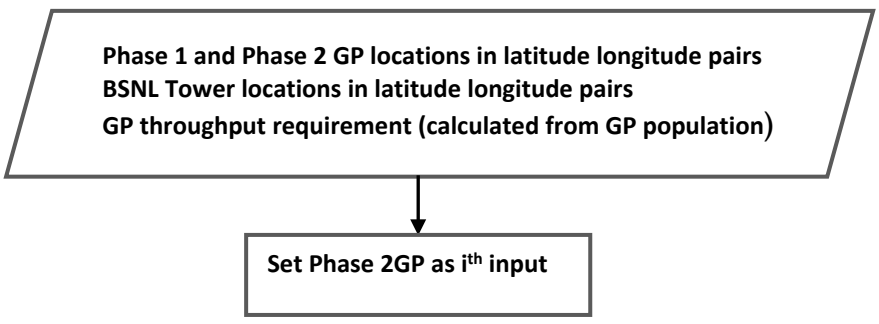
Step 10 - If all possible Phase 1 GPs are exhausted, choose nodes with greater than 100 Mbps and connect at most 2 unconnected GPs.

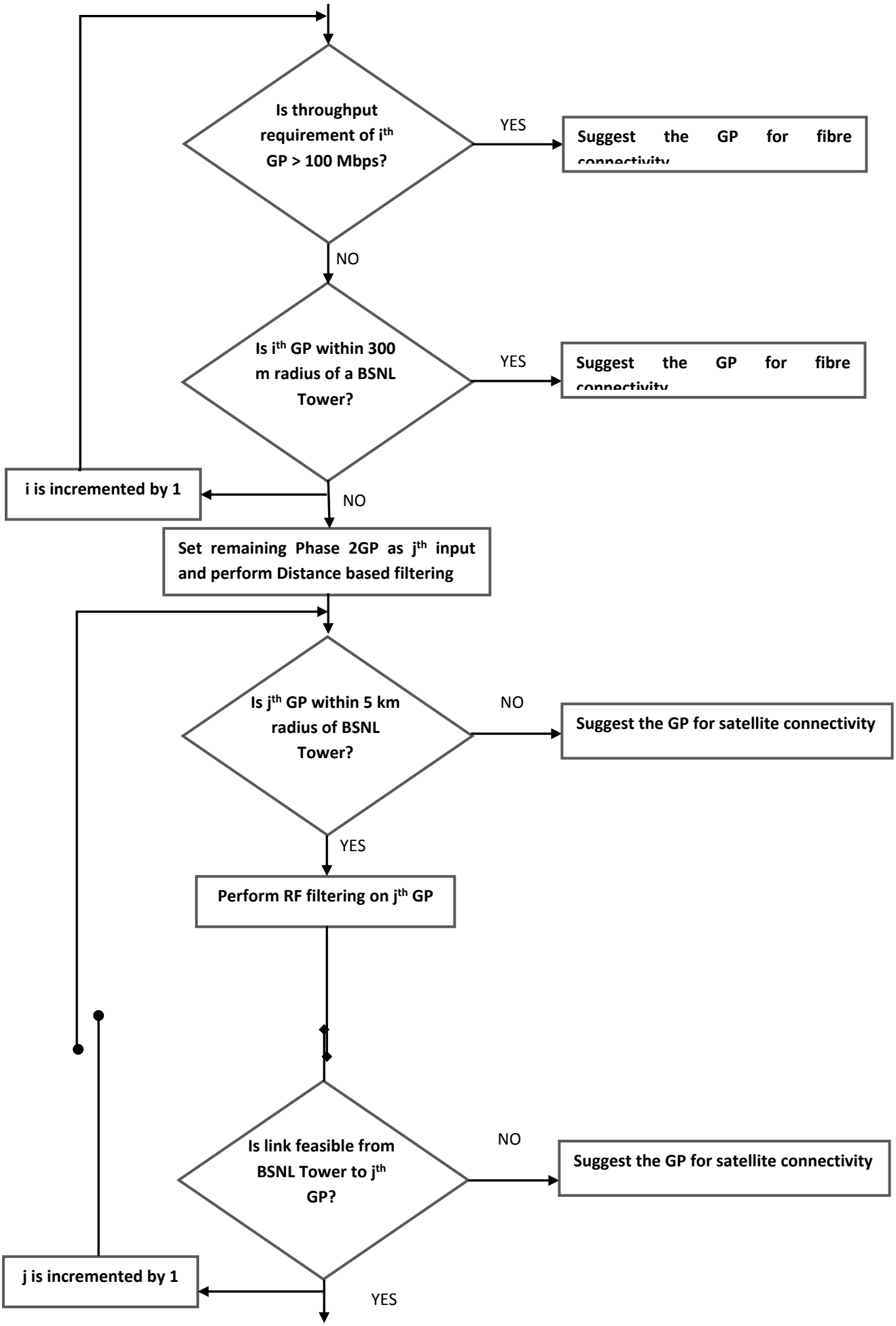
Step 11 - Repeat step 10 until all possible links from connected Phase 1 GP are exhausted.

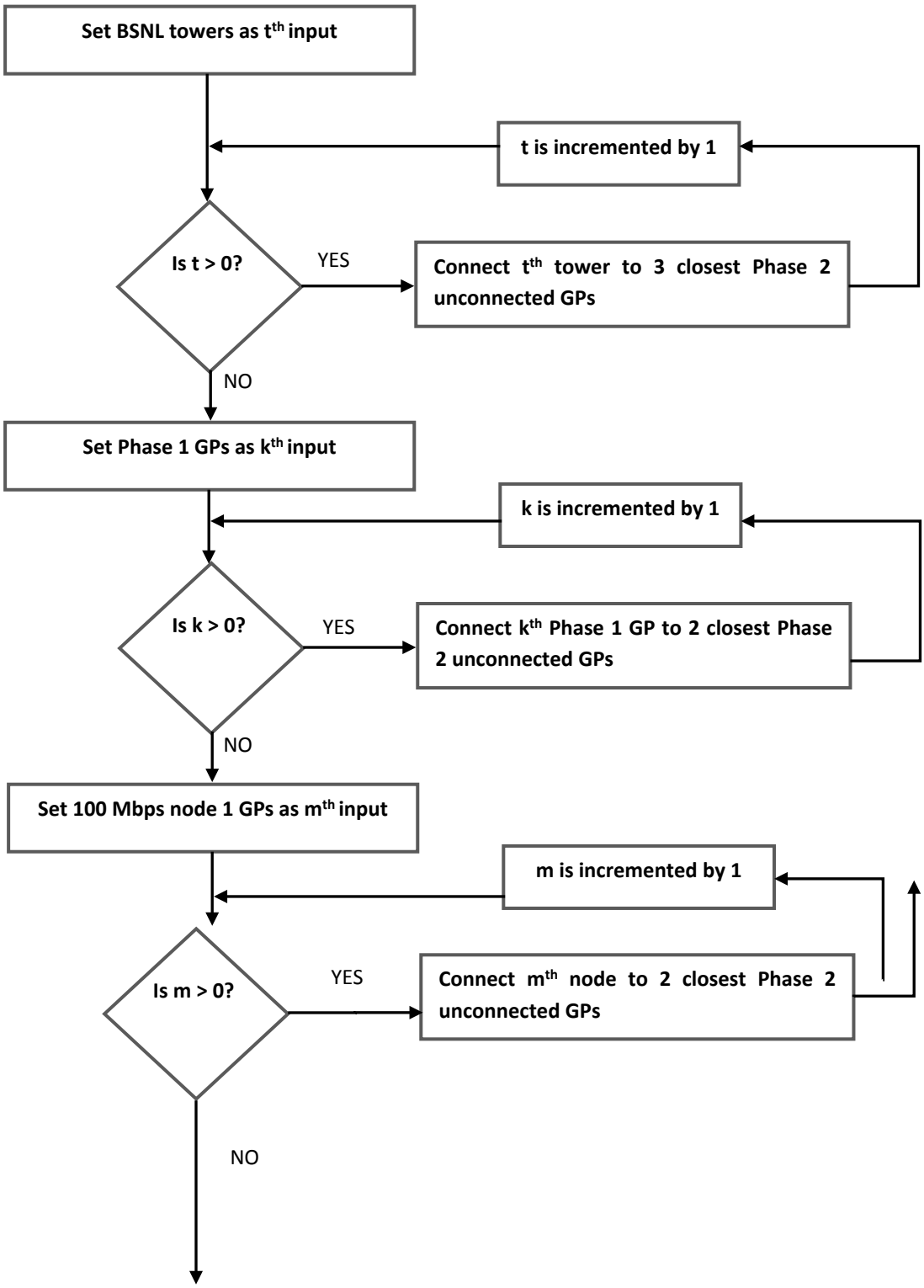
Step 12 - From remaining unconnected GPs, propose fibre connectivity to the GP with maximum population and create at most 2 wireless links from it.

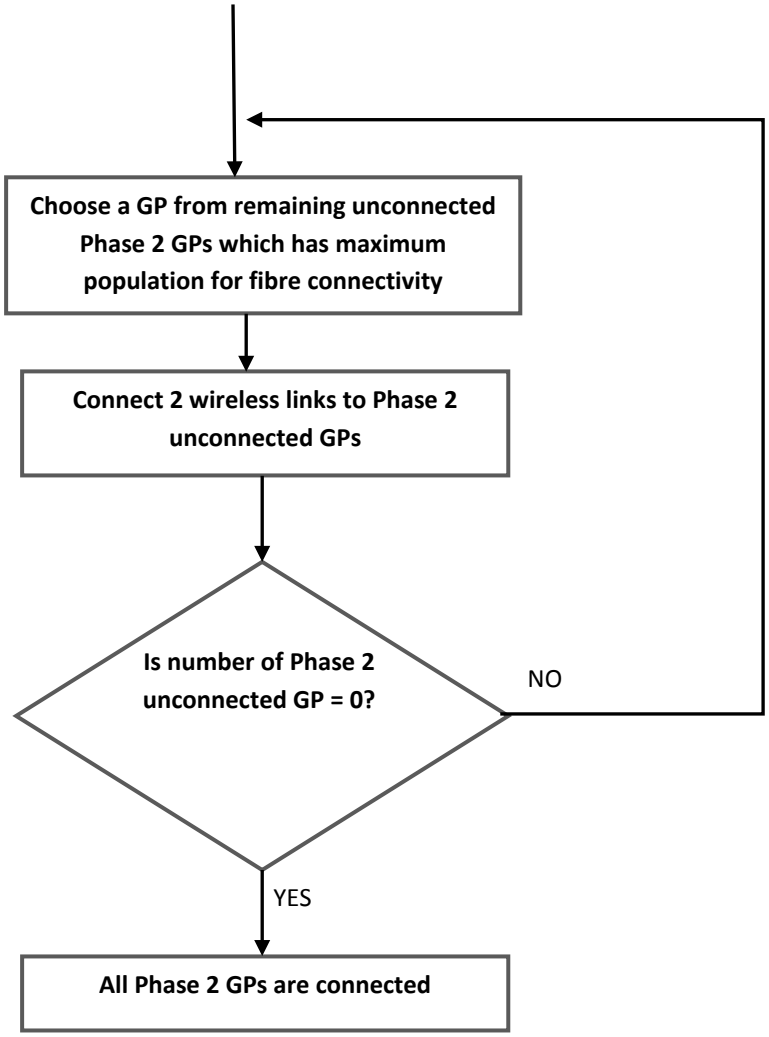
Step 13 - Repeat step 12 until all the Phase 2 GPs are connected.

5.4.1 Flowchart of processing of the tool




Is throughput requirement of ith GP > 100 Mbps?
YES
Suggest the GP for fibre connectivity
NO
Is ith GP within 300 m radius of a BSNL Tower?
YES
Suggest the GP for fibre connectivity
i is incremented by 1
NO
Set remaining Phase 2GP as jth input and perform Distance based filtering
Is jth GP within 5 km radius of BSNL Tower?
NO
Suggest the GP for satellite connectivity
YES
Perform RF filtering on jth GP
Is link feasible from BSNL Tower to jth GP?
NO
Suggest the GP for satellite connectivity
j is incremented by 1
YES


Set BSNL towers as t^th input
t is incremented by 1
Is t > 0?
YES
Connect t^th tower to 3 closest Phase 2 unconnected GPs
NO
Set Phase 1 GPs as k^th input
k is incremented by 1
Is k > 0?
YES
Connect k^th Phase 1 GP to 2 closest Phase 2 unconnected GPs
NO
Set 100 Mbps node 1 GPs as m^th input
m is incremented by 1
Is m > 0?
YES
Connect m^th node to 2 closest Phase 2 unconnected GPs
NO



5.5 Proposing Possible Satellite Sites

As per the *Report of the Committee on NOFN,*GPs with less than 150 households has been considered for satellite connectivity. However, IITB BharatNet Planning Tool recommends a slightly different design strategy for possible satellite sites. Satellite connectivity is recommended to those GPs which cannot be connected through wireless or wired possible means. It is suggested to give satellite connectivity in GPs which neither has throughput above 100 Mbps to qualify for fibre connectivity nor does it form a LoS wireless link with other connected GPs or block headquarter even with 15m tower at transmitter and/or receiver end.

Chapter 6
Results and Conclusion

6.1 Introduction

The primary outputs of the tool are network topology and bill of quantities. The network topology gives an insight to the wireless links that can be created from connected GP or BSNL Tower to unconnected GP. It also contains the throughput estimation and tower height required at the transmitter and receiver ends. Bill of quantities gives the estimated count of equipments/material/infrastructure required for establishment of wired and wireless links in a district. According to the input data received for the processing of the tool, States and Union Territories have been categorised as in following table.

Table 4: Categories of States/Union Territories of India as per the input data

States/UT completely covered in Phase 1	States/UT to be covered in Phase 2	Wrong/No input data received	Included with another State/UT
ANDAMAN & NICOBAR ISLANDS	ANDHRA PRADESH	GOA - No GP data	TELANGANA - included in Andhra Pradesh
CHANDIGARH	ARUNACHAL PRADESH	MANIPUR -No GP data	
HARYANA	ASSAM	MEGHALAYA - No Population Data	
KERALA	BIHAR	NCT OF DELHI - No GP data	
LAKSHADWEEP	CHHATTISGARH		
SIKKIM	DADRA & NAGAR HAVELI		
WEST BENGAL	DAMAN & DIU		
	GUJARAT		
	HIMACHAL PRADESH		
	JAMMU & KASHMIR		
	JHARKHAND		
	KARNATAKA		
	MADHYA PRADESH		
	MAHARASHTRA		
	MIZORAM		
	NAGALAND		
	ODISHA		
	PUDUCHERRY		
	PUNJAB		
	RAJASTHAN		
	TAMIL NADU		
	TRIPURA		
	UTTAR PRADESH		
	UTTARAKHAND		

The output of the Planning tool and bill of quantities are summarised in Table 5 (Part a & Part b) and Table 6 respectively.

6.2 Summary of the output

Table 5: Summary of the output of the IITB BharatNet Planning Tool

Part a

State Code	State/ Union Territory	Total no of GPs Processed (T)	Total no of GPs on Wireless (A)	Total no of GPs on Fibre (B)	Total no of GPs for Satellite Recommendations (C)	Total no of GPs wireless connection from Phase 1 & Towers (D)	Total no of GPs wireless connection from Phase 2 Fibre (E)	Wireless from existing BSNL tower (F)	Close to Tower (300m) * (G)	Total Fibre ** (H)
1	JAMMU & KASHMIR	1864	1012	713	139	291	721	179	15	852
2	HIMACHAL PRADESH	2961	1505	1167	289	754	751	733	85	1456
3	PUNJAB	6485	5023	1452	10	3246	1777	2302	264	1462
4	CHANDIGARH	0	0	0	0	0	0	0	0	0
5	UTTARAKHAND	5743	2955	2584	204	1007	1948	866	97	2788
6	HARYANA	0	0	0	0	0	0	0	0	0
7	NCT OF DELHI	0	0	0	0	0	0	0	0	0

8	**RAJASTHAN**	2072	1024	512	536	737	287	646	83	1048
9	**UTTAR PRADESH**	36987	24366	11631	990	6536	17830	2389	215	12621
10	**BIHAR**	1381	878	478	25	491	387	324	17	503
11	**SIKKIM**	0	0	0	0	0	0	0	0	0
12	**ARUNACHAL PRADESH**	1183	534	443	206	150	384	150	25	649
13	**NAGALAND**	1026	568	395	63	218	350	218	26	458
14	**MANIPUR**	0	0	0	0	0	0	0	0	0
15	**MIZORAM**	621	194	216	211	10	184	10	1	427
16	**TRIPURA**	383	252	115	16	178	74	176	15	131
17	**MEGHALAYA**	0	0	0	0	0	0	0	0	0
18	**ASSAM**	16	13	3	0	11	2	10	1	3
19	**WEST BENGAL**	0	0	0	0	0	0	0	0	0
20	**JHARKHAND**	2691	1573	906	212	832	741	831	125	1118

21	**ODISHA**	2340	1406	553	381	1117	289	1117	144	934
22	**CHHATTISGARH**	5398	3265	1778	355	1602	1663	1457	256	2133
23	**MADHYA PRADESH**	6283	4079	1876	328	2463	1616	2237	266	2204
24	**GUJARAT**	7977	5496	2320	161	3806	1690	3803	560	2481
25	**DAMAN & DIU**	17	6	10	1	0	6	0	0	11
26	**DADRA & NAGAR HAVELI**	12	2	2	8	0	2	0	0	10
27	**MAHARASHTRA**	7816	4255	2962	599	1469	2786	1258	202	3561
28	**ANDHRA PRADESH**	14447	8973	5084	390	4655	4318	4655	938	5474
29	**KARNATAKA**	465	206	120	139	117	89	16	1	259
30	**GOA**	0	0	0	0	0	0	0	0	0
31	**LAKSHADWEEP**	0	0	0	0	0	0	0	0	0
32	**KERALA**	0	0	0	0	0	0	0	0	0
33	**TAMIL NADU**	12251	8152	3933	166	4579	3573	4579	367	4099

34	**PUDUCHERRY**	97	52	45	0	0	52	0	0	45
35	**ANDAMAN & NICOBAR ISLANDS**	0	0	0	0	0	0	0	0	0
	TOTAL	**120516**	**75789**	**39298**	**5429**	**34269**	**41520**	**27956**	**3703**	**44727**

Part b

State Code	State/ Union Territory	Total No of GPs with 3,6,9 m height from Phase 1 & Tower (I)	Total No of GPs with 3,6,9 m height from Phase 1 (J)	Total No of GPs with 15 m height from Phase 1 (K)	Total No of GPs with 3,6,9 m height from BSNL Tower (L)	Total No of GPs with 15 m height from BSNL Tower (M)
1	**JAMMU & KASHMIR**	251	89	23	162	17
2	**HIMACHAL PRADESH**	666	17	4	649	84
3	**PUNJAB**	3169	872	72	2297	5
4	**CHANDIGARH**	0	0	0	0	0
5	**UTTARAKHAND**	875	108	33	767	99
6	**HARYANA**	0	0	0	0	0
7	**NCT OF DELHI**	0	0	0	0	0
8	**RAJASTHAN**	682	73	18	609	37
9	**UTTAR PRADESH**	6293	3909	238	2384	5

10	**BIHAR**	479	156	11	323	1
11	**SIKKIM**	0	0	0	0	0
12	**ARUNACHAL PRADESH**	130	0	0	130	20
13	**NAGALAND**	193	0	0	193	25
14	**MANIPUR**	0	0	0	0	0
15	**MIZORAM**	7	0	0	7	3
16	**TRIPURA**	164	2	0	162	14
17	**MEGHALAYA**	0	0	0	0	0
18	**ASSAM**	11	1	0	10	0
19	**WEST BENGAL**	0	0	0	0	0
20	**JHARKHAND**	784	1	0	783	48
21	**ODISHA**	1086	0	0	1086	31
22	**CHHATTISGARH**	1529	128	17	1401	56
23	**MADHYA PRADESH**	2288	173	53	2115	122
24	**GUJARAT**	3741	3	0	3738	65
25	**DAMAN & DIU**	0	0	0	0	0
26	**DADRA & NAGAR HAVELI**	0	0	0	0	0
27	**MAHARASHTRA**	1301	157	54	1144	114

28	**ANDHRA PRADESH**	4526	0	0	4526	129
29	**KARNATAKA**	87	72	29	15	1
30	**GOA**	0	0	0	0	0
31	**LAKSHADWEEP**	0	0	0	0	0
32	**KERALA**	0	0	0	0	0
33	**TAMIL NADU**	4437	0	0	4437	142
34	**PUDUCHERRY**	0	0	0	0	0
35	**ANDAMAN & NICOBAR ISLANDS**	0	0	0	0	0
	TOTAL	**32699**	**5761**	**552**	**26938**	**1018**

* Column G is currently fibre connected however these are within the range of 300 m of existing BSNL Towers

** Column His minimum total fibre length in km required to connect Phase 2 GPs which are recommended for Fibre connectivity

Column I represents Total No of GPs with 3,6,9 m height from Phase 1 & Tower

Column J represents Total No of GP's with 3,6,9 m height from Phase 1

Column K represents Total No of GP's with 15 m height from Phase 1

Column L represents Total No of GP's with 3,6,9 m height from Existing BSNL Tower

Column M represents Total No of GP's with 15 m height from Existing BSNL Tower

Table Description

Total no. of GPs Processed (T) – It is the total number of GPs which has been examined to determine wireless link feasibility, fibre connectivity requirement and satellite recommendations. These GPs are input to IITB BharatNet Planning Tool.

Total no. of GPs on Wireless (A) – Out of total number of GPs processed 'T', 'A' is the total number of GPs to be connected on wireless links. This is the sum of the number of GPs connected from Phase I GPs in the same district in addition to connectivity from BSNL Towers (D) and Phase 2 GPs proposed to be connected with fibre (E).

Total no. of GPs on Fibre (B) – Out of total number of GPs processed 'T', 'B' is the total number of GPs that can be connected via fibre as the throughput requirement of the GPs is more than 100 Mbps.

Total no. of GPs for Satellite Recommendations (C) – Out of total number of GPs processed 'T', 'C' is the number of GPs which are recommended for satellite connectivity as these GPs have difficult terrain (refer section 5.5 : Proposing Possible Satellite Sites)

GPs with wireless connection from Phase I GPs & Towers (D) – It is the sum of the total number of GPs which can be connected from Phase 1's connected GPs and existing BSNL Tower.

GPs with wireless connection from Phase 2 Fibre (E) – It is the total number of GPs which can be connected wirelessly from fibre connected Phase 2 GPs. It is the number of feasible wireless links which may change depending on the route of the fibre to be laid in Phase 2 of BharatNet project. These links can be reassessed after the fibre planning of Phase 2 GPs.

Wireless from existing BSNL tower (F) – It is the number of GPs connected from the existing BSNL towers at varying heights of 3m, 6m, 9 m and 15 m respectively. These links are proposed to be easier and faster to implement.

Close to Tower (300m)(G) – It is the number of GPs which lies within 300 m radius of the existing BSNL towers and are proposed to be served through fibre. Similar to wireless links from existing BSNL towers, these links are also easily achievable.

Total Fibre (km) (H) – It is the minimum length of fibre required to be laid in the Phase 2 of BharatNet for that state. However, depending on the technology used the fibre length may increase. This gives a gross estimate of minimum fibre needed.

Total no. of GPs with 3,6,9 m height from Phase I & Tower (I) - It is the total number of GPs which can be connected wirelessly from Phase I GPs or existing BSNL towers using 3 m, 6 m and 9 m height towers only.

Total no. of GPs with 3,6,9 m height from Phase I (J) - It is the total number of GPs connected wireless from Phase I GPs using 3 m, 6 m and 9 m height towers only.

Total no. of GPs with 15 m height from Phase I (K) - It is the total number of GPs connected wireless from Phase I GPs using 15 m height towers only.

Total no. of GPs with 3,6,9 m height from BSNL Tower (L) - It is the total number of GPs connected wireless from BSNL towers using 3 m, 6 m and 9 m height towers only.

Total no. of GPs with 15 m height from BSNL Tower (M) - It is the total number of GPs connected wireless from BSNL towers using 15 m height towers only.

6.3 Summary of State-wise Bill of quantities

Table 6: Summary of State-wise Bill of quantities

State Code	State/ Union Territory	15 m Tower	9 m Tower	6m Tower	3 m Tower	802.11ac 5.8 GHz Device	CAT6 cable (m)	Optical fibre (Km)	Solar Panel	Switches	Battery Capacity (50A 24V)
1	JAMMU & KASHMIR	99	76	115	242	532	3155	3382.741	532	532	532
2	HIMACHAL PRADESH	161	107	111	518	897	5290	4732.112	897	897	897
3	PUNJAB	491	483	1339	2236	4549	25200	3573.001	4549	4549	4549
5	UTTARAKHAND	186	131	147	537	1001	5935	6480.486	1001	1001	1001
8	RAJASTHAN	182	107	229	455	973	5775	7409.943	973	973	973
9	UTTAR PRADESH	737	1960	5106	5404	13207	69720	67587.9	13207	13207	13207
10	BIHAR	115	166	432	383	1096	6055	2907.106	1096	1096	1096
12	ARUNACHAL PRADESH	38	22	30	95	185	1115	2563.124	185	185	185
13	NAGALAND	58	28	39	174	299	1785	1800.994	299	299	299
15	MIZORAM	4	1	2	9	16	100	2088.587	16	16	16
16	TRIPURA	59	50	51	119	279	1690	794.581	279	279	279
18	ASSAM	3	2	6	7	18	105	5.396	18	18	18

20	**JHARKHAND**	198	204	308	552	1262	7300	37254.52	1262	1262	1262
21	**ODISHA**	165	113	120	529	927	5460	5161.645	927	927	927
22	**CHHATTISGARH**	291	208	393	1054	1946	11185	12570.7	1946	1946	1946
23	**MADHYA PRADESH**	529	370	607	1574	3080	18045	9860.355	3080	3080	3080
24	**GUJARAT**	446	163	443	1888	2940	16930	6049.935	2940	2940	2940
25	**DAMAN & DIU**	3	4	3	0	10	65	25.583	10	10	10
26	**DADRA & NAGAR HAVELI**	1	3	0	0	4	25	61.138	4	4	4
27	**MAHARASHTRA**	353	331	370	847	1901	11270	41898.46	1901	1901	1901
28	**ANDHRA PRADESH**	848	503	1049	4112	6512	36800	12182.26	6512	6512	6512
29	**KARNATAKA**	49	45	66	83	243	1460	1742.513	243	243	243
33	**TAMIL NADU**	645	496	1206	2756	5103	28740	9956.642	5103	5103	5103
34	**PUDUCHERRY**	0	13	35	26	74	370	132.002	74	74	74
	TOTAL	4924	3626	7101	18196	33847	193855	172633.8	33847	33847	33847

Annexure

Table Description

- **Total**- Total no. of Phase 2 GP's + Towers
- **Phase 1 GPs**- Total no. of GPs already connected in Phase 1 of BharatNet
- **Phase 2 GPs**- Total no. of unconnected GPs which will be connected in Phase 2 of BharatNet
- **Wireless from Phase 1**- Total no. of wireless links formed between Phase 1 GPs and unconnected Phase 2 GPs
- **Wireless from Tower**-Total no. of wireless links formed between existing BSNL towers and unconnected Phase 2 GPs
- **Close to Tower (300m)**- Total no. of GPs within 300 m radius of an existing BSNL tower
- **New ONTs**- It is the sum of New ONT (100Mb+), wireless from New ONT (100Mb+) and new ONTs to be formed.
- **Wireless from New ONTs**- Total no. of wireless links created from newly created ONTs to unconnected GPs
- **Total Fibre**- It is the minimum length of fibre required to connect all the Phase 2 GPs
- **Total wireless connected**- Total no. of wireless links formed to Phase 2 unconnected GPs
- **Satellite recommendations**- Total no. of GPs in Phase 2 for which satellite links can be formed

Andhra Pradesh

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
540	WARANGAL	1144	251	947	0	375	54	354	164	319	628	20
542	SRIKAKULAM	1279	257	1093	0	474	71	285	263	324	769	13
543	VIZIANAGARAM	1132	280	918	0	455	66	223	174	268	650	34
545	EAST GODAVARI	1194	327	948	0	407	81	415	45	396	552	57
546	WEST GODAVARI	1103	298	868	0	454	63	305	46	265	603	12

547	KRISHNA	1221	357	942	0	480	78	256	128	265	677	2
548	GUNTUR	1264	392	986	0	401	114	438	33	395	591	11
550	SPSR NELLORE	1113	245	937	0	376	69	292	200	309	628	9
552	KURNOOL	1088	424	836	0	387	172	211	66	358	478	28
553	ANANTAPUR	1204	327	962	0	319	85	401	157	426	536	71
554	CHITTOOR	1591	357	1319	0	527	85	437	270	454	865	39

Arunachal Pradesh

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
245	TAWANG	91	13	82	0	25	4	29	24	33	49	3
246	WEST KAMENG	122	28	97	0	21	3	58	15	61	36	30
247	EAST KAMENG	112	3	110	0	2	1	73	34	74	36	34
249	LOWER SUBANSIRI	164	15	153	0	20	4	67	62	71	82	17

250	KURUNG KUMEY	169	8	165	0	10	4	98	53	102	63	22
251	UPPER SUBANSIRI	99	8	93	0	7	2	64	20	66	27	31
254	UPPER SIANG	68	5	64	0	5	1	37	21	38	26	17
255	DIBANG VALLEY	22	0	22	0	0	0	19	3	19	3	13
256	LOWER DIBANG VALLEY	59	3	57	0	5	1	28	23	29	28	8
257	LOHIT	145	13	133	0	26	1	48	58	49	84	4
259	CHANGLANG	111	10	104	0	17	3	46	38	49	55	9
260	TIRAP	111	9	103	0	12	1	57	33	58	45	18

Assam

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300 m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
305	NAGAON	206	191	16	1	10	1	4	0	3	13	0

Bihar

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
203	PASHCHIM CHAMPARAN	333	266	69	8	13	2	41	17	28	41	3
204	PURBI CHAMPARAN	468	321	148	11	40	1	50	7	59	89	7
207	MADHUBANI	469	340	132	8	50	3	27	5	55	77	2
209	ARARIA	230	101	129	19	12	0	57	12	56	73	1
212	KATIHAR	275	237	39	8	17	1	7	3	10	29	0
213	MADHEPURA	200	165	38	3	19	3	1	0	16	22	0
215	DARBHANGA	394	277	118	11	41	1	41	5	38	80	2

217	GOPALGANJ	251	93	158	12	12	0	117	51	57	101	0
221	SAMASTIPUR	436	408	30	1	13	2	8	3	10	20	0
224	BHAGALPUR	309	300	10	0	3	1	1	0	7	3	1
229	NALANDA	284	157	127	22	40	0	41	6	37	90	0
230	PATNA	449	374	75	15	21	0	29	9	18	57	0
231	BHOJPUR	227	174	54	20	8	1	18	4	14	40	1
235	JEHANABAD	103	86	17	5	3	0	8	4	4	13	0
236	ARWAL	68	43	26	4	9	1	6	1	8	18	0
238	GAYA	348	138	211	20	23	1	125	26	86	125	8

Chhattisgarh

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300 m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
400	KORIYA	147	74	77	0	11	4	42	20	46	31	13
401	SURGUJA	398	57	354	0	77	13	127	137	140	214	11

402	JASHPUR	479	149	336	6	105	6	140	79	146	190	51
403	RAIGARH	798	182	627	7	197	11	217	195	228	399	30
404	KORBA	408	110	301	16	58	3	127	97	128	173	36
405	JANJGIR-CHAMPA	532	125	411	32	94	4	123	158	122	289	2
406	BILASPUR	633	145	512	5	190	24	152	141	170	342	10
407	KABIRDHAM	325	119	212	2	61	6	82	61	88	124	16
408	RAJNANDGAON	755	152	625	2	199	22	191	211	213	412	20
409	DURG	374	220	165	0	91	11	31	32	42	123	0
410	RAIPUR	484	197	292	9	99	5	78	101	79	213	0
411	MAHASAMUND	513	126	390	15	64	3	142	166	145	245	4
412	DHAMTARI	378	146	234	34	64	2	74	60	76	158	16
413	KANKER	423	115	332	5	68	24	135	100	159	173	27
414	BASTAR	365	125	293	9	62	53	111	58	164	129	44

415	NARAYANPUR	75	51	24	3	0	0	19	2	19	5	13
416	DANTEWADA	117	74	103	0	7	60	32	4	92	11	21
417	BIJAPUR	152	47	110	0	10	5	71	24	76	34	41

Dadara and Nagar Haveli

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300 m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
496	Dadara and Nagar Haveli	12	0	12	0	0	0	12	0	10	2	8

Daman and Diu

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300 m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
494	DIU	5	0	5	0	0	0	5	0	4	1	1
495	DAMAN	12	0	12	0	0	0	12	0	7	5	0

Gujarat

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300 m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
474	AHMEDABAD	795	326	505	0	209	36	151	109	165	340	1
475	SURENDRANAGAR	1136	320	869	0	406	53	218	192	255	614	14
476	RAJKOT	1135	352	835	0	422	52	218	143	252	583	7
479	JUNAGADH	1015	254	823	0	399	62	207	155	234	589	3
486	VADODARA	810	290	562	0	295	42	134	91	154	408	2
491	VALSAD	514	163	374	0	190	23	112	49	124	250	20
492	SURAT	812	212	646	0	308	46	160	132	202	444	4
493	TAPI	310	50	267	0	90	7	90	80	89	178	8

Himachal Pradesh

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
23	CHAMBA	300	20	283	0	38	3	173	69	176	107	45

24	KANGRA	847	110	761	0	213	24	281	243	303	458	27
25	LAHAUL AND SPITI	49	11	41	0	11	3	25	2	28	13	19
26	KULLU	260	75	202	0	78	17	83	24	95	107	10
27	MANDI	533	113	429	2	92	9	237	89	227	202	42
28	HAMIRPUR	264	208	56	15	24	0	10	7	10	46	0
29	UNA	263	33	235	0	65	5	83	82	87	148	6
30	BILASPUR	171	21	151	0	34	1	74	42	73	78	16
31	SOLAN	253	118	142	4	37	7	73	21	80	62	20
32	SIRMAUR	249	25	227	0	35	3	132	57	135	92	44
33	SHIMLA	460	98	372	0	93	10	192	77	198	174	41
34	KINNAUR	73	14	62	0	13	3	41	5	44	18	19

Jammu & Kashmir

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
1	KUPWARA	326	42	290	20	12	6	183	69	135	155	6

2	BADGAM	294	49	245	7	14	0	122	102	106	139	5
7	KATHUA (HIRANAGAR)	202	43	159	0	9	0	89	61	89	70	22
8	BARAMULLA	385	147	242	39	28	4	91	80	95	147	7
9	BANDIPORA	138	68	70	0	4	0	37	29	37	33	13
11	GANDERBAL	109	31	80	16	13	2	39	10	32	48	4
12	PULWAMA	193	7	186	0	21	0	115	50	111	75	42
14	ANANTNAG	252	43	210	11	27	1	81	90	82	128	5
15	KULGAM	170	20	150	13	9	0	55	73	55	95	3
21	KATHUA	367	218	149	0	9	0	91	49	85	64	27
22	SAMBA	130	49	83	6	33	2	25	17	25	58	5

Jharkhand

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
346	GARHWA	234	29	212	0	48	7	107	50	96	116	22
347	CHATRA	191	36	158	0	45	3	68	42	69	89	19

348	KODERMA	134	134	0	0	0	0	0	0	0	0	0
349	GIRIDIH	207	32	179	0	59	4	76	40	68	111	6
350	DEOGHAR	238	237	1	0	1	0	0	0	0	1	0
351	GODDA	233	31	208	1	53	6	86	62	72	136	3
352	SAHEBGANJ	183	183	0	0	0	0	0	0	0	0	0
353	PAKUR	142	14	134	0	19	6	75	34	60	74	6
354	DHANBAD	374	129	255	0	144	10	74	27	66	189	3
355	BOKARO	299	299	0	0	0	0	0	0	0	0	0
356	LOHARDAGA	81	22	64	0	34	5	15	10	19	45	2
357	EAST SINGHBUM	342	134	230	0	107	22	70	31	87	143	6
358	PALAMU	344	53	303	0	67	12	131	93	123	180	13
359	LATEHAR	138	26	120	0	29	8	51	32	58	62	16
360	HAZARIBAGH	333	333	0	0	0	0	0	0	0	0	0
361	RAMGARH	173	173	0	0	0	0	0	0	0	0	0
362	DUMKA	250	44	215	0	57	9	86	63	95	120	20

363	JAMTARA	135	14	124	0	26	3	46	49	49	75	4
364	RANCHI	490	490	0	0	0	0	0	0	0	0	0
365	KHUNTI	96	22	80	0	23	6	39	12	45	35	17
366	GUMLA	194	44	162	0	44	12	78	28	89	73	32
367	SIMDEGA	117	20	104	0	19	7	67	11	67	37	34
368	WEST SINGHBHUM	232	95	142	0	56	5	51	30	55	87	9
369	SARAIKELAKHAR SAWAN	234	29	212	0	48	7	107	50	96	116	22

Karnataka

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
555	BELGAUM	511	395	116	26	0	0	73	17	63	53	33
557	BIJAPUR	201	177	24	8	0	0	14	2	14	10	10
560	KOPPAL	149	149	0	0	0	0	0	0	0	0	0
561	GADAG	110	48	62	2	3	0	45	12	42	20	22

562	DHARWAD	162	104	58	7	2	0	34	15	28	30	12
563	UTTARA-KANNAD	115	75	40	0	2	0	33	5	30	10	14
565	BELLARY	218	216	2	1	0	0	1	0	1	1	1
567	DAVANGERE	243	189	54	22	0	0	24	8	24	30	9
569	UDUPI	157	131	26	18	1	0	7	0	7	19	2
570	CHIKMAGALUR	203	202	1	1	0	0	0	0	0	1	0
575	DAKSHINA KANNAD	146	137	10	1	2	1	6	0	7	3	4
576	KODAGU	106	106	0	0	0	0	0	0	0	0	0
578	CHAMARAJANAGAR	121	119	2	2	0	0	0	0	0	2	0
579	GULBARGA	241	208	33	7	3	0	21	2	21	12	18
580	YADGIR	112	75	37	6	3	0	23	5	22	15	14

Madhya Pradesh

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
418	SHEOPUR	452	144	318	4	86	10	111	107	121	197	15
419	MORENA	388	387	1	0	1	0	0	0	0	1	0
420	BHIND	393	187	208	6	86	2	73	41	73	135	13
421	GWALIOR	81	42	40	5	13	1	15	6	16	24	3
422	DATIA	410	249	164	4	58	3	56	43	59	105	15
423	SHIVPURI	950	374	605	10	235	29	228	103	254	351	85
425	CHHATARPUR	787	403	399	8	195	15	107	74	120	279	15
429	SATNA	803	349	467	17	197	13	125	115	131	336	16
430	REWA	724	382	353	12	95	11	138	97	144	209	22
431	UMARIA	263	135	131	6	46	3	54	22	55	76	22
432	NEEMUCH	168	165	3	0	2	0	1	0	1	2	1
433	MANDSAUR	539	341	243	5	112	45	44	37	87	156	0

434	RATLAM	517	364	154	5	51	1	52	45	53	101	4
436	SHAJAPUR	489	199	296	8	110	6	80	92	86	210	3
441	BARWANI	350	273	78	0	44	1	18	15	19	59	0
446	RAISEN	334	217	120	0	18	3	56	43	59	61	16
450	KATNI	303	118	190	3	88	5	57	37	61	129	13
451	JABALPUR	747	370	383	37	63	6	141	136	143	240	24
452	NARSINGHPUR	298	240	75	0	44	17	12	2	29	46	5
454	MANDLA	312	157	155	18	26	0	53	58	53	102	1
455	CHHINDWARA	581	412	175	6	85	6	47	31	52	123	5
456	SEONI	330	191	176	0	75	37	38	26	75	101	5
457	BALAGHAT	520	121	406	15	153	7	121	110	111	295	0
458	GUNA	555	147	420	17	149	12	143	99	128	292	5
460	SHAHDOL	173	87	88	6	8	2	41	31	41	47	4
461	ANUPPUR	305	161	164	3	68	20	45	28	65	99	8
465	ALIRAJPUR	682	399	293	23	93	10	90	77	98	195	17

466	KHANDWA (EAST NIMAR)	84	9	76	0	15	1	26	34	27	49	0
467	BURHANPUR	380	278	102	8	21	0	45	28	43	59	11

Maharashtra

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
497	NANDURBAR	551	296	256	2	17	1	119	117	114	142	24
498	DHULE	621	312	309	3	15	0	180	111	151	158	20
499	JALGAON	1339	732	627	44	117	20	248	198	221	406	12
501	AKOLA	430	185	246	11	28	1	110	96	96	150	8
503	AMRAVATI	462	403	59	6	6	0	27	20	22	37	3
516	NASHIK	1304	686	641	11	63	23	329	215	326	315	47
517	THANE	1022	523	503	18	71	4	246	164	241	262	47
520	RAIGAD	822	358	467	47	73	3	237	107	216	251	30
521	PUNE	1450	755	707	2	82	12	362	249	340	367	43

522	AHMEDNAGAR	1445	558	903	4	86	16	503	294	466	437	120
523	BEED	1093	415	691	14	69	13	312	283	309	382	38
527	SATARA	1457	693	769	13	52	5	365	334	348	421	24
528	RATNAGIRI	970	524	464	19	78	18	256	93	270	194	98
530	KOLHAPUR	1271	897	387	11	87	13	161	115	164	223	32
531	SANGLI	937	783	170	6	76	16	49	23	64	106	12

Mizoram

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
281	MAMIT	83	5	78	0	1	0	60	17	60	18	42
282	KOLASIB	44	1	43	0	3	0	32	8	32	11	19
283	AIZAWL	125	28	98	0	6	1	63	28	64	34	24
284	CHAMPHAI	92	0	92	0	0	0	67	25	67	25	39

285	SERCHHIP	33	0	33	0	0	0	25	8	25	8	15
286	LUNGLEI	103	0	103	0	0	0	78	25	78	25	41
287	LAWNGTLAI	100	0	100	0	0	0	64	36	64	36	25
288	SAIHA	74	0	74	0	0	0	37	37	37	37	6

Nagaland

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
261	MON	90	9	83	0	9	2	44	28	45	38	8
262	TUENSANG	85	8	79	0	10	2	39	28	41	38	6
263	LONGLENG	33	3	30	0	4	0	13	13	13	17	0
264	KIPHIRE	70	2	68	0	4	0	37	27	35	33	3
265	MOKOKCHUNG	88	20	71	0	26	3	26	16	29	42	8
266	ZUNHEBOTO	173	14	160	0	13	1	78	68	75	85	6

267	WOKHA	131	18	118	0	21	5	50	42	53	65	5
268	DIMAPUR	234	41	198	0	74	5	52	67	57	141	4
269	KOHIMA	99	23	80	0	27	4	34	15	38	42	9
270	PEREN	82	15	69	0	11	2	53	3	40	29	9
271	PHEK	81	13	70	0	19	2	30	19	32	38	5

Odisha

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
370	BARGARH	308	69	247	0	105	8	83	51	86	161	14
371	JHARSUGUDA	113	45	73	0	52	5	13	3	17	56	2
372	SAMBALPUR	237	105	147	0	71	15	48	13	63	84	27
373	DEOGARH	78	78	0	0	0	0	0	0	0	0	0
374	SUNDARGARH	434	197	262	0	144	25	77	16	102	160	46

378	BHADRAK	280	107	194	0	136	21	25	12	44	150	0
382	JAJPUR	400	137	279	0	197	16	41	25	50	229	1
384	ANUGUL	298	98	208	0	115	8	63	22	71	137	22
393	BALANGIR	353	87	282	0	126	16	84	56	100	182	20
396	RAYAGADA	214	56	171	0	51	13	97	10	110	61	72
397	NABARANGPUR	171	26	151	0	38	6	74	33	79	72	26
398	KORAPUT	287	72	225	0	56	10	136	23	146	79	101
399	MALKANGIRI	118	18	101	0	26	1	65	9	66	35	50

Puducherry

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
635	PONDICHERRY	70	0	70	0	0	0	65	5	35	35	0
637	KARAIKAL	27	0	27	0	0	0	27	0	10	17	0

Punjab

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
35	GURDASPUR	1625	624	1004	365	46	3	274	316	228	776	1
36	KAPURTHALA	664	311	374	14	166	21	73	100	88	286	0
37	JALANDHAR	1116	698	434	60	180	16	79	99	83	351	0
38	HOSHIARPUR	1531	855	700	151	231	24	123	171	147	553	3
39	NAWANSHAHR	553	310	264	7	133	21	41	62	62	202	0
40	FATEHGARH SAHIB	562	403	166	22	90	7	18	29	25	141	0
41	LUDHIANA	1075	705	388	50	173	18	76	71	85	303	0
42	MOGA	399	118	297	2	113	16	97	69	88	209	0
43	FIROZPUR	817	200	634	48	151	17	165	253	170	464	0
44	MUKTSAR	330	173	169	6	80	12	57	14	53	116	4
45	FARIDKOT	241	159	88	7	39	6	16	20	22	66	0
46	BATHINDA	447	288	184	3	125	25	27	4	44	140	0

47	MANSA	321	287	38	4	24	4	3	3	7	31	0
48	PATIALA	1146	539	639	38	287	32	114	168	140	499	0
49	AMRITSAR	948	456	507	99	173	15	126	94	103	404	1
50	TARN TARAN	602	311	304	55	100	13	76	60	69	235	0
52	S.A.S NAGAR	359	217	145	6	83	3	27	26	25	120	1
53	SANGRUR	723	640	88	5	63	5	11	1	10	10	0
54	BARNALA	217	161	62	2	45	6	6	24	41	52	0

Rajasthan

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
100	HANUMANGARH	340	308	34	1	4	2	23	4	25	9	20
102	CHURU	341	300	48	0	11	7	30	0	37	11	29
104	ALWAR	626	533	96	5	47	3	29	12	30	66	5
105	BHARATPUR	443	367	77	11	32	1	21	12	17	60	0

106	DHOLPUR	166	104	64	7	13	2	27	15	29	35	10
107	KARAULI	292	195	100	2	31	3	49	15	52	48	22
108	SAWAI MADHOPUR	275	240	36	1	23	1	7	4	8	28	1
111	SIKAR	455	385	73	4	37	3	24	5	26	47	9
112	NAGAUR	608	464	152	4	46	8	80	14	82	70	36
113	JODHPUR	527	422	110	0	35	5	64	6	69	41	54
114	JAISALMER	180	133	49	0	7	2	40	0	42	7	39
115	BARMER	487	305	191	0	42	9	133	7	142	49	123
116	JALORE	324	213	120	6	26	9	62	17	68	52	26
118	PALI	427	350	81	4	21	4	45	7	48	33	31
119	AJMER	452	424	30	4	16	2	7	1	9	21	3
120	TONK	297	267	31	0	13	1	13	4	14	17	8
122	BHILWARA	390	299	95	5	39	4	34	13	38	57	10
123	RAJSAMAND	265	246	20	0	9	1	9	1	10	10	5

124	DUNGARPUR	276	185	93	5	21	2	41	24	41	52	9
125	BANSWARA	293	192	102	7	19	1	44	31	45	57	9
126	CHITTORGARH	364	305	61	3	28	2	23	5	25	36	14
128	BARAN	279	222	61	6	18	4	28	5	32	29	13
129	JHALAWAR	302	220	84	10	19	2	38	15	39	45	13
130	UDAIPUR	604	445	162	4	58	3	69	28	71	91	31
131	PRATAPGARH	156	56	102	2	31	2	47	20	49	53	16

Tamil Nadu

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
602	THIRUVALLUR	539	14	525	0	6	0	313	206	201	324	2
604	KANCHIPURAM	654	19	635	0	21	0	326	288	249	386	2
606	DHARMAPURI	377	137	249	0	147	9	63	30	63	186	8
607	KRISHNAGIRI	500	183	334	0	170	17	104	43	102	232	10
608	TIRUVANNAMA	985	157	849	0	258	21	482	88	259	590	5

	LAI											
613	KOTAGIRI	92	65	29	0	11	2	15	1	17	12	10
614	COIMBATORE	527	326	208	0	114	7	63	24	54	154	3
616	DINDIGUL	496	193	317	0	154	14	115	34	110	207	30
617	KARUR	329	181	158	0	80	10	50	18	53	105	4
618	TIRUCHIRAPPALLI	582	241	355	0	134	14	172	35	123	232	5
619	PERAMBALUR	349	196	166	0	78	13	38	37	50	116	1
620	ARIYALUR	302	108	198	0	68	4	90	36	60	138	0
621	CUDDALORE	961	295	679	0	274	13	216	176	172	507	0
623	THIRUVARUR	628	207	428	0	204	7	169	48	101	327	0
624	THANJAVUR	861	284	588	0	174	11	403	0	322	266	0
625	PUDUKKOTTAI	746	270	497	0	195	21	246	35	159	338	1
627	MADURAI	624	200	431	0	182	7	125	117	111	320	2
628	THENI	193	68	132	0	63	7	53	9	48	84	6
629	VIRUDHUNAGA	598	162	457	0	109	21	327	0	279	178	2

	R											
630	RAMANATHAPURAM	546	119	446	0	161	19	187	79	138	308	1
631	TUTICORIN	605	209	413	0	194	17	130	72	119	294	1
633	KANNIYAKUMARI	300	203	101	0	62	4	29	6	29	72	3

Tripura

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
289	WEST TRIPURA	114	27	91	0	33	4	49	5	40	51	6
290	SOUTH TRIPURA	68	27	46	0	30	5	10	1	15	31	2
291	DHALAI	197	52	148	0	63	3	75	7	46	102	1
292	NORTH TRIPURA	150	55	98	2	50	3	32	11	30	68	7

Uttar Pradesh

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
132	SAHARANPUR	820	445	380	32	18	5	140	185	125	255	0
133	MUZAFFARNAGAR	785	496	290	35	45	1	162	47	134	156	48
134	BIJNOR	1050	773	279	37	40	2	89	111	77	202	1
135	MORADABAD	840	403	438	52	8	1	200	177	145	293	6
136	RAMPUR	593	429	166	45	46	2	34	39	32	134	1
137	JYOTIBA PHULE NAGAR	501	134	368	22	31	1	159	155	129	239	11
138	MEERUT	528	281	249	15	69	2	121	42	89	160	26
139	BAGHPAT	296	231	66	15	23	1	20	7	17	49	2
140	GHAZIABAD	258	145	113	25	10	0	41	37	32	81	0
142	BULANDSHAHR	936	527	413	91	77	4	129	112	98	315	0
143	ALIGARH	944	511	434	111	74	1	129	119	96	338	0
144	MAHAMAYA NAGAR	466	314	153	36	16	1	45	55	43	110	2
145	MATHURA	538	339	208	23	36	9	88	52	70	138	6

146	AGRA	671	340	333	23	34	2	170	104	123	210	7
147	FIROZABAD	553	339	216	27	30	2	76	81	62	154	1
148	MAINPURI	557	394	163	52	37	0	50	24	32	131	0
149	BUDAUN	1133	673	464	95	89	4	123	153	112	352	4
150	BAREILLY	1040	511	533	88	87	4	163	191	147	386	8
151	PILIBHIT	590	304	286	36	29	0	110	111	95	191	7
152	SHAHJAHANPUR	897	525	378	82	23	6	110	157	112	266	0
153	KHERI	1566	540	1038	142	62	12	519	303	363	675	22
156	UNNAO	1448	524	938	198	139	14	297	290	246	692	6
158	RAE BARELI	567	453	114	0	0	0	50	64	42	72	0
159	FARRUKHABAD	756	326	436	48	36	6	157	189	135	301	0
160	KANNAUJ	815	95	726	38	15	6	336	331	272	454	24
161	ETAWAH	460	423	37	5	4	0	14	14	13	24	0
162	AURAIYA	464	130	336	40	37	2	115	142	101	235	0
163	KANPUR DEHAT	900	216	684	149	91	0	264	180	230	454	56

164	KANPUR NAGAR	622	230	392	74	38	0	161	119	143	249	28
165	JALAUN	782	384	404	37	25	6	166	170	156	248	8
166	JHANSI	757	197	564	27	12	4	277	244	245	319	26
167	LALITPUR	538	176	364	33	17	2	171	141	149	215	20
169	MAHOBA	338	230	112	13	15	4	41	39	43	69	2
170	BANDA	565	413	152	22	12	0	70	48	51	101	0
171	CHITRAKOOT	415	301	114	15	9	0	74	16	47	67	6
172	FATEHPUR	1285	359	934	83	30	8	424	389	382	552	22
173	PRATAPGARH	1738	626	1132	268	141	20	299	404	292	840	2
174	KAUSHAMBI	703	155	552	33	14	4	228	273	192	360	2
175	ALLAHABAD	515	427	88	0	2	0	47	39	35	53	0
176	BARABANKI	1050	546	508	111	62	4	158	173	137	371	6
178	AMBEDKAR NAGAR	750	388	364	39	30	2	125	168	109	255	6
180	BAHRAICH	1509	361	1148	95	31	0	514	508	392	756	4
181	SHRAVASTI	542	156	388	61	13	2	134	178	124	264	0

182	BALRAMPUR	1190	166	1026	66	9	2	482	467	442	584	86
183	GONDA	1877	305	1582	176	59	10	608	729	516	1066	14
184	SIDDHARTH NAGAR	1969	59	1910	59	13	0	715	1123	647	1263	0
189	KUSHI NAGAR	1879	75	1806	36	14	2	884	870	632	1174	16
190	DEORIA	1451	517	934	164	77	0	335	358	307	627	50
193	BALLIA	1203	473	734	16	14	4	330	370	262	472	16
194	JAUNPUR	1939	601	1338	87	38	0	492	721	428	910	4
195	GHAZIPUR	1756	416	1344	202	83	4	548	507	408	936	16
196	CHANDAULI	1175	95	1080	44	20	0	457	559	393	687	16
198	SANT RAVIDAS NAGAR	809	109	700	58	36	0	269	337	221	479	2
199	MIRZAPUR	1280	344	940	37	34	4	508	357	466	474	184
200	SONBHADRA	957	53	904	19	11	0	575	299	497	407	150
201	ETAH	578	409	171	40	35	2	46	48	38	133	0
202	KANSHIRAM NAGAR	422	190	233	76	44	1	55	57	51	182	0

Uttarakhand

District Code	District Name	Total	Phase 1 GPs	Phase 2 GPs	Wireless from Phase 1	Wireless from tower	Close to Tower(300m)	New ONTs	Wireless from New ONTs	Total Fibre (km)	Total Wireless connected	Satellite recommendations
56	UTTAR KASHI	505	112	411	0	70	18	194	129	212	199	18
57	CHAMOLI	626	46	589	0	74	9	288	218	295	294	20
58	RUDRA PRAYAG	355	36	322	0	31	3	154	134	157	165	16
59	TEHRI GARHWAL	1050	223	842	34	134	15	377	282	392	450	21
60	DEHRADUN	507	326	194	0	24	13	107	50	120	74	12
61	PAURI GARHWAL	1302	383	927	46	90	8	451	332	457	470	25
62	PITHORAGARH	711	137	581	16	81	7	307	170	312	269	39
63	BAGESHWAR	428	215	215	5	23	2	118	67	120	95	20
65	CHAMPAWAT	316	96	225	12	55	5	99	54	104	121	7
66	NAINITAL	538	261	281	12	67	4	133	65	137	144	18
67	UDHAMSINGH NAGAR	367	269	99	7	41	1	28	22	25	74	2

References

[1] *NOFN, 'Report of the committee on National Optical Fibre Network', March, 2015.*

[2] *Progress report of village electrification as on May, 2015, https://data.gov.in/catalog/progress-report-village-electrification: Last assessed on 02-07-2016.*

List of Figures

List of Tables

About the Report

This report is a planning document for Phase 2 deployment of BharatNet. Here we primarily explore alternate ways of broadband connectivity like wireless in unlicensed band. It is expected that approximately 30% of Phase 2 Gram Panchayats (GP) can be connected wirelessly from existing BSNL towers. This can potentially expedite deployment as this process can start immediately. For the remaining GPs, fibre connectivity is proposed for some and from them feasibility of wireless links is examined. We have also provided recommendations for GPs to be connected via satellite. Detailed BOQ and wireless link budget along with minimum fibre length requirement is also provided.