LAN Design for Village/Rural Region

20173098 – Ram Pratap Bachina

What is this document?

This is the design document to create LAN for Abburu Village, AP state.

Problem Statement

India has internet users with 54% of total country's population and which is ranked second in world but total percentage use is not high and we also ranked 86th with 8.2 Mbps connectivity speed and our ranking down by 10 places compared with last year, according to Akmai. The remaining users of 46% is who doesn't use internet is because of several reasons but important reason for them to not get acquainted with broadband because of no connectivity to their villages. ISP see good ROI in cities and not in villages but due to pandemic world has incorporated new work style and new way of teaching next generation kids. With remote learning and working majorly everyone back to roots and expecting high speed internet or at least connectivity in their counties/villages.

What are the possible reasons for no connectivity in remote regions/villages?

a. Building a new network is always expensive considering the facts like cables, new hardware equipment, need of increase in electrical demand, cost of setup like poles and its rights.
b. Lack of state government co-operation with ISP
c. ISP is not ready to invest as they see less returns when it comes to rural areas.
d. Unable to find field workers with network knowledge in rural regions to support in case of technical issues
e. Size of town/village not enough size to support ISP.
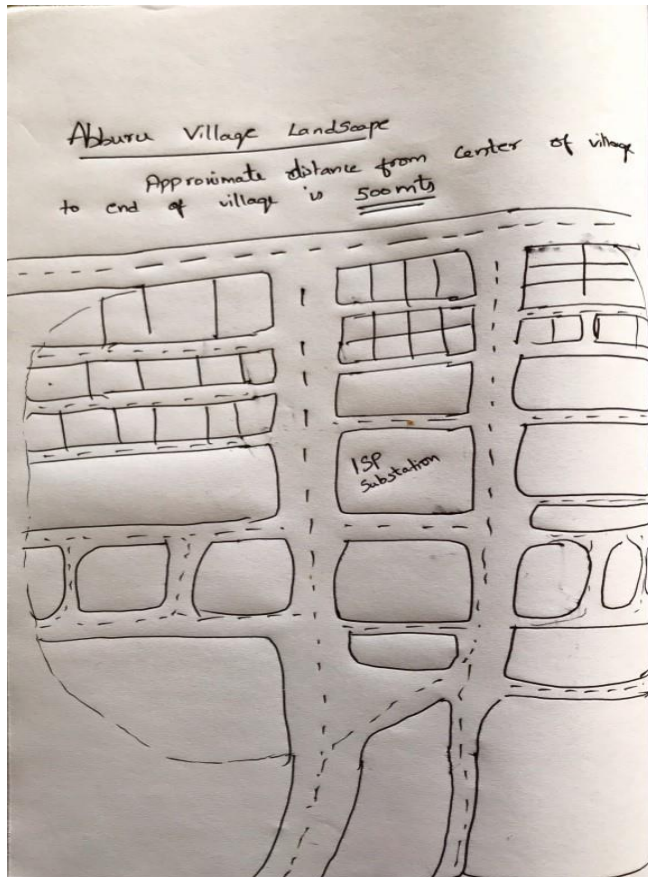f. Too expensive to buy new connection

Need of Hour

Any public and private sector with digitalization, life of work is smoother and faster. There is latest increase in demand of IT employment and e-learning students for internet in rural regions due to pandemic and country with highest number of rural population if we can take the world of internet to rural areas it will increase internet usage percentage of India.
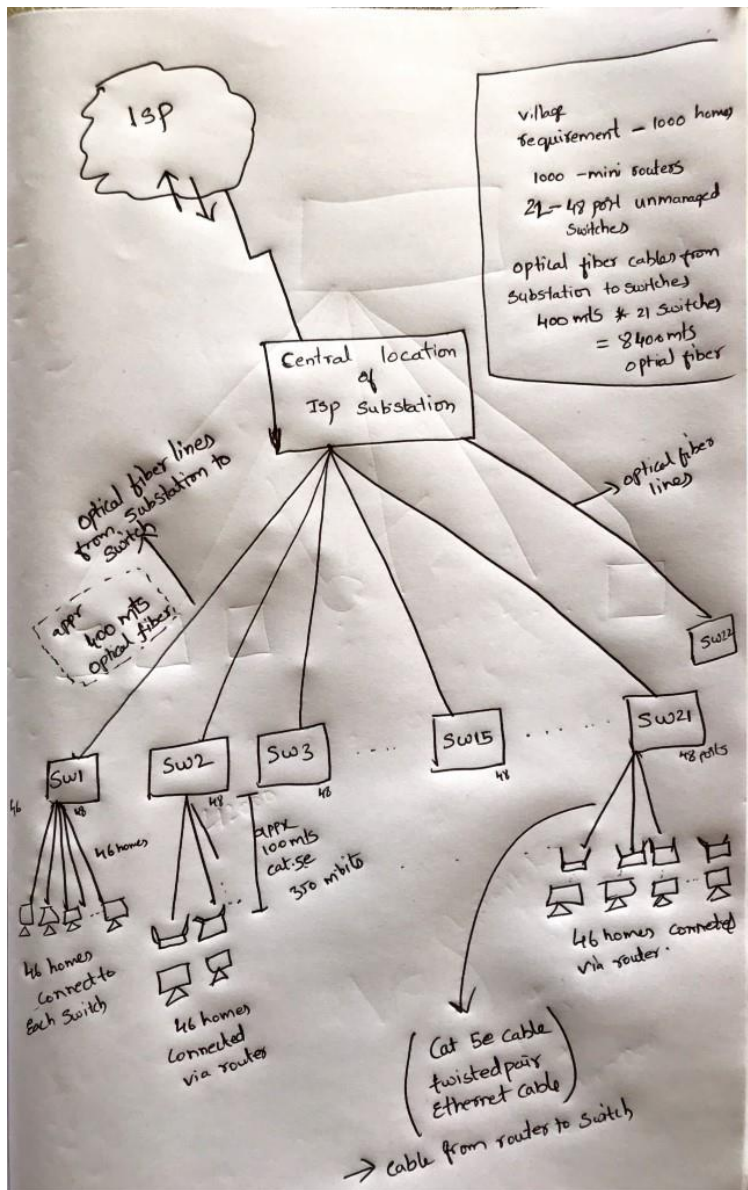
Identifying Village(Abburu) region and requirements

Total Population	4200+
Total Homes	Appx 1200
Internet Requirement	At least 1000
Speed requirement 10-18 Mbps	700 Homes
Speed Requirement 25-30 Mbps	300 Homes
House Sizes	1500 sqft – 300 sqft
Radius of village	500mts

Village Landscape

Design idea for village

The hand-drawn network diagram contains the following notations:

- ISP
- Central location of ISP Substation
- Village requirement – 1000 homes
- 1000 – mini routers
- 21 – 48 port unmanaged switches
- optical fiber cables from substation to switches
- 400 mts * 21 switches = 8400 mts optical fiber
- Optical fiber lines from substation to switch
- optical fiber lines
- appr 400 mts optical fiber
- SW1, SW2, SW3 . . . SW15 . . . SW21, SW22
- 48 ports
- 48, 48, 48, 48
- 46 homes
- appx 100 mts cat.5e 350 mbits
- 46 homes connected to each switch
- 46 homes connected via router
- 46 homes connected via router
- Cat 5e cable twisted pair Ethernet cable
- → cable from routes to switch

REQUIREMENTS GATHERING

How much villagers ready to pay for broadband?

50% homes	200 – 300 rs per month
20% homes	300 – 400 rs per month

15% homes	400 – 500 rs per month
10% homes	100 –200 rs per month
5% homes	500+ rs per month

Note – Above information is collected from Village revenue officer (VRO) based on the percentage that villagers own and cable TV operator based on how much of money customers are happy and ready to pay for their cable tv connection

How much optical fiber/ broadband ISPs are charging for the required data speed

Internet speed	Price	Speed Post FuP	Setup charges (free router)
18Mbps	400	512kbps	6 months' payment
30 Mbps	500	1Mbps	6 months' payment

*Speed post Fair usage policy (FuP)

CHOOSING THE ROUTER (at user end)

Router requirements for village homes

Specification	Need?
Internet Access Ports LAN	2-3 Lan ports
Internet Access Ports WAN	1 WAN port
Internet Access Port Speed	100 Mbps
Wifi Speed	300 Mbps
Wifi standard	Wifi4 IEEE 802.11n
Range	50 mts

Range - Unlink cities we need high range antennas require in villages because houses area is huge, and people expect wireless to reach everywhere at the home surroundings.

2.4 GHz vs 5 GHz

Which is best suited router for village environment?

A larger area needs longer coverage, 2.4GHz suits for this requirement as it has a longer range and penetration ability. For small homes, and city flats 5GHz will not only provide greater speed but also help with minimum interference from cluttering networks.
Design decision to go with 2.4 GHz

What option in wi-fi to find to get the 2.4Ghz frequency?

Wi-fi standard - I have chosen wifi4 IEEE 802.11n other than 802.11 b/g because of it has features like

Table 1. Technology comparison.

	IEEE 802.11a	IEEE 802.11b	IEEE 802.11g	IEEE 802.11n
Frequency band	5.7 GHz	2.4 GHz	2.4 GHz	2.4 / 5 GHz
Average Theoretical speed	54 Mbps	11 Mbps	54 Mbps	600 Mbps
Modulation	OFDM	CCK modulated with QPSK	DSSS, CCK, OFDM	OFDM
Channel bandwidth	20 MHz	20 MHz	20 MHz	20 / 40 MHz
Coverage radius	35 m	38 m	38 m	75 m
Unlicensed spectrum	Yes (it depends on countries)	Yes	Yes	Yes (it depends on countries)
Radio Interference	Low	High	High	Low
Introduction cost	Medium-Low	Low	Low	High-medium
Device cost	Medium-Low	Low	Low	Medium
Mobility	Yes	Yes	Yes	Yes
Current use	Medium	High	High	High
Security	Medium	Medium	Medium	High

Table reference - https://www.semanticscholar.org/paper/WLAN-IEEE-802.11-a%2Fb%2Fg%2Fn-Indoor-Coverage-and-Study-Sendra-Pineda/25830e9d4035c908c623ddab77d860c2db3144be

Out in the world of routers with my design requirement there are plenty of router making companies I have chosen the top 5 companies based below parameters

1. Product quality and reliability
2. Price of router
3. customer support

- Netgear
- TP-LINK
- D-LINK
- Asus

Out of above brands cost for feature and number of years of warranty is best in TP-LINK along with my requirements to router.

TL-WR845N V4 - cost 950 /-

4. This one also has 3 fixed antennas - Multiple antennas form a signal-boosting array to cover more directions and large areas
5. Another best feature with this router has WISP mode(Connect to ISP directly with wirelessly if the home or region doesn't have the wired connection)

Note - This router will accept only ethernet cables will not support optical fiber

Why did I selected Ethernet port Router(TP-LINK **TL-WR845N V4**)?

Cost issues - as part of design we can also directly connect optical fiber cables to router via optical fiber modem and connect the modem's LAN port with the router's WAN port using an Ethernet cable.

Each home must have cost of either 4000/- or 2000/- if going with optical fiber to home (FTTH - **fiber**-to-the-**home**)

Therefore we need,

Optical fiber modem	1000/- to 10000/-
Router	1000/-

Or else

Router with inbuilt fiber optic modem	4000/-

So, I have decided to go with Ethernet port router

How much data is required for the entire village?

30000Mbps (30Gbps)

CHOOSING THE CABELS

Considerations

Optical Fiber cable (single mode optical fiber)

- Price – 50 rupees per meter
- Distance – 40 Kms
- Advantages -
    - No degradation of signal
    - Low dispersion
    - Well suited for long distance communication
-

Twisted pair cables

Cat 5e

- Price – 2 pair cat5e 4 rupees per meter
- Distance – 100 meters
- Speed – 350 Mbit/s over 100 meters

Cat 6

- Price – cat 6, 15 to 20 rupees per meter
- Distance – 100 meters
- Speed - 1 Gbps network speeds, CAT6 can also support higher data rates of 10Gbps. However, 10Gbps is only supported over shorter distances of **37-55** meters.

Coaxial cable

- Price – 15 to 18 rupees
- Distance – 500 meters
- Bandwidth – 10Mbps
    - **Coaxial cable for the internet**
    - Coaxial cables can be used to carry signals for internet connections, but internet signals run at higher frequencies than traditional analogue video.

RG6 VS RG59

Going with RG6 high bandwidth and high frequency compared with RG59

What is my choice of medium to connect to ethernet router and ethernet unmanaged switch?

Cat 5e unshielded twisted pair cable

Reason for selecting cat 5e

Network speed	30mbps is requirement	It can support up to 350Mbps
Amount of users	Cat 5e cable to each home for 2 to 3 devices	Tens of users can connect(Multiple homes by default)
Indoor/outdoor purpose	Using it to connect local switch at near main road 90 mts away	Can you in both cases with up to 100 mts
Interference	No interference	With interference frequency and speed reduces

- The factors that need to consider while choosing CAT 5e
    - Quality copper cable
    - Lifetime support vendor

What are the reasons for selecting cat 5e twisted pair ethernet cables?	- Whole 500 meters village is divided into 22 spots. - Each spot is installed with ethernet unmanaged switch - Distance between ethernet unmanaged switch and central ISP station is 400 meters away. - Distance between (spot)switch and home router is 100 meters - Each switch is connected with 46 mini routers or homes - Since all the mini routers are just ethernet(LAN cable) supported routers and twisted pair 5e cable is selected between mini router and switch

What is my choice of medium to connect ethernet unmanaged switch and ISP substation?

Reason for selecting fiber optical cable OM3, wavelength 850, maximum channel length 550 meters

Network speed	1500 mbps is requirement	It can support up to 1.5 gbps
Amount of users	Optical fiber cable from central substation to each switch which is 400 meters awy	Based on the Transmission requirement to users we can select OM1, OM2, OM3 and OM4 fiber cables
Indoor/outdoor purpose	Outdoor purpose	Can you in both cases
Interference	No interference	Very less

- The factors that need to consider while choosing OM3 single mode optical fiber
    - Only OM2 and OM3 gives the combination of transmission speed of 1gbps and distance of 550 meters(my requirement is 400 meters)

Ref doc - https://www.stl.tech/optical-interconnect-products/optical-fibre/pdf/Differences_between_OM1__OM2__OM3__OM4_.pdf

What are the reasons for selecting single mode OM2 fiber optic cable?	- Whole 500 meters village is divided into 22 spots. - Each spot is installed with ethernet unmanaged switch - Distance between ethernet unmanaged switch and central ISP station is 400 meters away in village. - Village speed requirement is 30Gbps - Total cost for installation 400 meters * 22 switches = 8800 meters 50 rupees for each meter = 4,40,000/- Only fiber optic is reasonable compared with coaxial or twisted pair cables. If I consider the coaxial cable extra cost must be spent on switches and buying converter modems

ISP central location is placed in center of village (if not, close to the center of village). Since the village radius is not more than 500 mts

CHOOSING THE SWITCH IN MY LAN DESIGN

What is the requirement?

- As connection requirement is 1000 homes and identified and divided whole village region into 22 spots if I install switch at every spot, 22 switches with 48 ports can give connections up to 1056 homes and this will be enough for current need.

- Switch is nearly or less than 100 meters away from each mini router.

- All the routers at home supports only cat 5e cables so medium between router and switch has to be ethernet twisted pair cable so the switch is also ethernet switch.

- Keeping the cost in mind each switch that connects home is unmanaged switch, and no of ports for each switch has 48 so cost per each varies based on the brand.

- Speed requirement for each switch is 1440 Mbps

- As we are connecting optical fiber from central managed switch at substation to ethernet switch is 400 meters we need switch with sfp port enabled for gigabit data as input

By considering all above parameters, investment and brand chosen the DES-1050G(D-LINK) - L2 unmanaged switch - DES-1050G

**Why did I select L2 unmanaged switch - DES-1050G?**

6. It has 48 ports
7. 2 Gigabit sfb ports (will use it to connect the transceiver)
8. Switching capacity 3.6Gbps (My requirement is 1.5 Gbps and may increase in future)
9. Why L2 – requirement is only about ethernet connection
10. Each port speed 100mbps
11. Price 16000/-

https://www.dlink.com/en/products/des-1050g-48-port-unmanaged-ethernet-switch-with-2-gigabit-coppersfp-ports

Need of Transceiver to connect ethernet switch sfp(short form-factor pluggable)

1000Base –LS SFP	We are connecting only on fibre from main switch to ethernet switch so, 1000 base LS is suggestable Considering - TP-LINK TL-SM311LS Gigabit SFP module, Single-mode, MiniGBIC, LC interface, Up to 10km distance Cost – 2000/- Install Transceiver at each switch

Core Switch(also called as ISP substation managed system)
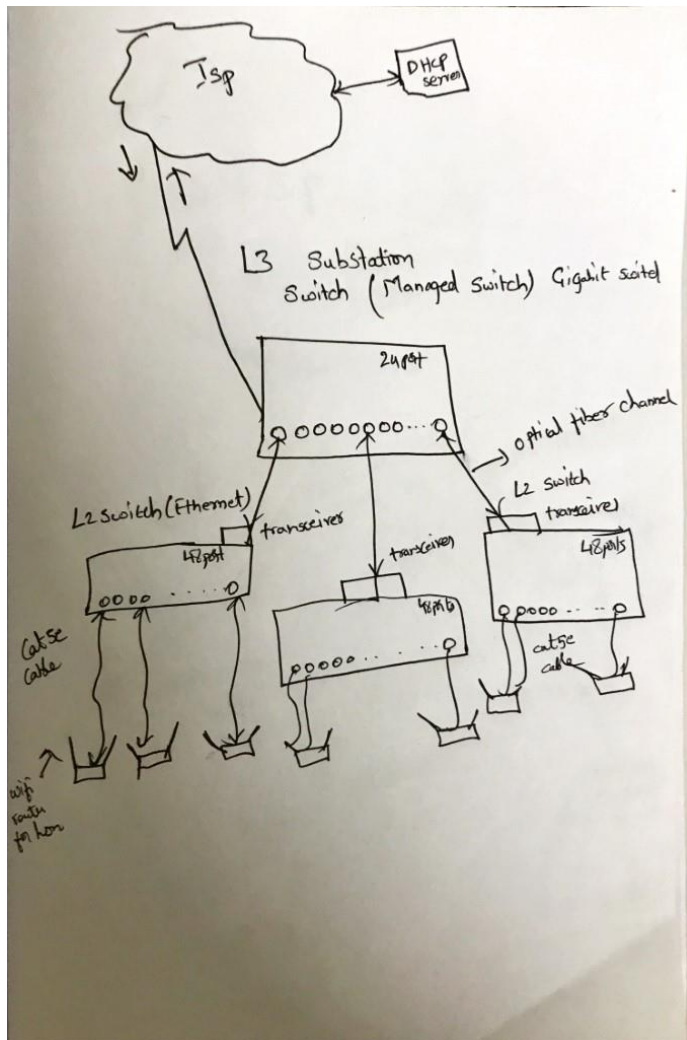
How are 22 spots/sub-regions in village are connected (22 L2 switches)?

As this is multi switching environment all 22 unmanaged switches are connected to managed L3 switch and data is transferred through medium fiber optic

- I need one administrative switch which is L3 connected on top of all 22, L2 unmanaged switches. As all L2 switches are expecting 1.5Gbps and my administrative switch should have a capacity of 33Gbps.

- Along with that medium between L2 switch and L3 switch is fiber optic cable so, my administrative switch cannot be fast ethernet switch but optical fiber supported gigabit switch.

- As I have 22 switches my Administrative switch must have minimum of 24 ports.

- Should I consider **Connect Multiple Ethernet Switches by Switch Cluster?**
    - Reason for not going with switch cluster concept because Only specific cluster-capable switches from the same manufacturer can be clustered.
    - I selected 22 unmanaged switches from D-LINK company but my administrative switch is chosen from Cisco. So, I by passed this option and setup the multi-vendor switches as child and parent.

WS-C3850-24T - CISCO WS-C3850-24T-S STACKABLE 24 10/100/1000 ETHERNET PORTS switch serves my requirement

IP Addressing schema for the village

I am designing LAN for already existing **ISP** network which they **get the block of IPs from Indian registry for internet names and numbers(IRINN)**. With their block **everyday dynamic IP is generated and assigned to my host which is a public IP.** Dynamic IP allocation will happens at remote region or remote site where ISP is located 30 kms away from the Village through **DHCP server.**

Within the given range or pool of IP address allocated in ISP, where ISP saves the IP in DHCP database where server identifies the clients and allocated the IP based on given number of days.

As my village has only 1000 host better I can go with class B

With class B

- Class B can have 14 bits for network and remaining for hosts
- But with Class B total of 65536 host can connect
- In this case I need consider the network bits as 22 and my subnet will be 255.255.252.0 (hosts 1022)

Main issue with class B is IP efficiency but ISP might be connected to several urban hosts and other LANs so IP inefficiency is not going to be a problem

How and where DHCP Server setup is located?
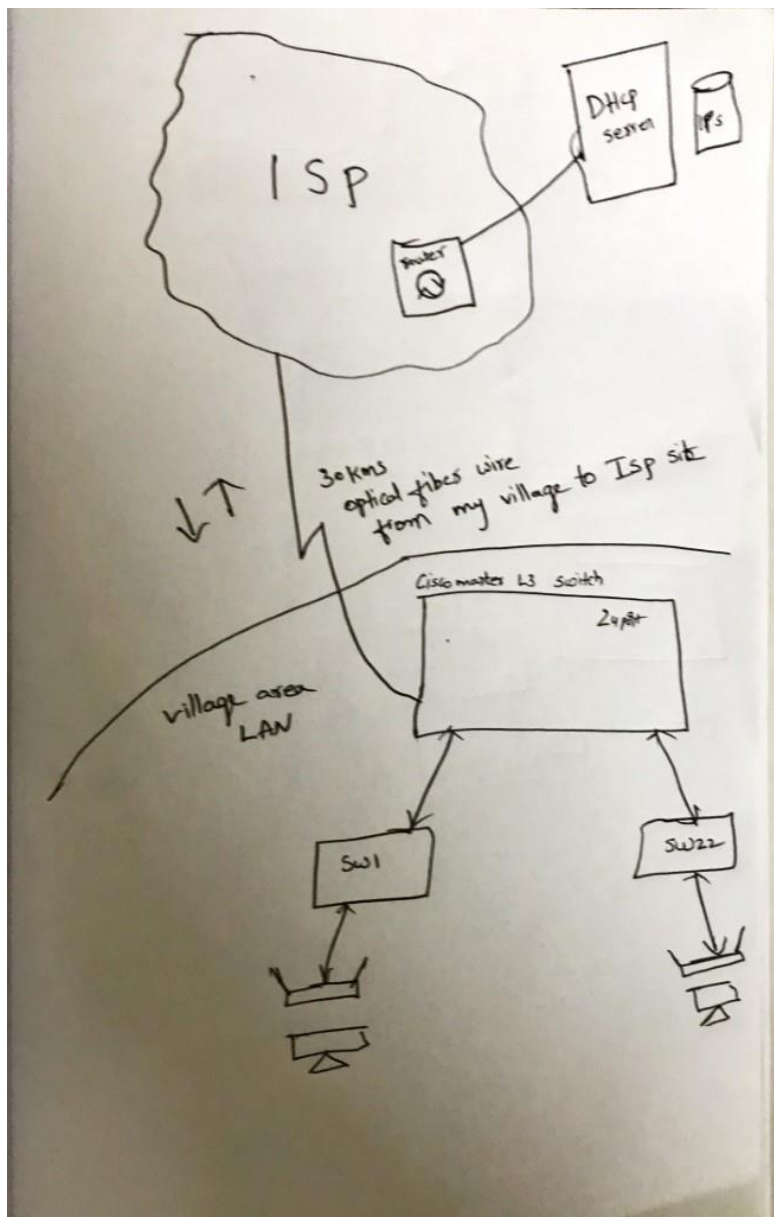
Total cost is required for setting the village with internet service (below table will gives brief idea total cost required to buy infrastructure and how much vendor ISP and end user need to spend for their connection)

Hardware	Requirement	Cost
Mini Routers for Home	1000 routers	950 rupees each router 950 * 1000 = 9,50,000/-

Cat 5e cable	100 meters * 46 ports in switch * 22 switches = 1,012,00 meters	Each meter 4 rupees 101200 meters * 4 rupees = 4,0,4800/-
Ethernet switch	22 switches 22, 48 port L2 ethernet switches	Each switch 16000 22 switches * 16000 =3,52,000/-
Transceivers	23 Transceivers 22 Ethernet switches and one L3 48 port switch	Each transceiver 1975/- 23 * 1975 = 43,450/-
OM2 Single mode optical fiber	400 meters * 22 = 8800 meters	Each meter 50 rupees 50 * 8800 = 4,40,000/-
L3 Managed switch	22 ports at least, 30gbps capacity,	60,000/- 80,000/-
Other(wiring, one time installations, electrical wirings to switches)		20,000/-
		- Total cost of setup 22,90250/- 9,50,000 is spent by end users 404800 will spend by end users (2290250-950000-404800) Total cost of ISP to my village = 935450/- Total cost of for end users = 13,50,000/- <mark>Each end user need to pay 1350/- for initial setup (1000*1350)</mark>

What are the other infrastructure and its cost not covered in this design?

As this is the optical fibered network, medium(optical fiber) installation from ISP headquarter which 30kms from village its cost and setup is not designed in this document. This document is primarily based on infra setup and cost within the village region.

This is not an expensive design and with requested data rate 30Mbps end users can also ready to pay 400 - 500 per month and ISP can invest initial amount into rural regions to get timely returns. For example now every village almost installing with local sub antennas for mobile networks. Moreover, this is optical fiber design data rates can increase and decrease based on need. In this design, each and every L2 fast ethernet switch is having 48 ports but left 2 ports available in case any new connection join in. As the network grows we can go ahead and increase the spots but unlike urban region, villages are not going to be expanded in area or with new connections but there is a scope of designing the LAN not only internet but also for other components like IPTV and IP-phone for all homes and camera setup across the village. Design can extend by adding some infrastructure(new switches) to handle these devices.