AN INDUSTRIAL TRAINING REPORT AT

BSNL MEERUT

ON

HIGH SPEED INTERNET CONNECTION

Wef 21-01-2026 to 10-02-2026 (3 weeks)

Submitted By:

Deepika Kulshreshtha
Lecturer Electronics
Government Polytechnic Hindalpur, Hapur

DECLARATION

I hereby declare that the work presented in this Industrial Training Report is an original work carried out by me during my training at BSNL Meerut. This report has not been submitted to any other institute or university for the award of any degree or diploma.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude **to** Bharat Sanchar Nigam Limited (BSNL), Meerut**,** for providing me the opportunity to undergo 21 days of Industrial Training in the Broadband Section**,** specifically at the Switching Room of the National Internet Backbone (NIB)**.**

This training has been a valuable learning experience, offering practical exposure to real-time telecom network operations, broadband infrastructure, and switching systems. The hands-on experience gained during this period has significantly enhanced my understanding of theoretical concepts related to broadband technologies, IP/MPLS networks, aggregation and access networks, and overall telecom infrastructure.

I extend my heartfelt thanks to the **training coordinator Mr. Lalit SDE and other officials at the NIB Switching Room, Meerut**, for their continuous guidance, support, and cooperation throughout the training period. Their willingness to share knowledge, explain technical details, and provide insights into live network operations made this training highly informative and meaningful.

I am also grateful to **Mr. Krishna Murari DE Tx BSNL Meerut** the for granting permission and facilitating a conducive learning environment. Their professional approach and technical expertise greatly contributed to the successful completion of this industrial training.

.

TABLE OF CONTENTS

ABSTRACT

This report presents a comprehensive account of the Industrial Training undertaken at **Bharat Sanchar Nigam Limited (BSNL), Meerut**, in the Broadband Section**,** with practical exposure at the **Switching Room of the National Internet Backbone (NIB)**. The training was aimed at bridging the gap between theoretical knowledge and real-time telecom network operations.

During the training period, detailed insights were gained into the architecture and functioning of broadband networks, including access, aggregation, and core network elements. Emphasis was laid on understanding technologies such as **DSL**,**FTTH, IP/MPLS networks, aggregation switches, Broadband Network Gateway (BNG), VLAN concepts, transmission systems, and switching operations** within the NIB and Mobile communication environment. Practical exposure to live network infrastructure enhanced the understanding of service provisioning, traffic flow, and network management in a large-scale telecom setup.

This industrial training proved to be highly beneficial in strengthening technical competence and providing a clear understanding of modern broadband and backbone network operations deployed by BSNL. The knowledge and experience gained through this training will be valuable for academic, professional, and teaching purposes in the field of telecommunications

INTRODUCTION

Remarkable progress in telecommunication technology has had, and will continue to have, an enormous impact on telecommunications manufacturing and service industries. In particular, digital technology that integrates the transmission, switching, processing, and retrieval of information provides opportunities to merge various service modes into an integrated system. This digitalization, which combines communication and computation functions, has been made possible by significant advances in device and material technologies, including integrated circuits and optical fibers. As the role of digital processing continues to increase, systems and services are becoming more intelligent and labor-saving on one hand, and more software-intensive on the other.

Satellite communication and optical fiber technologies contribute significantly to the globalization of telecommunication services. Standardization and interoperability of systems have become global concerns, along with the compatibility of regulatory measures that ensure free trade in telecommunication products and services.

As telecommunications have become indispensable to socioeconomic activities, the reliability and security of telecommunication services have emerged as critical issues. In the information age, information retrieval is gaining importance, while concerns are also increasing regarding the integrity and authenticity of information, as well as the protection of user privacy. These issues collectively play a vital role in shaping the future of telecommunication.

OVERVIEW OF BSNL

Bharat Sanchar Nigam Limited (commonly known as BSNL) is an Indian central public sector undertaking, under the ownership of Department of Telecommunications. It was established on 1st October 2000 by the Government of India. It provides mobile voice and internet services through its nationwide telecommunications network across India. It is the largest government-owned-wireless telecommunications service provider in India.

Products and services

Telephone and Mobile

BSNL provides both fixed line telephones and mobile telephony services on the GSM platform.

BSNL Mobile

BSNL Mobile is a major provider of GSM network services under the brand names *CellOne* and BSNL all over India. It has wide network coverage in both urban and rural areas of India. It has over 121.82 million customers across India.

BSNL Mobile offers prepaid, postpaid services and value-added services such as Free Phone Service (FPS), India Telephone Card (Prepaid card), Account Card Calling (ACC), Virtual Private Network (VPN), Tele-voting, Premium Rate Service (PRM). It also offers the IPTV which enables customers to watch television through the Internet and Voice and Video Over Internet Protocol (VVoIP).

BSNL Landline

BSNL Landline was launched in the early 1990s. It was the only fixed-line telephone service for the whole country before the New Telecom Policy was announced by the Department of Telecom in 1999. Only the Government-owned BSNL and MTNL were allowed to provide land-line phone services through copper wire in the country. BSNL Landline is the largest fixed-line telephony in India. It has over 9.55 million customers and 47.20% market share in the country as of 28 February 2021.

Internet

BSNL is the fourth-largest ISP in India, having a presence throughout the country. It also has the largest Firebase telecom network in the country, around 7.5 lakh kilometers, among the four operators in the country.

BSNL Broadband

BSNL Broadband provides telecom services to enterprise customers including MPLS, P2P and Internet leased lines. It provides fixed-line services and landline using CDMA technology and its own extensive optical fiber network. BSNL provides Internet access services through dial-up connections as prepaid, *NetOne* as postpaid, and *DataOne* as BSNL Broadband.

BSNL Bharat Fiber

BSNL Bharat Fiber (FTTH) was launched in February 2019. It offers TV over IP (IPTV), Video On-Demand (VoD), Voice over IP (VoIP), Audio On-Demand (AoD), Bandwidth On-Demand (BoD), remote education, video conferencing services, interactive gaming, and Virtual Private LAN services. BSNL has said that its optic fiber network provides fixed access to deliver high-speed Internet up to 300 Mbit/s.

Bharat Net

With effect to the government of India's policy decision to provide state-owned BSNL with another revival package worth 1.64 lakh crore rupees, the struggling PSU was merged with the Government's special purpose vehicle BBNL. This gave the struggling PSU a boost and an additional advantage of additional 5.67 lakh kilometers of optical fiber which has been laid across 1.85 lakh village panchayats in the country using the Universal Service Obligation Fund (USOF). Currently, it has an optical fibre cable network of over 6.83 lakh kilometres.

BSNL 4G

BSNL is the first telecom operator in India which started rolling out 4G service by using Mobile Broadband in 2009. In 2010 BWA auction, BSNL was allocated with 4G spectrum under 2300MHz Bandwidth (in all 20 telecom circles in India except Delhi & Mumbai because it is administered under MTNL network but MTNL also allocated with the same) which is also known as BWA or Broadband Wireless Access spectrum. It is initially used for WiMAX and later same is used for LTE service. BSNL was allocated with the spectrum by without participating in the BWA auction why because it is a state owned entity owing to which it has been provided with Auction Exception, So in order to acquire the spectrum, BSNL has to pay the equivalent amount that private telecom players paid for the same Bandwidth in the Auction to the Government. So, BSNL has provided 8,500 crores to the Government for this spectrum. MTNL also provided 1120 crores to the Government for the same. In the meanwhile other telecom players were using LTE technology to provide 4G services, BSNL alone used WiMAX technology to provide 4G service. But WiMAX technology is not accepted globally due to which the technology got failed to prove. So BSNL returned back all the 4G WiMAX technologies

to the Government and brought back the investment amount due to heavy financial debt incurred at the time. Reason behind the financial burden is because of its Legacy Systems and increasing pension to retired employees. Later in 2017-18 period BSNL provided 4G services in Few areas of India under Spectrum Reframing despite being not a proper 4G service. Under Make in India initiative, C-DOT (Centre for Development of Telemarics) developed the 4G core network for India. But the assembly segment was developed by Tejas Network (which was later brought by TATA) and the Government owned entity ITI (Indian Telephone Industries Limited).

BSNL started 4G service in some parts of India such as Bihar, Jharkhand, and Uttar Pradesh in January 2019, but it is limited to a few cities and towns. Most of its 4G services are currently available in Southern India. However, BSNL is trying to launch pan India 4G services up to September 2022. The telecom minister said that BSNL will launch its 4G services all over India on the 75th Independence Day of India along with various other projects. BSNL is using 700 MHz and 2100 MHz bands to roll out the 4G services which can be upgraded to 5G in the future. BSNL has installed more than 40,000 plus 4G enabled and 5G ready towers.On September 27, 2025, PM Narendra Modi launched BSNL's Swadeshi 4G Network and commissioned 97500 towers developed indigenously.

BSNL 5G

On behalf of the government of India, the Minister of Communications Ashwini Vaishnaw announced that the State-Owned Telco would start its 5G operations by 15 August 2023. He also added that the 4G and 5G network of the state-owned BSNL would be a completely home-grown indigenous 4G and 5G network technology; thus, emphasizing more on Govt. of India's Atmanirbhar Bharat.

Direct-to-Device

In November 2024, BSNL introduced and made a trial of the new **Direct-to-Device** technology for the first time in India in partnership with VIASAT. This technology enables users to communicate without transversing a Base Station or Core Network. This technology is used in direct interaction between 5G-enabled devices to connect seamlessly to both terrestrial and satellite coverage.

IP & cloud services

BSNL Managed Cloud Services

On 28 May 2013, BSNL launched "Internet Data Centre – Managed Cloud Services". This includes computation, software, data access and storage services for individuals as well as enterprises.

Services include:

- Cloud compute
- Cloud Storage
- Hosted Exchange
- Hosted Virtual Desktop Infra (VDI)
- Hosted Gateway
- Hosted Email filter
- Hosted web filter
- Hosted backup and restore
- Hosted DR
- Hosted communication Services
- Hosted Database

BSNL Wing Services

On 16 August 2018, BSNL launched "BSNL Wings Services" in 22 telecom circles, in which there is no need for a SIM card or FTTH as it is a VoIP service through an app. It offers unlimited free calling for one year throughout India.

BASICS OF TELECOMMUNICATION

Telecommunication systems and services involve the transfer of some type of information from one point to another. Telecommunication may consist of the transfer of voice, data, video media and telecommunication systems may combine and control this media in many ways.

Telecommunications technologies and systems are designed to reliably transfer information between the originating source of the information and the intended destination(s). Certain types of communication systems are designed to effectively transfer specific types of information. Although these systems may be capable of other types of telecommunications services (e.g. voice and data), other types of communication systems may be better choices. For example, mobile telephone system is very good at transferring voice information, but not very capable of handling video.

Telecommunications systems are characterized as being made up of end user equipment, access lines, interconnection equipment, and a coordinating (controlling) structure. Examples of end user equipment are telephone handsets, computer terminals, or pagers. These devices communicate with a telecommunication network through access lines and/or access points. Access systems can be interconnected with each other to form large networks. Control systems are responsible for authorizing access to the system, managing network resources, and measuring usage for billing and accounting purposes.

Some communication networks that have been traditionally used for non-telecommunication services have evolved to provide voice services. For example, cable television systems now offer high-speed Internet services and it is relatively simple to upgrade these two-way data networks to offer voice services.

BROADBAND COMMUNICATION

The term **"broadband"** refers to an advanced telecommunication service that developed from the need to transmit greater amounts of information across the Internet. The **Federal Communications Commission (FCC)** defines broadband in terms of speed. The current standard specifies a minimum of **25 megabits per second (Mbps)** for downloading and **3 Mbps** for uploading. In essence, broadband is a service that enables reliable, high-speed transfer of data, voice, and video over the Internet.

In the 1990s, the only option for Internet access was through a dial-up connection using a home telephone line and a modem. However, technologies have evolved significantly over time. As interest in Internet usage increased and Internet-based applications expanded, new solutions were required to meet the growing demand for higher data transmission rates.

Broadband connectivity has become a foundation for economic growth, job creation, global competitiveness, and an improved quality of life. It enables entirely new industries and unlocks vast new possibilities for existing ones. Broadband is transforming the way education is delivered, healthcare services are provided, public safety is ensured, government services are accessed, and knowledge is shared, organized, and disseminated within communities.

Broadband is defined as an **always-on data connection** with a minimum download speed of **256 kbps or higher**, capable of supporting multiple services simultaneously.

Broadband communication refers to high-speed data transmission that supports multiple services such as voice, video, and data. It is characterized by high bandwidth and always-on connectivity.

BSNL, being a Government of India enterprise, plays a crucial role in providing broadband connectivity to both **urban and rural areas**, including remote locations where private operators have limited reach.

BSNL broadband services are designed to support:

- High-speed internet access
- Voice over IP (VoIP)
- IPTV
- Video conferencing
- Online education and e-governance services

BROADBAND TECHNOLOGIES

Various broadband technologies are used such as DSL, Fiber Optics, Cable Broadband, and Wireless Broadband. Each technology has its advantages and limitations depending on deployment scenarios.

Classification of Broadband Technologies in BSNL

BSNL uses the following major broadband technologies:

1. DSL (Digital Subscriber Line)
2. FTTH (Fiber to the Home)
3. Leased Line Broadband
4. Wireless Broadband
5. Satellite Broadband (Limited/Remote Areas)

1. DSL (Digital Subscriber Line) Technology

DSL technology uses existing **copper telephone lines** to provide broadband services along with voice communication. It was the first broadband technology widely deployed by BSNL.

Types of DSL Used in BSNL

a) ADSL (Asymmetric Digital Subscriber Line)

- Downstream speed is higher than upstream
- Suitable for home and small office users

Typical Speeds:

- Download: up to 8 Mbps
- Upload: up to 1 Mbps

b) ADSL2 / ADSL2+

- Improved version of ADSL
- Better speed and stability

Typical Speeds:

- Download: up to 24 Mbps
- Upload: up to 3 Mbps

c) VDSL (Very High Bit Rate DSL)

- Used in limited areas
- Requires shorter copper loop length

Typical Speeds:

- Download: up to 50–100 Mbps

Advantages of DSL

- Uses existing copper infrastructure
- Low deployment cost
- Wide availability

Limitations of DSL

- Speed decreases with distance
- Affected by noise and attenuation
- Limited bandwidth

2. FTTH (Fiber to the Home) Technology

FTTH is the most advanced broadband technology used by BSNL, where **optical fiber** is extended directly to customer premises.

Technology Used: GPON

BSNL uses **GPON (Gigabit Passive Optical Network)**.

- OLT (Optical Line Terminal)
- Optical Splitters
- ONT (Optical Network Terminal)

FTTH Network Architecture

OLT (Exchange) → Feeder Fiber → Splitter → Distribution Fiber → ONT

Services Provided over FTTH

- High-speed internet
- IPTV
- VoIP
- Video on demand

Advantages of FTTH

- Very high bandwidth (up to 1 Gbps)
- Low latency
- High reliability
- Long life infrastructure

Limitations of FTTH

- High initial installation cost
- Fiber cuts require skilled maintenance

3. Leased Line Broadband Technology

Leased lines are **dedicated point-to-point connections** provided to enterprises and government organizations.

Features

- Dedicated bandwidth
- High availability
- SLA-based services

Technologies Used

- Optical fiber
- MPLS network

Applications

- Banks
- Government offices
- Educational institutions

4. Wireless Broadband Technology

Wireless broadband is provided where wired connectivity is difficult.

Types of Wireless Broadband

- 3G Mobile Data
- 4G LTE
- Wi-Fi Hotspots
- Fixed Wireless Access (FWA)

Advantages

- Quick deployment
- Mobility

Limitations

- Speed fluctuations
- Signal interference

5. Satellite Broadband

Used in:

- Remote areas
- Disaster management

Limitations

- High latency
- Expensive equipment

BSNL uses a mix of broadband technologies to meet diverse customer requirements. While DSL played a major role in initial broadband deployment, FTTH is now the backbone of future broadband services. Leased lines and wireless broadband further strengthen BSNL's service portfolio, ensuring connectivity across India.

Comparison of BSNL Broadband Technologies

Technology	**Medium**	**Speed**	**Reliability**	**Cost**
DSL	Copper	Medium	Medium	Low
FTTH	Fiber	Very High	Very High	Medium
Leased Line	Fiber	High	Very High	High
Wireless	Radio	Medium	Medium	Low

Broadband Network Architecture

Broadband Network Architecture defines the **end-to-end structure** through which high-speed data services such as **Internet, VoIP, IPTV, and cloud applications** are delivered from the service provider to end users.

Modern broadband architecture is **multi-layered**, scalable, and designed to support **high bandwidth, low latency, and Quality of Service (QoS)**.

In BSNL and other telecom operators, broadband architecture integrates **optical fiber, IP/MPLS networks, access technologies, and service platforms**.

Broadband Network Architecture – High Level View

Broadband networks are typically divided into **four logical layers**:

1. **Core Network**
2. **Aggregation Network**
3. **Access Network**
4. **Customer Premises Network**

1. Core Network Architecture

The **core network** forms the backbone of the broadband system and is responsible for:

- High-speed data transport
- Routing and switching
- Interconnection with national and international networks

Technologies Used

- IP/MPLS
- DWDM
- High-capacity routers (100G/400G)

Characteristics

- Very high bandwidth
- Redundant paths
- High availability (99.999%)

2. Aggregation Network Architecture

Function

The aggregation layer:

- Collects traffic from multiple access nodes
- Aggregates and forwards it to the core network

Devices

- Aggregation switches
- Broadband Network Gateway (BNG)
- L2/L3 switches

Protocols

- VLAN
- MPLS
- QoS policies

BNG Role

- PPPoE termination
- Subscriber authentication
- Policy control
- Bandwidth management

3.Access Network Architecture

The access network connects the **service provider** to the **subscriber**.

Wired Access Technologies

- **FTTH (GPON / XGS-PON)** – used by BSNL
- DSL (ADSL/VDSL – legacy)
- Ethernet access

Wireless Access Technologies

- 4G/5G FWA
- Wi-Fi hotspots

4. Customer Premises Network

Components

- ONT / Modem
- Wi-Fi router
- End devices (PC, mobile, IPTV)

Functions

- Signal termination
- Local network creation
- Service delivery

5. Service Control & Management Layer

This layer ensures:

- User authentication
- Billing
- Service provisioning
- Network monitoring

Key Systems

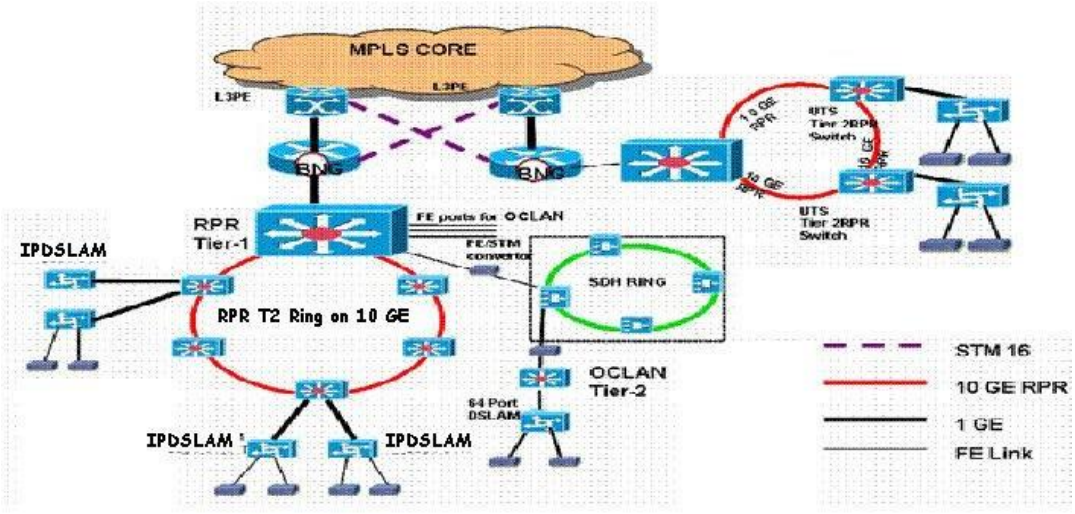
- AAA servers (RADIUS)
- Network Management System (NMS)
- OSS/BSS platforms

BROADBAND MULTIPLAY

What is BBMultiplay?

The triple play service means providing the following service to the customer:-

- Data (Internet)
- Voice(VoIP and not the PSTN which is already provided on broadband also)
- Video(IPTV, Video on Demand (VoD), live broadcast, and stored broadcast content, provided over IP networks using video streaming protocols.)



N/W Architecture Broadband Multiplay Components of Broadband Multiplay

The BSNL broadband multiplay network consists of the following components:

- L3PE(MCR /PERouter ofNIB-2Project1–Supplied by HCL).
- BNG– Broadband Network Gateway(Connects MultiplayNetworktoNIB2 Backbone Project 1, through L3PE).
- RPR (Tier-1 Switch and Tier-2 switches in the ring Provides connectivity to BNG & vice versa).
- OCLANTier-2 Switch.
- DSLAM.
- ADSL CPE.
- DSL Tester.

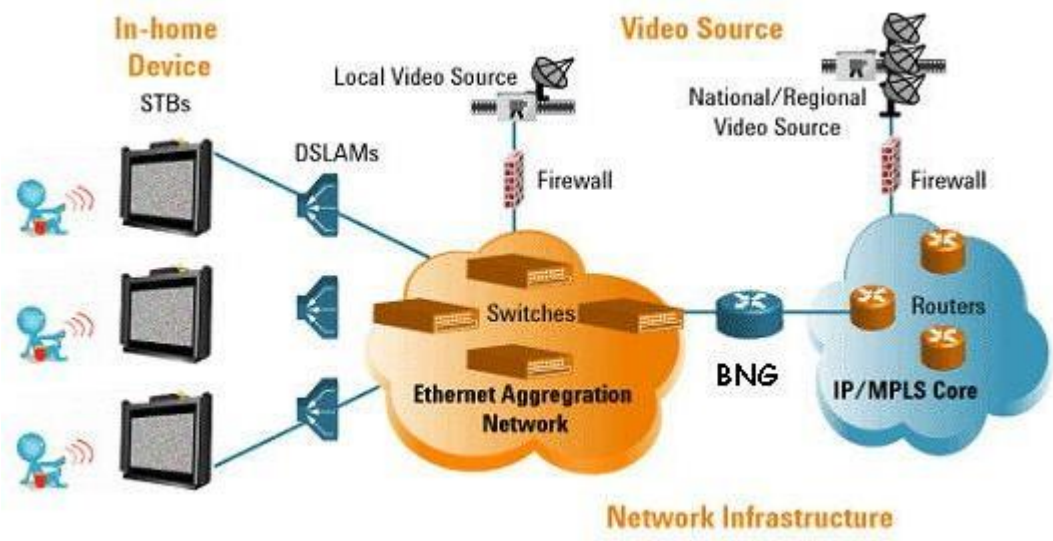
Changes in Broadband Multiplay after Broadband

- T1 & T2 transmission networks have been migrated from star topology to RPR (Resilient Packet Ring) ring topology, resulting in higher reliability, better protection switching, and improved network availability.

- IP-DSLAMs are now connected through Gigabit Ethernet (GE) interfaces instead of Fast Ethernet (FE), enabling higher bandwidth, improved scalability, and better support for broadband services.

- BNG (Broadband Network Gateway) functions as a Customer Edge (CE) router, whereas the earlier BRAS (Broadband Remote Access Server) architecture operated as a Provider Edge (PE) router.

- BRAS nodes were deployed only at 23 ‘A’ category locations, while BNG deployment has been extended up to ‘B’ type cities, ensuring wider broadband service reach and improved access network coverage.



Services on BB-Multiplay

TVOIP - Television Voice over Internet Protocol

i)TVOIP (also called as IPTV) delivers television programmes to households via broadband connection using Internet protocols.

ii.)It requires a subscription and IPTV set-top box (STB).

iii.)IPTV is typically bundled with other services like Video on Demand (VOD), Voice Over IP (VOIP) or digital Phone, and Web access.

iv)IPTV viewers will have full control over functionality such as rewind, fast-forward, pause, and so on.

v.)IPTV (Internet Protocol Television) is a system where a digital television service is delivered by using Internet Protocol over a network.

vi.)For residential users, IPTV is provided with Video On Demand and may be bundled with Internet services such as Web access and VoIP.

vii.)The video stream is broken up into IP packets and dumped into the core network, which is a massive IP network that handles all sorts of other traffic (data, voice, etc)

viii.) The box will connect to the home DSL line and is responsible for reassembling the packets into a video stream and then decoding the contents.

VOIP

i.) The technology used to transmit voice conversations over a data network using the Internet Protocol.

ii.) A category of hardware and software that enables people to use the Internet as the transmission medium for telephone calls.

iii.) VoIP works through sending voice information in digital form in packets,

iv.) VoIP also is referred to as Internet telephony, IP telephony, or Voice over the Internet (VOI)

NATIONAL INTERNET BACKBONE

NATIONAL INTERNET BACKBONE (NIB-I)

National Internet Backbone has been conceived to provide Nation-wide connectivity to ISPs as well as customers. NIB consists of 550 nodes available at almost all the district headquarters. NIB is connected to VSNL Gateways at 6 locations i.e. Mumbai, Kolkata, New Delhi, Bangalore, Chennai and Ernakulam.

Access Mechanisms

The NIB supports internet access with the following mechanisms.

• PSTN Dial-up access to Internet, at port speeds up to 33.6 Kbps through access number 172233.

• ISDN Dial-up at Basic Rate Interface (BRI) through access number 172225.

• Leased line access to Internet at 64 Kbps, N X 64 Kbps , 2 Mbps and N x 2 Mbps speeds

Equipments of NIB

NIB consists of the following equipments

1.Router : To route customer traffic to desired sites.

2. Remote Access server : To give dialup access to the customer.

3. LAN Switch : To interconnect Servers, Router and RAS.

3. Server /Storage : For running various applications

Help Desks and Call management

in NIB Primary function of NIB Helpdesk are given below :

1. Customer care through defined management process.

2. Technical help on Internet usage.

3. Tariff and other commercial details are available on http://www.bsnl.co.in

NATIONAL INTERNET BACKBONE (NIB-II)

The BSNL NIB2 network is primarily designed to be a high speed IP/MPLS network. The network is intended to be used for convergent services, integrating data, voice and video. It will provide services like Internet bandwidth for ISPs, Corporate, Institutions, Government bodies and retail users. The BSNL network is designed to be capable of meeting a wide range of customer requirements, including security, Quality of Service (QoS), and any-to-any connectivity. It is designed to be able to offer fully managed services to customers and allow BSNL to introduce additional services such as bandwidth on demand, etc. over the same network. The backbone infrastructure consists of an MPLS core with Internet services and VPN services edge networks. Cisco 12416 GSR & Cisco 12410 GSR routers are used to build the core network with the edge network consisting of Cisco 7613 routers. Cisco 7613 Routers serve also as the miscellaneous routers like Router Reflectors, International Data Center Routers, Internet Exchange Point Routers, IP Tax Routers, International Gateway Routers.

Below are the services, which the network is designed to offer:

i. L3 MPLS VPN services

1. Intranet -Managed & Unmanaged

2. Extranet – Managed & Unmanaged

3. Internet Access services

ii. Layer 2 MPLS VPN Services

1. Ethernet over MPLS

2. Frame relay over MPLS

3. PPP over MPLS

4. VPLS (Virtual Private LAN Service)

5. Layer 2 Any-to-Any Interworking (except ATM)

iii. Encryption services

iv. Firewall Services

v. NAT Services

vi. Multicast Services

NETWORK OVERVIEW

The BSNL NIB2 network is primarily designed to be a Carrier Grade high speed IP/MPLS network. The backbone infrastructure consists of an MPLS core with Internet services and VPN services edge networks. Cisco 12416 GSR & Cisco 12410 GSR routers are used to build the core network with the edge network consisting of Cisco 7613 routers.

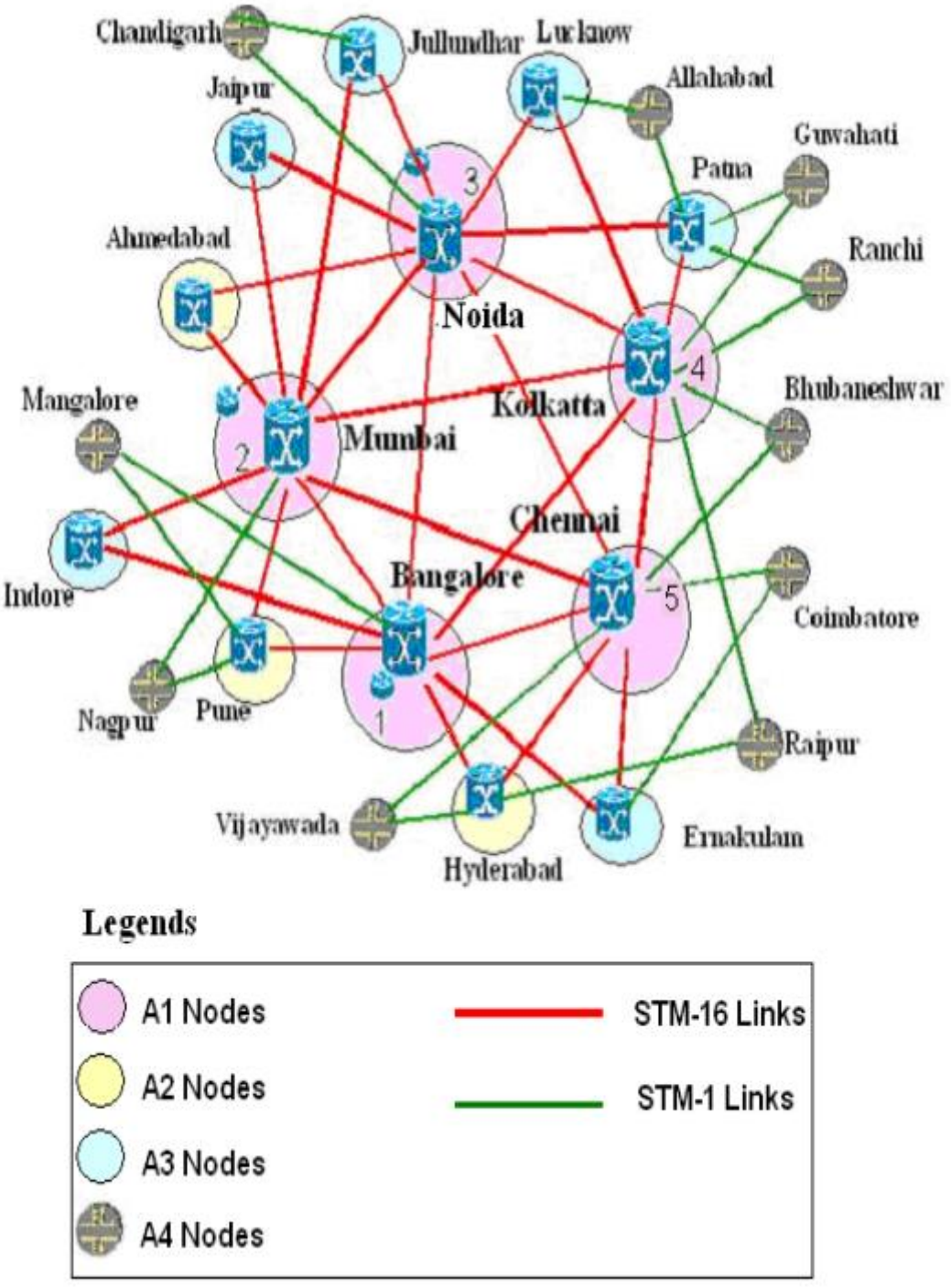
The NIB-2 Layer-1 core network (A1, A2 and A3) constitutes high speed Backbone (STM-16) that comprise of fully or partially meshed Core routers with built-in redundancies supporting MPLS protocol with link capacities in accordance with the traffic justification. Its function is primarily limited to high-speed packet forwarding between the core nodes. The five major nodes of Mumbai, Bangalore, Noida, Kolkatta and Chennai are the A1 nodes and are configured in full mesh with link bandwidths of STM-16. The Core routers at A2, A3 and A4 cities are dual homed to the nearest A core routers. The 9 nodes of Pune, Hyderabad Ahmedabad, Lucknow, Jullunder, Jaipur, Indore, Ernakulam and Patna are the A2 and A3 nodes and are configured in dual mesh with link bandwidths of STM-16. The Juniper based MPLS infrastructure at Chandigarh, Allahabad, Ranchi, Guwahati, Bhubaneshwar, Raipur, Vijayawada, Coimbatore, Mangalore, and Nagpur classify as A4 cities, which are dual homed to nearest A locations with link bandwidth of STM-1.

The Layer-2 Edge network constitutes the second layer of the IP backbone network comprising of 71 cities consisting of MPLS “Provider Edge” routers (or “PE” routers) connected to the Core layer either locally through the Gigabit Ethernet switch or remotely through STM-1 links. The Edge network architecture provides for dual homing links from the Edge router to be terminated one each on the dual redundant Core routers to which the Edge router is parented. The NIB-II Edge nodes are classified into five categories according to their respective sizes. The A1 node represents the 5 core nodes of Noida, Mumbai, Bangalore, Chennai and Kolkatta. A2 represents nodes in the 3 cities of

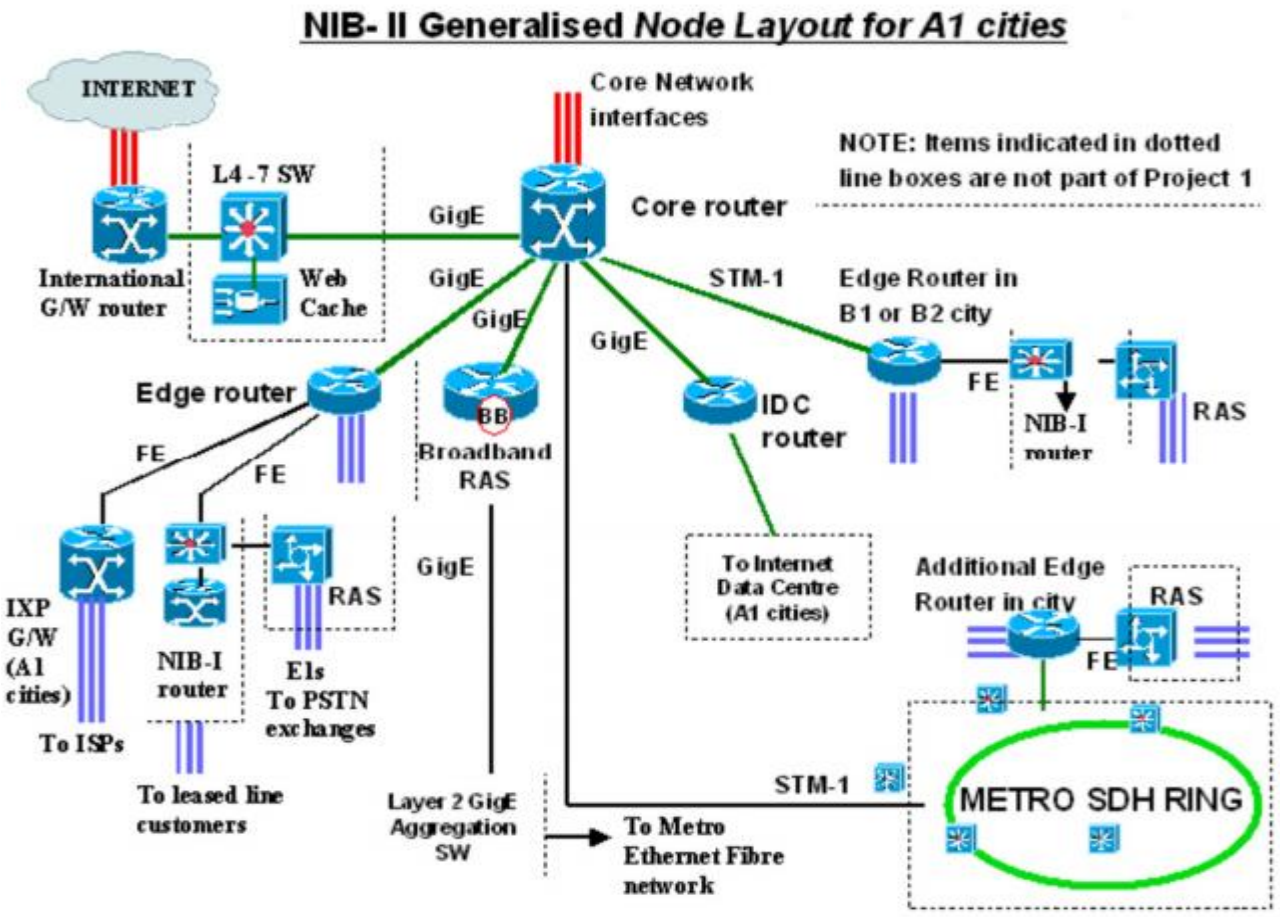
Pune, Hyderabad and Ahmedabad. A3 represents the 6 nodes in Ernakulam, Lucknow, Jaipur, Jullandhar, Indore and Patna. The B nodes (47 in total) are classified into 21 * B1 nodes du

The function of this Edge layer is aggregation of customer traffic. This layer enforces QoS and other administrative policies. This layer provides customer access through three mechanisms, (a) Dialup (b) Dedicated Access and (c) Broadband Access. This layer provides connectivity to secure VPNs as well as to Internet Data Centers. The Interior gateway protocol used is OSPF and is based on a single Area model, which would offer a scalable, reliable, & redundant architecture, increasing efficiencies in the dynamics of the carrier grade IP Network of BSNL.

NETWORK LAY-OUT OF NIB-II PROJECT-1



Connectivity Details Each A1 location is fully meshed with other four A1s through STM-16 links, & will have A2 & A3 connected through STM-16 links and A4, B1 & B2 locations connected through STM-1 links



Provision of Internet and MPLS-VPN Services by BSNL

1. Round the clock Maintenance of NIB Node (24 x 7) basis.

2. Periodic monitoring and augmentation of National and International Bandwidth and dynamic distribution of traffic to ensure effective utilization of links

3. Provision of Layer-3 MPLS VPN Services

4. Provision of Layer-2 MPLS VPN Services

5. Encryption services

6. Multicast services

7. Firewall Services

8. Voice Over IP (VOIP) services

9. Network Address Translation (NAT) services

10. Provision of IP-VPN services

11. Provision of Internet Leased lines and Dial-up internet connections

12. Fault reporting and redressal for internet and VPN Links

13. Guaranteed up time of circuits up to 99% in core network

14. Ensuring minimum latency and delay in browsing (less than one minute)

15. Maintaining Quality of Service.

DIGITAL SUBSCRIBER LINE

An emerging application of network elements having great near-term importance is the Digital Subscriber Line. This facility does not necessarily provide switched service in the usual sense—its most visible application is for "always-on" access to an ISP. In that sense, it is a private-line channel from one user to a DSL access multiplexer (DSLAM). The DSLAM aggregates the data traffic from a group of users, usually by packet switching via Asynchronous Transfer Mode (ATM) techniques in the interoffice environment.

This is an emerging technology whose standards are still evolving, with a variety of pre-standard and proprietary versions being made available. Some implementations of them use equipment built into the line card of a digital switch or DLC terminal to minimize the effort of installation. The core idea is to send bidirectional digital data, usually on a two-wire loop, at previously unattainable speeds by use of combinations of signal processing, automatic equalization, error correction, and echo cancellation. The base facility is the nonloaded copper subscriber loop. The terminals compensate for signal attenuation at high frequencies, irregularities in transmission and echoes caused by bridged taps and changes in gauge at splices, crosstalk from the other direction of transmission and other DSL systems in the same cable, errors caused by impulse noise, and even radio-frequency interference from broadcast stations.

On a given loop, the speed attainable may be controlled by either the technical conditions of the loop or by marketing considerations of the service provider.

Types of DSL:

xDSL, a term that encompasses the broad range of digital subscriber line (DSL) services, offers a low-cost, high-speed data transport option for both individuals and businesses, particularly in areas without access to cable internet.

xDSL provides data transmission over copper lines, using the local loop, the existing outside-plant telephone cable network that runs right to your home or office. DSL technology is relatively cheap and reliable.

While the quality of the signals in all xDSL technologies deteriorates as distance increases, some types of DSL are more suitable than others to a specific distance and bandwidth demands.

This is the most common form for residential users because download speeds are significantly higher than upload speeds, matching typical internet usage like streaming or browsing.

- ADSL/ADSL2+: Offers download speeds up to 24 Mbps.
- ADSL Lite (G.Lite): A slower, "splitterless" version that users can install themselves, offering up to 1.5 Mbps.
- RADSL (Rate-Adaptive DSL): Automatically adjusts speed based on the quality and distance of the phone line.

Symmetric DSL (SDSL)

SDSL provides equal speeds for both uploading and downloading. It is primarily used by businesses that need to host servers or conduct high-quality video conferencing.

- HDSL (High-bit-rate DSL): An early symmetric technology often used as a cost-effective alternative to T1 lines, typically requiring two or more copper pairs.
- SHDSL (Single-pair High-speed DSL): A newer standard that can achieve higher symmetric speeds (up to 5.7 Mbps) over a single pair of wires.

High-Performance Variants

- VDSL / VDSL2 (Very-high-bit-rate DSL): Provides extremely high speeds (up to 100 Mbps or more) but only over very short distances from the provider's equipment. It is often used in Fiber-to-the-Cabinet (FTTC) setups.
- G.fast: A next-generation technology capable of gigabit speeds (up to 1 Gbps) over very short copper loops, serving as a bridge to full fiber.

Comparison Table

Type	Symmetry	Typical Download Speed	Key Use Case
ADSL	Asymmetric	Up to 24 Mbps	Home internet, streaming
SDSL	Symmetric	Up to 2.3 Mbps	Business, cloud backups
VDSL2	Both	Up to 100 Mbps	HD video, Triple Play
IDSL	Symmetric	144 Kbps	Areas where standard DSL fails

Major Components of a DSL Broadband System

A DSL broadband network consists of both **customer-side components** and **service-provider-side components**, interconnected through the copper access network.

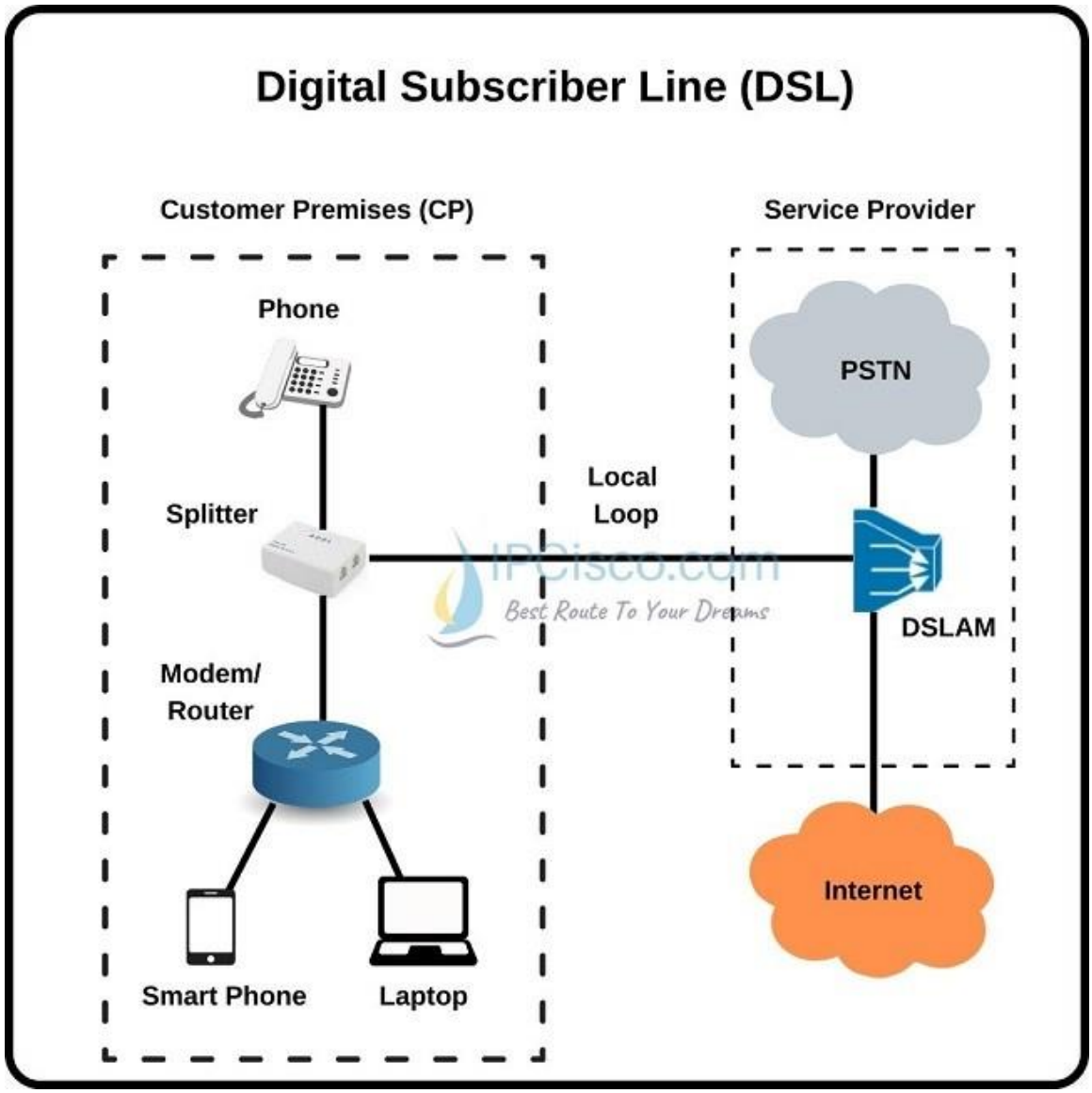
1 Customer Premises Equipment (CPE)

a) DSL Modem

The DSL modem is installed at the subscriber's premises and converts digital data from the user's device into DSL signals suitable for transmission over copper telephone lines. It also demodulates incoming signals from the network.

Functions:

- Modulation and demodulation of DSL signals
- Error detection and correction
- Interface between user equipment and access network



b) Splitter / Microfilter

A splitter or microfilter separates voice and data signals by frequency.

Purpose:

- Prevents interference between telephone voice signals and DSL data
- Ensures clear voice calls while broadband is active

2. Copper Local Loop

Local loop is the physical link that connects Customer to the Service Provider. The copper local loop is the twisted-pair telephone cable connecting the subscriber's premises to the nearest telephone exchange.

Characteristics:

- Uses existing PSTN infrastructure
- Performance depends on loop length, quality, and noise levels
- Susceptible to attenuation and crosstalk

3. Digital Subscriber Line Access Multiplexer (DSLAM)

The **DSLAM** is a key network element located at the telephone exchange or remote cabinet. It aggregates multiple DSL subscriber lines and connects them to the service provider's backbone network.

Functions:

- Terminates DSL lines from subscribers
- Aggregates traffic from multiple users
- Applies line profiles and bandwidth control
- Forwards traffic towards the IP/MPLS network

In BSNL networks, DSLAMs act as the primary access devices for copper-based broadband services.

4. Aggregation Network

The aggregation network connects DSLAMs to higher-level network devices such as aggregation switches or routers.

Features:

- Uses Ethernet or IP-based transport
- Supports VLAN tagging and traffic segregation
- Ensures efficient traffic flow toward the core network

5. Broadband Network Gateway (BNG)

The **BNG** (also known as BRAS) is responsible for subscriber authentication, authorization, and accounting.

Functions:

- PPPoE session termination
- User authentication using RADIUS servers
- IP address allocation
- Policy enforcement and bandwidth management

6. Authentication and Billing Systems

a) RADIUS Server

- Authenticates users
- Maintains subscriber profiles
- Supports billing and usage records

b) OSS/BSS Systems

- Network monitoring and fault management
- Customer provisioning
- Billing and service management

Working Principle of DSL Broadband

1. User connects to the Internet via a DSL modem.
2. Voice and data signals are separated using a splitter.
3. Data travels over the copper local loop to the DSLAM.
4. DSLAM aggregates traffic from multiple users.
5. Aggregated traffic passes through the aggregation network.
6. BNG authenticates the user and assigns IP resources.
7. Traffic enters the core IP/MPLS network and reaches the Internet.

Advantages of DSL Broadband

- Utilizes existing copper infrastructure
- Simultaneous voice and data transmission
- Cost-effective deployment
- Wide coverage in legacy telecom networks

Role of DSL in BSNL Broadband Network

DSL technology formed the backbone of BSNL's initial broadband rollout. Despite the growing adoption of FTTH, DSL continues to serve legacy customers and areas where fiber deployment is challenging. It remains an important access technology in BSNL's broadband ecosystem.

FIBER OPTIC COMMUNICATION

Fiber optic communication is the backbone of modern telecommunication networks. optical fiber communication is used for for providing high-speed broadband, mobile backhaul, leased lines, and long-distance transmission. Optical fiber has replaced traditional copper networks due to its high bandwidth, low signal loss, and high reliability**.**

BSNL adopted fiber optic communication to:

- Support high-speed internet services (FTTH)
- Carry large volumes of voice and data traffic
- Provide reliable mobile backhaul
- Reduce transmission losses
- Expand services in rural and urban areas

Types of Optical Fibers Used in BSNL

1 Single Mode Fiber (SMF)

- Used for long-distance communication
- Small core diameter (~9 µm)
- High bandwidth
- Low attenuation

Applications in BSNL:

- FTTH
- Backbone networks
- Mobile backhaul

2 Multi Mode Fiber (MMF)

- Used for short distances
- Larger core diameter (50/62.5 µm)
- Higher attenuation than SMF

Limited use in BSNL (mainly LANs)

Fiber Optic Network Architecture

1 Core Network

- High-capacity fiber rings
- DWDM systems
- IP/MPLS backbone

2 Access Network

- FTTH
- Fiber to towers (mobile)

3 Distribution Network

- Splitters
- Joint enclosures

FIBER TO THE HOME (FTTH) & PON TECHNOLOGY

Growing demand for high speed internet is the primary driver for the new access technologies which enable experiencing true broadband. Today‟s, there is an increasing demand for high bandwidth services in market around the world. However, traditional technologies, like Digital Subscriber Line (DSL) and cable modem technologies, commonly used for "broadband access," which have access speeds to the order of a megabit per second, with actual rates strongly dependent on distance from the exchange (central office) and quality of the copper infrastructure, can not fulfill today‟s customer demand for bandwidth hungry applications such as high-definition TV, high-speed Internet access, video on demand, IPTV, online gaming, distance learning etc. Amongst various technologies, the access methods based on the optical fiber has been given extra emphasis keeping into long term perspective of the country. It has many advantages over other competing access technologies of which „Being Future Proof‟ and providing „True Converged Network‟ for high quality multi-play are the salient ones. The stable and long term growth of Broadband is, therefore, going to be dependent on robust growth of fiber in the last mile.

However, for providing multi-play services (voice, video, data etc.) and other futuristic services fiber in the local loop is must. The subscriber market for multi-play is large and growing and includes both residences and businesses. Businesses need more bandwidth and many of the advanced services that only fiber can deliver. All view Multi- Play as a strong competitive service offering now and into the future and are looking at fiber as the way to deliver. Optical fiber cables have conventionally been used for long-distance communications. However, with the growing use of the Internet by businesses and general households in recent years, coupled with demands for increased capacity, the need for optical fiber cable for the last mile has increased. A primary consideration for providers is to decide whether to deploy an active (point-to-point) or passive (point-to-multipoint) fiber network.

1.3 FIBER TO THE X (FTTX)

Today, fiber networks come in many varieties, depending on the termination point: building (FTTB), home (FTTH), curb (FTTC) etc. For simplicity, most people have begun to refer to the fiber network as FTTx, in which x stands for the termination point. As telecommunications providers consider the best method for delivering fiber to their subscribers, they have a variety of FTTx architectures to consider. FTTH, FTTB, and FTTC each have different configurations and characteristics.

FTTH (Fiber To The Home):

FTTH is now a cost-effective alternative to the traditional copper loop. "Fiber to the Home" is defined as a telecommunications architecture in which a communications path is provided over optical fiber cables extending from an Optical

Line Terminal (OLT) unit located in central office (CO) connects to an Optical Network Terminal (ONT) at each premise. Both OLTs and ONTs are active devices. This communications path is provided for the purpose of carrying telecommunications traffic to one or more subscribers and for one or more services (for example Internet Access, Telephony and/or Video-Television). FTTH consists of a single optical fiber cable from the base station to the home. The optical/electrical signals are converted and connection to the user‟s PC via an Ethernet card. FTTH is the final configuration of access networks using optical fiber cable.

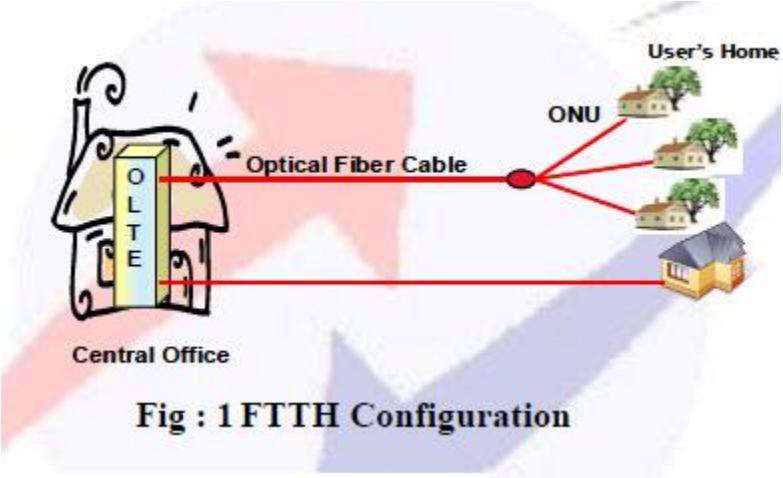


Fig : 1 FTTH Configuration

FTTB (Fiber To The Building):

“Fiber to the Building” is defined as a telecommunications architecture in which a communications path is provided over optical fiber cables extending from an Optical Line Terminal (OLT) unit located in central office (CO) connects to an Optical Network Unit (ONU at the boundary of the apartment or office or building enclosing the home or business of the subscriber or set of subscribers, but where the optical fiber terminates before reaching the home living space or business office space and where the access path continues to the subscriber over a physical medium other than optical fiber (for example copper loops).

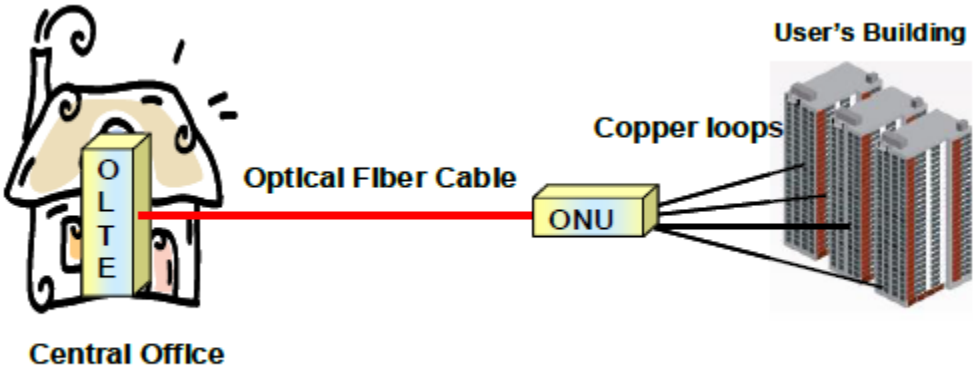


Fig : 2 FTTB Configuration

FTTC (Fiber To The Curb):

A method of installing optical fiber cable by the curb near the user‟s home.
An optical communications system is then used between the ONU installed outside (such as near the curb or on Street Cabinet) from the installation center. Finally, copper cable is used between the ONU and user.

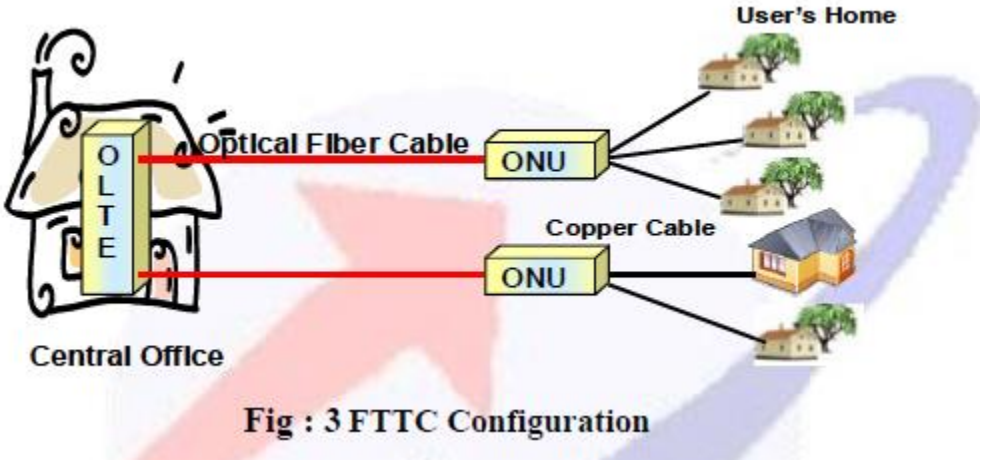


Fig : 3 FTTC Configuration

WHY FTTH?

FTTH is a true multi-service communications access which simultaneously handles several phone calls, TV/video streams, and Internet users in the home/office. There are several advantages of deploying FTTH over other traditional access technologies as given below:

- FTTH provides end-users with a broad range of communications and
- entertainment services, and faster activation of new services.
- Competition is beginning to offer a “multi-play” (i.e., voice, video,
- data etc) bundle.
- FTTH provides Service Provider‟s with the ability to provide “cutting
- edge” technology and “best-in-class” services.
- Deploying a fiber optic cable to each premise will provide an
- extraordinary amount of bandwidth for future services.
- FTTH provides carriers with an opportunity to increase the average revenues per user (ARPU), to reduce the capital investment required to deliver multiple services, and to lower the costs of operating networks (fewer outdoor electronics, remote management, ..) will result in less operational expense.
- FTTH provides the community in which it‟s located with superior communications which enhance the efficiency of local business and thus deliver economic advantage for the community.
- Around the world FTTH is viewed as strategic national infrastructure similar to roads, railways, and telephone networks.

TECHNOLOGY OPTIONS FOR FTTH ARCHITECTURE:

When deciding which architecture to select a provider has many things to consider including the existing outside plant, network location, the cost of deploying the network, subscriber density and the return on investment (ROI). At present different technology options are available for FTTH architecture .The network can be installed as an **active optical network**, or **a passive optical network (PON)**. **1.5.1 Active Optical Network**
The active optical network implementation is known as the "Active Node" and is simply described as a "point-to-point" solution. Subscribers are provided a dedicated optical cable and the distribution points are handled by active optical equipment. These active architectures have been setup as either "**Home Run Fiber**" or "**Active Star Ethernet**".

1. Home Run Fiber (Point-to-Point) Architecture

A Home Run Fiber architecture is one in which a dedicated fiber line is connected at the central office (CO) to a piece of equipment called an Optical Line Terminator (OLT). At the end user location, the other side of the dedicated fiber connects to an Optical Network Terminal (ONT). Both OLTs and ONTs are active, or powered, devices, and each is equipped with an optical laser The Home Run fiber solution offers the most bandwidth for an end user and, therefore, also offers the greatest potential for growth. Over the long term Home Run Fiber is the most flexible architecture; however, it may be less attractive when the physical layer costs are considered. Because a dedicated fiber is deployed to each premise, Home Run Fiber requires the installation of much more fiber than other options, with each fiber running the entire distance between the subscriber and the CO.

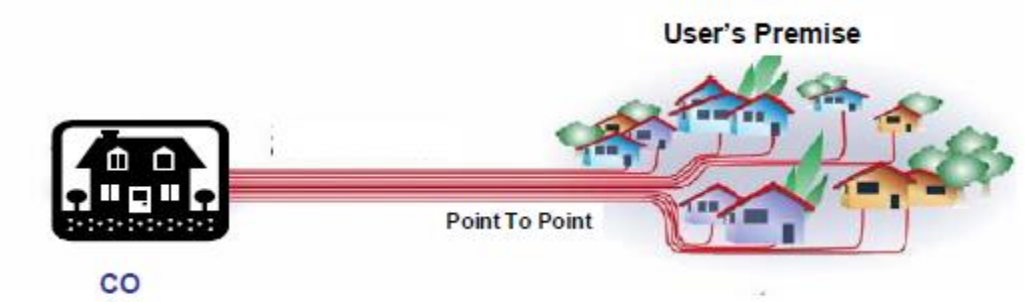


Fig : 4 Home Run Fiber (Point-to-Point) architecture

2.Active Star Ethernet (Point-to-Multi Point) Architecture

Active Star Ethernet (ASE) architecture is a point-to-Multi-point architecture in which multiple premises share one feeder fiber through a Ethernet switch located between the CO and the served premises.

With Active Star Ethernet (ASE) architecture, end users still get a dedicated fiber to their location; however, the fiber runs between their location and Ethernet switch. Like Home Run Fiber, subscribers can be located as far away from the

Ethernet switch and each subscriber is provided a dedicated “pipe” that provides full bidirectional bandwidth. Active Star Ethernet reduces the amount of fiber deployed; lowering costs through the sharing of fiber.

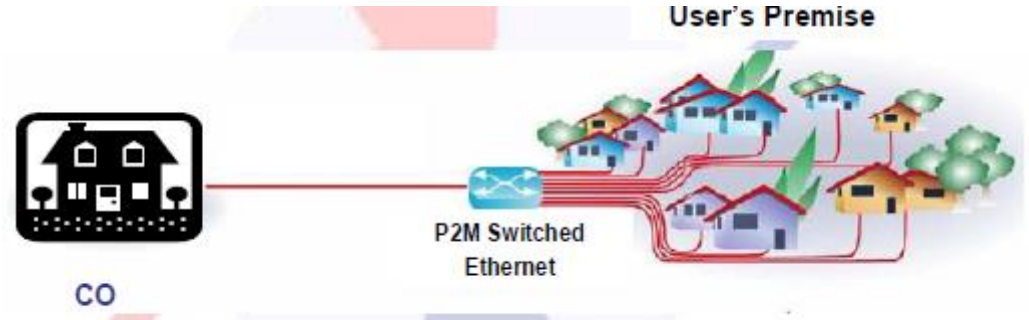


Fig : 5 Active Star Ethernet (ASE) architecture

PASSIVE OPTICAL NETWORK (POINT-TO-MULTIPOINT) ARCHITECTURE

The key interface points of PON are in the central office equipment, called the OLT for optical line terminal, and the CPE, called ONU for optical network unit (for EPON) and ONT for optical network terminal (for GPON). Regardless of nomenclature, the important difference between OLT and ONT devices is their purpose. OLT devices support management functions and manage maximum up to 128 downstream links. In practice, it is common for only 8 to 32 ports to be linked to a single OLT in the central office. On the other hand the ONT (or ONU) devices in the CPE support only their own link to the central office. Consequently, the ONT/ONU devices are much less expensive while the OLTs tend to be more capable and therefore more expensive.

OLT:

The OLT resides in the Central Office (CO). The OLT system provides aggregation and switching functionality between the core network (various network interfaces) and PON interfaces. The network interface of the OLT is typically connected to the IP network and backbone of the network operator. Multiple services are provided to the access network through this interface,.

ONU/ONT:

This provides access to the users i.e. an External Plant / Customer Premises equipment providing user interface for many/single customer. The access node installed within user premises for network termination is termed as ONT. Whereas access node installed at other locations i.e. curb/cabinet/building, are known as ONU. The ONU/ONT provide, user interfaces (UNI) towards the customers and uplink interfaces to uplink local traffic towards OLT.

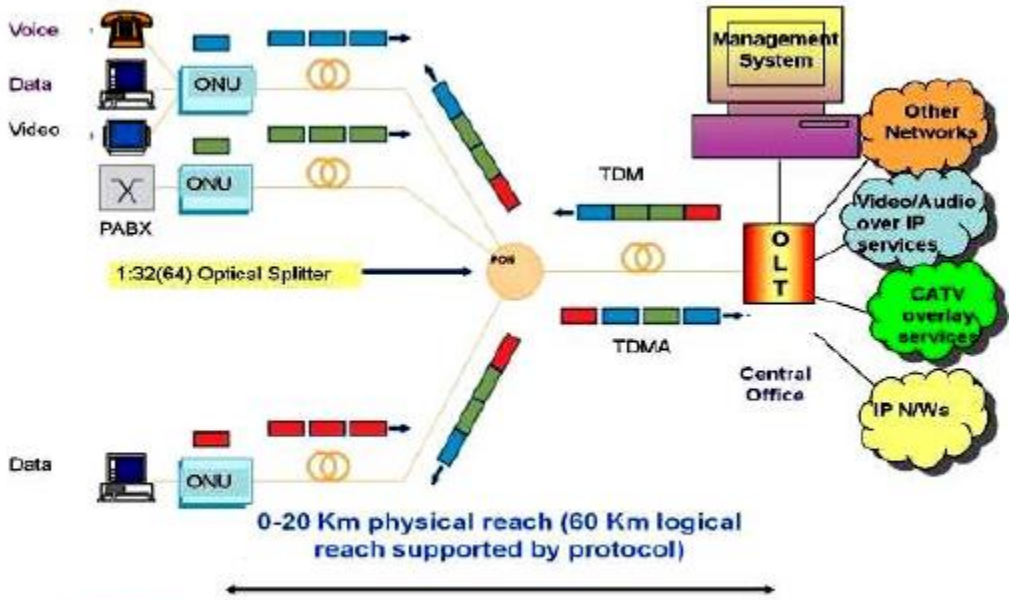


Fig : 6 PON Architecture

PON:

Distributed or single staged passive optical splitters/combiners provides connectivity between OLT & multiple ONU/ONTs through one or two optical fibers. Optical splitters are capable of providing up to 1:64 optical split, on end to end basis. These are available in various options like 1:4, 1:8, 1:16, 1:32 and 1:64.

NMS:

Management of the complete PON system from OLT.

- One OLT serves multiple ONU/ONTs through PON
- TDM/TDMA protocol between OLT & ONT
- Single Fiber/ Dual Fiber to be used for upstream & downstream
- Provision to support protection for taking care of fiber cuts, card failure etc.
- Maximum Split Ratio of 1:64
- Typical distance between OLT & ONT can be greater than 15Km (with unequal splitting - up-to 35Km)
- Downstream transmission I.e. from OLT to ONU/ONT is usually TDM
- Upstream traffic I.e. from ONU/ONT to OLT is usually TDMA
- PON system may be symmetrical or asymmetrical
- PON and fiber infrastructure can also be used for supporting any one way distributive services e.g. video at a different wavelength

PON is configured in full duplex mode in a single fiber point to multipoint (P2MP) topology. Subscribers see traffic only from the head end, and not from each other. The

OLT (head end) allows only one subscriber at a time to transmit using the Time Division Multiplex Access (TDMA) protocol. PON systems use optical splitter architecture, multiplexing signals with different wavelengths for downstream and upstream.

SPLITTER CONFIGURATIONS

There are two common splitter configurations are being used for PON architecture i.e. **centralized and the cascaded** approaches.

Centralized Splitter Approach

In Centralized Splitter Approach typically uses a 1x32 splitter in an outside plant enclosure, such as a fiber distribution terminal. In the case of a 1x32 splitter, each device is connected to an OLT in the central office. In this approach, optical splitters are concentrated in a single location from which all customer"s optical network terminals (ONTs) at 32 homes are connected as shown in fig. 7.

Fig : 7 Centralized Splitter Approach

Cascaded Splitter Approach

A cascaded split configuration results in pushing splitters deeper into the network as shown in fig.8. Passive Optical Networks (PONs) utilize splitter assemblies to increase the number of homes fed from a single fibre. In a Cascaded PON, there will be more than one splitter location in the pathway from central office to customer. Currently, standard splitter formats range from 1 x 2, 1 x 4, 1 x 8, 1 x 16 and 1 x 32 so a network might use a 1 x 4 splitter leading to a 1 x 8 splitter further downstream in four separate locations. Optimally, there would eventually be 32 fibers reaching the ONTs of 32 homes.

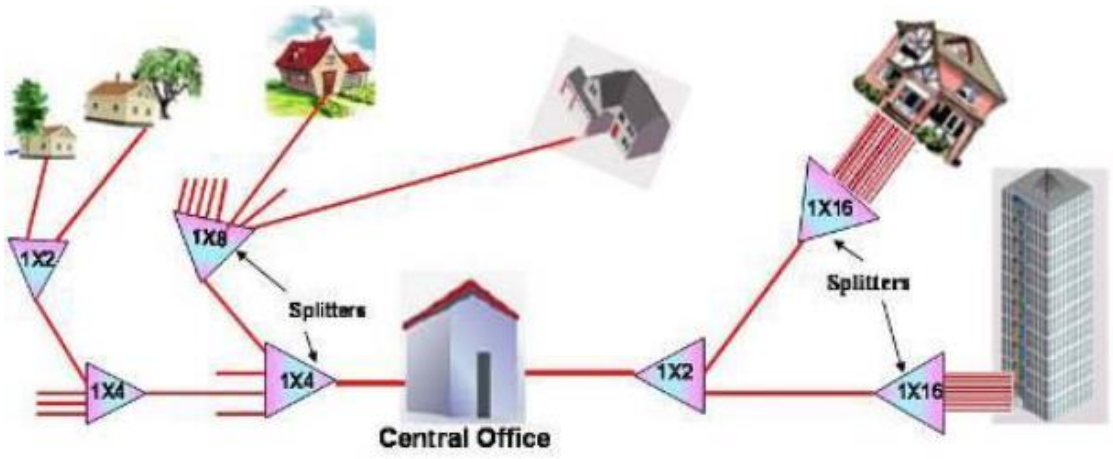


Fig : 8 Cascaded Splitter Approach

There are several "flavors" of PON technology, i.e. new access technology named **APON** (ATM Passive Optical Network), **BPON** (Broadband Passive Optical Networking), **EPON** (Ethernet Passive Optical Networking) and **GPON** (Gigabit Passive Optical Networking) which delivers gigabit-per-second bandwidths while offering the low cost and reliability.

APON

ATM PON (APON) was standardized by the ITU in 1998 and was the first PON standard developed. It uses ATM principles as the transport method and supports 622 Mbps downstream services and 155 Mbps upstream service shared between 32-64 splits over a maximum distance of 20 km.

BPON

Shortly after APON, Broadband PON (BPON) followed and is very similar to APON. BPON also uses ATM, but it also boasts superior features for enhanced broadband services like video. BPON has the higher performance numbers then APON pre-splitting maximum of 1.2 Gbps downstream and 622 Mbps upstream.

EPON

The IEEE standardized Ethernet PON (EPON) in the middle of 2004. It uses Ethernet encapsulation to transport data over the network. EPON operates at rates of 1.25Gbps both downstream and upstream (symmetrical), using 8B/10B encoding over a maximum reach of 20. EPON is also called now as Gigabit Ethernet PON (GE-PON). It is defined as a single fiber network using Wavelength Division Multiplexing (WDM) operating at a wavelength of 1490 nm downstream and 1310 nm upstream. This leaves the 1550 nm window open for other services, such as analog video or private WDM circuits.

GPON

Gigabit PON (GPON) is the next generation of PON‟s from the line of APON and BPON. The ITU has approved standard G.984x for it. GPON will support both ATM and Ethernet for Layer 2 data encapsulation so is clearly an attractive proposition. GPON supports two methods of encapsulation: the ATM and GPON encapsulation method (GEM). GEM supports a native transport of voice, video, and data without an added ATM or IP encapsulation layer. GPONs support downstream rates as high as 2.5 Gbits/sec and an upstream rate from 155 Mbits/sec to 2.5 Gbits/sec. BSNL is procuring the GPON that will support downstream rate 2.5Gbps and upstream 1.25 Gbps.

BSNL uses **Gigabit Passive Optical Network (GPON)** standardized under **ITU-T G.984**.

Features	**BPON**	**GPON**	**EPON**
Responsible Standard body	FSAN & ITU-T SG15 (G-983 Series)	FSAN & ITU-T SG15 (G-984 Series)	IEEE 802.3ah
Bandwidth	Down Stream up to 622 Mbps Up Stream up to 155.52 Mbps	Down Stream up to 2.5 Gbps Up Stream up to 2.5 Gbps	Down Stream up to 1.25 Gbps Up Stream up to 1.25 Gbps
Downstream	1490 nm & 1550 nm	1490 nm & 1550 nm	1490 nm
Upstream	1310 nm	1310 nm	1310 nm
Layer-2 Protocols	ATM	ATM, Ethernet, TDM over GEM	Ethernet
Max. Distance (OLT to ONU)	20 Km	20 Km(supports logical reach up to 60 Km)	10 & 20 Km
Split Ratio	1:16, 1:32 and 1:64	1:16, 1:32 and 1:64	1:16 and 1:32
Line Codes	NRZ (Scrambled)	NRZ (Scrambled)	8B/10B
No. of fibers	1 or 2	1 or 2	1

From the BSNL network point of view GPON, being the TDM based technology, shall integrate into the existing switching network. While the VOIP feature in the GE-PON provides easy migration path to the **Next Generation Network (NGN)** of the BSNL. Since TDM switches and the NGN are to coexist for up to 2015 as per the NGN vision plan both GPON and GE-PON are the most suitable PON technologies for BSNL.

IP/MPLS

Bharat Sanchar Nigam Limited (BSNL) operates one of the **largest and most complex telecom networks in India**, providing services such as broadband, FTTH, leased lines, MPLS VPNs, mobile backhaul, and government connectivity. To efficiently support these services with scalability, reliability, and Quality of Service (QoS), BSNL has deployed **IP/MPLS technology** across its **core and aggregation networks**.

IP/MPLS combines the flexibility of **Internet Protocol (IP)** with the speed and traffic control capabilities of **Multiprotocol Label Switching (MPLS)**, making it the backbone of BSNL's Next Generation Network (NGN).

Need for IP/MPLS

Traditional IP routing is based on hop-by-hop destination lookup, which is:

- Slow for large-scale networks
- Poor in traffic engineering
- Weak in QoS support

BSNL requires a transport network that can:

- Carry **voice, data, video** on the same infrastructure
- Support **enterprise VPNs**
- Ensure **QoS for IPTV, VoIP, and mobile traffic**
- Scale across **pan-India geography**

➡ **IP/MPLS technology fulfills all these requirements**

What is IP/MPLS Technology?

IP/MPLS is a packet-switched networking technology where:

- IP routing decides **path selection**
- MPLS labels decide **packet forwarding**

Instead of examining IP headers at every hop, MPLS routers forward packets using **short fixed-length labels**, enabling faster and more deterministic packet movement.

Logical Architecture

```
Customer / Access Nodes
        ↓
Aggregation IP/MPLS Routers
        ↓
Core IP/MPLS Routers
        ↓
Internet / NIB / Data Centers
```

IP/MPLS Router Roles in BSNL

1 Label Edge Router (LER)

- Located at edge of MPLS domain
- Pushes (Ingress) and Pops (Egress) MPLS labels
- Connects customer traffic to MPLS backbone

2 Label Switching Router (LSR)

- Located inside MPLS core
- Performs label swapping
- High-speed packet forwarding

Working of IP/MPLS in BSNL

1. Customer IP packet enters BSNL network
2. Ingress LER classifies packet into FEC
3. MPLS label is attached
4. Packet traverses MPLS core using label switching
5. Egress LER removes label
6. Packet delivered to destination

MPLS Services Provided by BSNL

1 MPLS Layer-3 VPN

- Secure enterprise connectivity
- VRF-based isolation
- Used by banks, PSUs, government departments

2 MPLS Layer-2 VPN

- Transparent Ethernet services
- VPLS and VPWS

QoS in BSNL IP/MPLS Network

IP/MPLS enables BSNL to:

- Prioritize voice and video traffic
- Guarantee bandwidth
- Reduce latency and jitter

QoS is implemented using:

- MPLS EXP bits
- Traffic shaping and policing
- Priority queuing

DWDM TECHNOLOGY IN BSNL

Bharat Sanchar Nigam Limited (BSNL) operates one of the largest optical fiber backbone networks in India. To meet the rapidly increasing demand for **high bandwidth, long-distance transmission, and multiple services**, BSNL has adopted **Dense Wavelength Division Multiplexing (DWDM)** technology in its **core and long-haul transmission network**.

DWDM enables BSNL to transmit **multiple high-speed data channels simultaneously over a single optical fiber**, significantly increasing fiber capacity without laying new fiber.

Need for DWDM in BSNL Network

The major drivers for deploying DWDM include:

- Explosive growth of broadband and FTTH traffic
- Mobile backhaul for 4G/5G networks
- MPLS VPN and leased line services
- Efficient utilization of existing fiber infrastructure
- Requirement of ultra-high capacity backbone

➡ DWDM allows BSNL to scale capacity from **10 Gbps to multiple Tbps** on the same fiber.

What is DWDM Technology?

Dense Wavelength Division Multiplexing (DWDM) is an optical multiplexing technique where:

- Multiple optical signals
- Each at a **different wavelength (λ)**
- Are transmitted simultaneously through a **single optical fiber**

Each wavelength acts as an **independent communication channel**.

4. DWDM Architecture in BSNL

Basic DWDM Block Diagram (Conceptual)

```
IP/MPLS Router → Transponder → MUX → Optical Fiber → DEMUX →
Transponder → IP/MPLS Router
```

Key Components of DWDM System

1 Transponder

- Converts electrical signals into optical signals
- Assigns specific wavelength
- Supports 10G / 40G / 100G

2 Multiplexer (MUX)

- Combines multiple wavelengths
- Sends them into a single fiber

3 Optical Fiber

- Single-mode fiber (SMF)
- Used for long-haul transmission

4 Optical Amplifiers

BSNL extensively uses **EDFA (Erbium Doped Fiber Amplifier)**.

- Amplifies optical signals directly
- No electrical conversion
- Used every 80–100 km

5 Demultiplexer (DEMUX)

- Separates wavelengths at receiving end

DWDM Network Topology in BSNL

BSNL typically uses:

- **Ring topology** (for protection)
- **Mesh topology** (for national backbone)

Advantages

- High reliability
- Fast restoration during fiber cuts

Integration of DWDM with IP/MPLS in BSNL

DWDM forms the **physical transport layer**, while IP/MPLS operates on top.

```
Services → IP/MPLS → DWDM → Optical Fiber
```

- DWDM provides bandwidth
- IP/MPLS provides intelligence (routing, QoS)

Channel Spacing and Capacity

- Channel spacing: **100 GHz / 50 GHz**
- Number of wavelengths: **40 / 80 / 96**
- Capacity per wavelength: **10G / 100G**

➡ Total fiber capacity can exceed **8 Tbps**

Advantages of DWDM

- Massive bandwidth expansion
- Efficient fiber utilization
- Low latency
- Scalable and future-proof
- Reduced operational cost

Applications of DWDM in BSNL

- National IP/MPLS backbone
- FTTH aggregation transport
- Mobile backhaul
- Inter-circle connectivity
- Leased line services

AGGREGATION SWITCHES

In modern broadband and telecom networks, data traffic generated by a large number of access devices must be efficiently collected and transported to the core network. This task is performed by the **aggregation layer**, where **aggregation switches** play a critical role. Aggregation switches act as an intermediate layer between **access networks (FTTH, DSL, mobile access)** and the **core IP/MPLS network**.

In BSNL's broadband architecture, aggregation switches ensure **high-capacity traffic concentration, Quality of Service (QoS), redundancy, and seamless service delivery**.

Position of Aggregation Switches in Network Architecture

Aggregation switches are deployed between:

- **Access Layer** (OLT, DSLAM, BTS, ONT)
- **Core Layer** (IP/MPLS core routers)

Layered Architecture

```
Core IP/MPLS Routers
        ↑
Aggregation Switches
        ↑
Access Devices (OLT, DSLAM, BTS)
        ↑
Customer Premises
```

Functions of Aggregation Switches

1 Traffic Aggregation

Aggregation switches combine traffic from:

- Multiple OLTs
- DSLAMs
- Mobile access nodes
- Enterprise access switches

This reduces network complexity and improves manageability.

2 VLAN Handling

Aggregation switches support:

- VLAN tagging (IEEE 802.1Q)

- VLAN stacking (Q-in-Q)

In BSNL FTTH:

- Each service (Internet, IPTV, VoIP) uses separate VLANs
- Subscriber isolation is maintained

3 Quality of Service (QoS)

QoS mechanisms include:

- Traffic classification
- Priority queuing
- Bandwidth shaping
- Policing

This ensures:

- Voice and IPTV get priority
- Internet traffic is best-effort

4 Redundancy and High Availability

Aggregation switches support:

- Link aggregation (LACP)
- Redundant uplinks
- Spanning Tree Protocol (STP/RSTP/MSTP)

Ensures:

- Zero service interruption
- Fast recovery during failures

Technologies Used in Aggregation Switches

1 Layer-2 Switching

- MAC address learning
- Frame forwarding
- VLAN-based switching

2 Layer-3 Switching

Modern aggregation switches also support:

- IP routing
- Static and dynamic routing
- Inter-VLAN routing

Protocols supported:

- OSPF
- Static routing

3 MPLS Support

Some aggregation switches in BSNL:

- Support MPLS
- Act as Provider Edge (PE) devices
- Connect to MPLS core routers

Aggregation Switch Architecture

Role of Aggregation Switches in BSNL FTTH Network

Traffic Flow

```
ONT → OLT → Aggregation Switch → BNG → IP/MPLS Core → Internet
```

Functions

- Collect traffic from multiple OLTs
- Forward subscriber traffic to BNG
- Enforce service-level QoS

Aggregation Switches vs Core Routers

Feature	Aggregation Switch	Core Router
Main Function	Traffic concentration	Traffic routing
Port Density	High	Moderate
Routing	Limited	Advanced
MPLS	Optional	Mandatory
Location	District / Exchange	Circle / National

Security Features

Aggregation switches provide:

- Port security
- MAC filtering
- VLAN isolation
- Storm control
- Access control lists (ACLs)

These features prevent:

- Unauthorized access
- Broadcast storms
- Network attacks

Advantages of Aggregation Switches

- Efficient bandwidth utilization
- Reduced core network load
- Scalable architecture
- Improved QoS
- Cost-effective design

Applications :

- FTTH broadband aggregation
- DSL broadband networks
- Mobile backhaul aggregation
- Enterprise network concentration
- Government project connectivity

LAYER-2 AND LAYER-3 SWITCHES

Modern broadband and telecom networks require high-speed, reliable, and scalable data forwarding mechanisms to handle massive traffic generated by broadband, FTTH, mobile, and enterprise services. **Layer-2 (L2) and Layer-3 (L3) switches** play a vital role in achieving this objective by combining **switching efficiency** with **routing intelligence**.

In BSNL's broadband and IP/MPLS network architecture, L2/L3 switches are widely deployed in **access and aggregation layers** to provide VLAN-based traffic segregation, inter-VLAN routing, Quality of Service (QoS), redundancy, and secure service delivery.

OSI Model and Switch Classification

OSI Layer	Function	Device
Layer 2	Data Link (MAC-based forwarding)	L2 Switch
Layer 3	Network (IP-based routing)	L3 Switch / Router

L2/L3 switches operate across **multiple OSI layers**, making them more versatile than traditional switches.

1. Layer-2 (L2) Switches

A **Layer-2 switch** forwards Ethernet frames based on **MAC addresses**. It operates at the **Data Link Layer** of the OSI model and does not perform IP routing.

Functions of L2 Switches

- MAC address learning
- Frame forwarding and filtering
- VLAN creation and management
- Broadcast domain segmentation
- Loop prevention using STP

L2 Switching Process

1. Frame received on a port
2. Source MAC learned and stored in MAC table
3. Destination MAC checked
4. Frame forwarded to appropriate port

VLAN Support

L2 switches support:

- IEEE 802.1Q VLAN tagging
- Access VLANs
- Trunk ports

In BSNL:

- Separate VLANs for Internet, IPTV, and VoIP
- Subscriber traffic isolation in FTTH networks

Limitations of L2 Switches

- Cannot route between VLANs
- Large broadcast domains
- Limited scalability

2. Layer-3 (L3) Switches

A **Layer-3 switch** combines the speed of switching with the routing capabilities of a router. It forwards packets based on **IP addresses** and supports routing protocols.

Functions of L3 Switches

- Inter-VLAN routing
- IP packet forwarding
- Static and dynamic routing
- Policy enforcement
- QoS and ACL implementation

Inter-VLAN Routing

L3 switches enable:

- Communication between VLANs
- Reduced dependency on external routers
- High-speed routing using ASICs

Routing Protocol Support

L3 switches support:

- Static routing

- OSPF
- RIP (limited use)
- Policy-based routing

Architecture of L2/L3 Switches

Hardware Architecture

- High-speed switching fabric
- ASIC-based forwarding
- Multiple Gigabit / 10G / 40G ports
- Redundant power supply
- Hot-swappable modules

Software Architecture

- Network Operating System (NOS)
- CLI-based configuration
- SNMP and NETCONF support
- Integration with NMS systems

Role of L2/L3 Switches in BSNL Network

1. Access Layer

- Connects ONTs, OLTs, DSLAMs
- Performs VLAN tagging
- Handles subscriber traffic segregation

2. Aggregation Layer

- Aggregates traffic from multiple access switches
- Performs inter-VLAN routing
- Forwards traffic to BNG or IP/MPLS core

Traffic Flow in BSNL FTTH Network

```
ONT → OLT → L2/L3 Aggregation Switch → BNG → IP/MPLS Core
```

QoS in L2/L3 Switches

L2/L3 switches implement:

- Traffic classification
- Priority queuing
- Bandwidth shaping
- Rate limiting

This ensures:

- Voice and IPTV traffic priority
- Controlled internet bandwidth usage

Security Features

- Port security
- MAC filtering
- VLAN isolation
- Access Control Lists (ACLs)
- Storm control

Used in BSNL to prevent:

- Unauthorized access
- Broadcast storms
- Network attacks

Comparison: L2 Switch vs L3 Switch vs Router

Feature	L2 Switch	L3 Switch	Router
MAC-based switching	Yes	Yes	No
IP routing	No	Yes	Yes
Speed	Very High	High	Moderate
QoS	Limited	Advanced	Advanced
Cost	Low	Medium	High

Advantages of L2/L3 Switches

- High-speed forwarding
- Reduced network latency
- Scalability
- Cost-effective routing
- Simplified network design

13. Applications in BSNL

- FTTH aggregation
- DSL broadband networks
- Mobile access aggregation
- Enterprise LAN/WAN
- Government connectivity projects

BROADBAND NETWORK GATEWAY (BNG)

With the rapid expansion of broadband services such as FTTH, DSL, IPTV, and enterprise internet, telecom operators require a centralized and intelligent node to manage subscriber traffic. The **Broadband Network Gateway (BNG)** plays this crucial role in modern broadband networks.

Definition of BNG

A **Broadband Network Gateway (BNG)** is a high-performance network device that:

- Terminates subscriber sessions
- Authenticates users
- Enforces service policies
- Routes broadband traffic to the core network

BNG is also known as **BRAS (Broadband Remote Access Server)** in traditional networks, but BNG provides more advanced features and scalability.

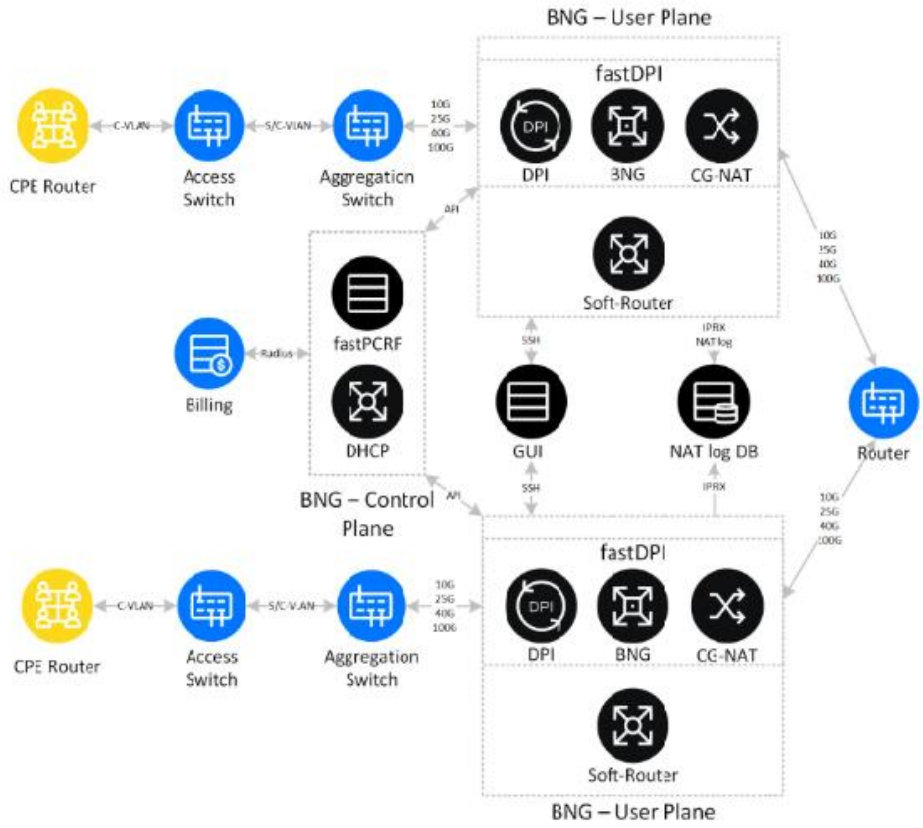
BSNL has been using Broadband Network Gateway (BNG) technology as part of its internet services for many years, with its first broadband services (DataOne) launched in **January 2005**. The BNG is a core component of a broadband network architecture, not a single new service introduced at a specific point in time.

More recently, BSNL has undertaken a nationwide project to upgrade its legacy BNG infrastructure to a more advanced version using the **Control and User Plane Separation (CUPS)** architecture. This upgrade project started in October 2022 and was successfully commissioned across India in **August 2024**.

Key aspects of BSNL's BNG deployment:

- **Original Broadband Services:** BSNL launched its initial broadband services using BNG infrastructure under the brand name "DataOne" on January 14, 2005.
- **Recent Upgrade (CUPS BNG):** The advanced CUPS BNG technology was introduced to enhance network efficiency, scalability, and service quality, especially for Fiber-to-the-Home (FTTH) customers.
- **Commissioning:** The first of the new high-speed CUPS BNGs was rolled out in Chennai on April 26, 2024, with the full national project completed and commissioned in August 2024.
- **Purpose:** This technology is essential for managing subscriber traffic, authenticating users, assigning IP addresses, and enforcing Quality of Service (QoS) policies across the network.

Position of BNG in BSNL Network Architecture



Logical Placement

```
Customer → ONT → OLT → Aggregation Switch → BNG → IP/MPLS Core → Internet
```

Network Layer

- Located at **aggregation layer**
- Interfaces with:
  - Access networks (OLT/DSLAM)
  - IP/MPLS core routers
  - AAA servers

Architecture of BNG

1 Hardware Architecture

- High-capacity routing engine

- Multi-core processors
- High-speed interfaces (10G / 40G / 100G)
- Redundant power supply
- Hot-swappable line cards

2 Software Architecture

BNG runs advanced network operating systems supporting:

- Subscriber management modules
- Policy enforcement engines
- QoS and traffic shaping
- Routing protocols (OSPF, BGP)

1 Subscriber Authentication

BNG authenticates users using:

- PPPoE (Point-to-Point Protocol over Ethernet)
- Credentials stored in AAA server

2 Authorization

After authentication, BNG:

- Assigns IP address
- Applies service profile
- Determines allowed bandwidth and services

3 Accounting

BNG records:

- Session duration
- Data usage
- Billing information

This data is sent to **AAA/Billing servers**.

Role of AAA in BNG Operation

AAA Components

- **Authentication** – Verifies user identity
- **Authorization** – Assigns service permissions

- **Accounting** – Tracks usage

Protocols used:

- RADIUS
- Diameter

PPPoE Session Establishment Process

1. ONT initiates PPPoE request
2. Request reaches BNG via OLT and aggregation switch
3. BNG contacts AAA server
4. User credentials verified
5. IP address assigned
6. Session established

Bandwidth Management in BNG

BNG enforces bandwidth using:

- Traffic shaping
- Policing
- Rate limiting

Each subscriber receives:

- Speed as per plan (e.g., 100 Mbps)
- Guaranteed QoS for priority services

Quality of Service (QoS) in BNG

BNG prioritizes traffic based on service type:

Service Priority

VoIP Highest

IPTV High

Internet Best effort

QoS mechanisms include:

- Queue scheduling

- Traffic classification
- Rate control

VLAN Handling in BNG

BNG manages:

- Service VLANs
- Subscriber VLANs
- VLAN aggregation

In BSNL FTTH:

- Separate VLANs for Internet, IPTV, VoIP
- VLAN isolation ensures security

Routing Functions of BNG

BNG supports:

- IP routing
- Static routing
- OSPF
- BGP (towards IP/MPLS core)

BNG acts as a **gateway router** for broadband users.

Applications of BNG in BSNL

- FTTH broadband services
- DSL broadband
- Government broadband projects
- Enterprise internet access
- IPTV and VoIP delivery