# Computer Networks
# Assignment 1

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## A) A Brief History of the Internet

**The Development of Packet Switching: 1961–1972**

The journey towards the modern Internet began with researchers looking for a more efficient alternative to circuit switching—this led to the development of packet switching. Leonard Kleinrock used queuing theory to show the effectiveness of packet switching for handling bursty traffic. In 1964, Paul Baran at the RAND Corporation further developed packet switching as part of his work on secure military communications. Around the same time, Donald Davies and Roger Scantlebury at the National Physical Laboratory in England also explored packet switching. Lawrence Roberts spearheaded the creation of ARPAnet, the first packet-switched computer network and a direct ancestor of today's Internet. The initial nodes were installed at UCLA, Stanford Research Institute (SRI), UC Santa Barbara, and the University of Utah, forming the precursor to the Internet. In 1972, Robert Kahn publicly demonstrated ARPAnet, which had grown to about 15 nodes. The Network Control Protocol (NCP), the first host-to-host protocol for ARPAnet, enabled the development of networked applications. Ray Tomlinson developed the first email program in 1971, marking a significant milestone.

**Proprietary Networks and Internetworking: 1972–1980**

In the early 1970s, additional stand-alone packet-switching networks were developed, including:

- **ALOHAnet**: A microwave network connecting universities across the Hawaiian Islands introduced the first multiple-access protocol.
- **DARPA's Networks**: These included packet-satellite and packet-radio networks.
- **Telenet**: A commercial packet-switching network by BBN.
- **Cyclades**: A French packet-switching network led by Louis Pouzin.
- **Time-sharing Networks**: Tymnet and the GE Information Services network.
- **IBM's SNA (Systems Network Architecture)**: IBM's network protocol for managing communication between computing systems.

During this period, the **File Transfer Protocol (FTP)** was developed to allow users to upload, download, and manage files on a network. Vinton Cerf and Robert Kahn introduced the concept of "Internetting," referring to the interconnection of networks. They also worked on the early versions of TCP (Transmission Control Protocol), combining reliable data delivery with network forwarding. The separation of IP (Internet Protocol) from TCP and the development of UDP (User Datagram Protocol) were results of experimentation, highlighting the need for a non-flow-controlled, end-to-end transport service for certain applications like voice. By the late 1970s, TCP, UDP, and IP had taken shape. **Metcalfe and Boggs** at Xerox PARC developed the

**Ethernet protocol** for wired LANs to connect multiple PCs, printers, and shared disks, laying the foundation for modern PC networks. By the end of the 1970s, ARPAnet had grown to over 200 nodes.

### A Proliferation of Networks: 1980–1990

During the 1980s, networks proliferated:

- **BITNET**: Provided email and file transfers among universities in the Northeast.
- **CSNET**: Linked university researchers across different institutions.
- **NSFNET**: Established in 1986 to provide access to NSF-sponsored supercomputing centers, serving as a primary backbone for regional networks.

On January 1, 1983, **TCP/IP** replaced NCP as the standard protocol for ARPAnet, marking a significant milestone in Internet development. Host-based congestion control was introduced in TCP, and DNS (Domain Name System) was developed to map human-readable names to IP addresses. The **Minitel project** was launched in France, making data networking accessible to the general public through a system based on the X.25 protocol, Minitel servers, and low-cost terminals with built-in modems. Minitel offered over 20,000 services, including free telephone directory services and private, fee-based sites.

### The Internet Explosion: The 1990s

In the early 1990s, ARPAnet was decommissioned. **NSFNET** was commercialized in 1991 and eventually replaced by commercial Internet Service Providers (ISPs). A significant paradigm shift occurred in the 1990s with the development of the **World Wide Web**. Between 1989 and 1991, Tim Berners-Lee at CERN invented the Web, creating HTML, HTTP, a Web server, and a browser. He introduced the concept of **Hypertext**, allowing researchers to access and share information easily. **Marc Andreessen and Jim Clark**, founders of Netscape Communications, developed Web browsers with a graphical user interface, making it easier for people to navigate the Web. Microsoft entered the browser market in 1996, competing with Netscape. By the early 2000s, the Internet had supported revolutionary applications like **email, the web, instant messaging**, and **Napster's peer-to-peer file sharing** of MP3s.

### The New Millennium: 2000 onwards

The 2000s saw the deployment of broadband Internet, including cable modems, DSL, and fiber to the home. This led to an explosion of video applications, streaming platforms, and video conferencing. The rise of **4G cellular networks** and widespread **public Wi-Fi** increased Internet accessibility. In 2011, the number of wireless devices connecting to the Internet surpassed that of wired devices. Social networks like **Facebook, Instagram, and Twitter** created massive online communities. **Google and Microsoft** built their own private content provider networks, connecting their global data centers and directly peering with ISPs. The advent of **cloud computing** platforms like **Amazon's EC2, Google's App Engine,** and **Microsoft's Azure** further revolutionized the way applications and services are delivered online.

# B) Internet & India: development of ERNet

The history of the Internet in India is a fascinating journey that began in the mid-1980s and saw significant developments throughout the 1990s, culminating in the country becoming a key player in the global digital landscape. The establishment of the Education and Research Network (ERNET) was central to this process, as it marked India's official entry into the world of the internet. The timeline from 1986 to 1998 was particularly crucial, as it laid the foundation for the widespread adoption of the Internet in the country. The following points highlight the key developments during this period.

## ERNET's TCP/IP Launch in January 1990

India Becomes the 14th Country on the Internet. In January 1990, India launched its first TCP/IP network through the ERNET project, marking a significant milestone in the country's technological progress. TCP/IP, or Transmission Control Protocol/Internet Protocol, is the fundamental communication protocol of the Internet, enabling different networks to connect and communicate with each other. By adopting TCP/IP, India joined the ranks of the first few countries globally to embrace the internet, becoming the 14th country to do so. This was a major achievement for India, as it signaled the beginning of the nation's internet era and opened up new possibilities for communication, research, and collaboration.

## The mix of Networking Technologies

Ethernet LAN, Leased Circuits, VSAT Satellite Channels, Terrestrial Links. ERNET's infrastructure was built using a diverse mix of networking technologies to ensure robust and reliable connectivity across the country. The backbone of ERNET relied on Ethernet Local Area Networks (LANs), which were essential for creating fast and efficient networks within institutions. These LANs were interconnected using leased circuits, which provided dedicated communication lines between various nodes, ensuring consistent and secure data transmission.

In addition to leased circuits, ERNET also utilized Very Small Aperture Terminal (VSAT) satellite channels. VSAT technology was particularly important in a country like India, where geographical diversity posed challenges to terrestrial communication. VSAT enabled remote and underserved regions to connect to the network, bridging the digital divide and ensuring that the benefits of the internet could reach across the country.

Terrestrial links were another crucial component of the ERNET infrastructure. These links connected different regions via ground-based communication channels, complementing the satellite-based systems and leased circuits to create a comprehensive and reliable network. The combination of these technologies ensured that ERNET could support the varying needs of academic and research institutions across India.

## Financial Support

*US$ 6 Million Grant from UNDP and Rs. 50 Crore from GoI*

The development of ERNET was made possible through substantial financial support from both international and domestic sources. The United Nations Development Programme (UNDP) provided a grant of US$ 6 million, recognizing the importance of building a strong internet infrastructure in India to support education and research. This international support was crucial in the initial phases of the project, helping to lay the groundwork for what would become India's digital backbone.

Domestically, the Government of India (GoI) contributed Rs. 50 crore to the ERNET project. This funding underscored the government's commitment to fostering technological advancement and digital connectivity in the country. The financial resources provided by both the UNDP and the GoI were instrumental in setting up the necessary infrastructure, purchasing equipment, and training personnel to manage and operate the network.

## Gigabit LANs and Fiber-Based Ethernet at IITs

*Building the Backbone of India's Internet*

One of the most significant outcomes of the ERNET project was the establishment of high-speed Gigabit LANs at premier educational and research institutions, particularly the Indian Institutes of Technology (IITs) and the Indian Institute of Science (IISc) Bangalore. These Gigabit LANs were based on fiber-optic Ethernet technology, which provided exceptionally high-speed internet access that was crucial for academic and research activities.

The implementation of fiber-based Ethernet at these institutions was a game-changer, as it allowed for rapid data transfer, seamless communication, and efficient collaboration on research projects. The IITs in Delhi, Bombay, Kanpur, Kharagpur, and Madras, along with IISc Bangalore, became key nodes in this network, serving as the backbone of India's early internet infrastructure. The success of these networks at the IITs demonstrated the potential of the Internet to transform education and research in India, laying the foundation for the rapid expansion of Internet connectivity across the country.

### International Collaboration and India's Global Integration

ERNET's development was not just a national effort; it involved significant international collaboration, particularly with the United States. American institutions and experts played a pivotal role in helping to establish connections between Indian institutions and the global internet. This collaboration facilitated the exchange of knowledge, resources, and best practices, further strengthening India's position in the global digital community.

The collaboration with the USA and other international partners also helped Indian institutions to integrate more effectively with global research networks, opening up new opportunities for academic exchange and collaboration. This global integration was a critical factor in the success of ERNET and in positioning India as a significant player in the global internet landscape.

## C) IIITD LAN

IIIT-Delhi has a large campus with high connectivity demands, given the thousands of clients utilizing our on-campus networks daily. To meet these demands, our network infrastructure is both sophisticated and robust, ensuring reliable, secure, and easily scalable connectivity. Here are some key features that set our commercial network apart from a typical home network:

### Network Features

1. **Extensive Access Points**
   The campus is equipped with numerous access points that broadcast the same SSID. For security, devices must have their MAC addresses registered before they can connect. This extensive deployment ensures broad coverage and strong connectivity throughout the campus.
2. **Internal Resources**
   IIIT-Delhi's network hosts various critical internal resources, including data center servers for portals and extensive databases. Access to these resources is restricted to the campus LAN or via VPN, enhancing security and controlling access to sensitive information.
3. **Campus-Wide Surveillance**
   The network supports a comprehensive campus-wide surveillance system. Network cameras and dedicated storage servers are integrated into the campus network, providing enhanced security through constant monitoring and data storage.
4. **VPN Access**
   Authorized users can connect to local network resources from external networks through a VPN. This secure remote access ensures that users can work seamlessly from off-campus locations while maintaining the integrity and security of the network. VPN access through FortiClient requires student or faculty usernames and passwords, adding an extra layer of security by verifying authorized users before granting access.
5. **Commercial ISP Uplink**
   IIIT-Delhi maintains a high-speed internet connection through a 1 Gbps leased line from the National Knowledge Network (NKN), complemented by a 100 Mbps backup connection in failover mode. This setup guarantees reliable and continuous internet access for all users, minimizing downtime and ensuring consistent connectivity.
6. **Fortinet Firewall**
   The network is protected by a Fortinet firewall, which blacklists potentially harmful

resources and mitigates the risk of phishing attacks and malware. This layer of security is crucial in maintaining a safe and secure network environment.

7. **Isolated Guest Network**
   The Guest-N LAN provides internet access for visitors without requiring device registration. This isolated network ensures that guests have a seamless experience while keeping their devices separate from the main campus network, protecting the integrity of the internal network.
8. **Isolated Mobile and Laptop SSIDs**
   The campus network differentiates between mobile devices and laptops by using separate SSIDs: LAPTOP-S for laptops and MOBILE-S for mobile devices. This segregation helps in managing network traffic efficiently and ensuring optimal performance for different types of devices.
9. **Dynamic IP Address Allocation**
   IP addresses within the campus network are dynamically allocated and may vary. This setup allows for efficient use of available IP addresses and supports a large number of devices by assigning IP addresses on-demand. While this approach ensures optimal network utilization, it also adds a layer of complexity in tracking and managing network resources.

**Connectivity to the Rest of the World**

1. **Global Internet Access**
   IIIT-Delhi's connection to the global internet is facilitated through its 1 Gbps leased line from NKN, providing high-speed access to the outside world. The 100 Mbps backup connection ensures redundancy and reliability, maintaining continuous internet access even in the event of primary connection issues.
2. **Secure Remote Access**
   Through the VPN, authorized users can securely access campus resources from anywhere in the world. This capability is essential for remote work, allowing staff and students to connect to the campus network and access resources as if they were on-site. The use of FortiClient for VPN access requires valid student or faculty credentials, adding a layer of authentication and enhancing security.
3. **Integration with External Networks**
   The campus network's design allows for seamless integration with external networks, ensuring that data flows efficiently between the campus and the broader internet. This integration supports various external communications, including academic collaborations, research activities, and online services.
4. **Enhanced Security Measures**
   The Fortinet firewall and other security measures safeguard the network from external threats. This proactive approach ensures that the campus network remains secure against potential cyber-attacks and unauthorized access, maintaining a safe environment for all users.

## 2) A New, Innovative, and Useful application in the future

The internet has consistently transformed the way we communicate, learn, and work. As technology progresses, one of the most promising developments is the integration of neural interfaces with the Internet. This paper explores a realistic and innovative application using the internet to enable seamless brain-to-brain communication, advanced remote collaboration and enhanced learning through Neuralink, a pioneering technology in the field of neural interfaces. Moreover, this discussion will pivot towards potential applications in fields like defense, cognitive enhancement, and the entertainment industry, opening new frontiers for human interaction and capabilities.

### Neuralink: From Concept to Human Trials

Neuralink, founded by Elon Musk in 2016, was established with the ambitious goal of developing ultra-high-bandwidth brain-machine interfaces (BMIs). The primary objective was to create a direct communication pathway between the human brain and computers, thereby reducing the inefficiencies in current human-computer interactions. Initially aimed at treating neurological disorders, Neuralink's vision has since expanded to include broader applications, such as enhancing cognitive abilities and enabling new forms of human communication.

#### Recent Developments and Human Trials

Neuralink has experienced both significant milestones and challenges in its development journey. In May 2023, the company received FDA approval to begin human trials after addressing safety concerns related to the device's lithium battery and the risk of implant wires migrating within the brain. By September 2023, Neuralink initiated its first human trials, focusing on individuals with quadriplegia caused by spinal cord injuries or neurodegenerative diseases.

On January 29, 2024, Neuralink successfully implanted its brain-computer interface device, named "Telepathy," into a human patient for the first time. This patient, Noland Arbaugh, demonstrated his ability to control a computer cursor through thought, offering a glimpse into the potential of this technology to enhance communication and autonomy for individuals with severe physical limitations. However, challenges arose when the device's threads detached due to unexpected brain shifts, leading to ongoing refinements in subsequent trials. The second trial participant received an implant in August 2024, and the trial continues to progress as the technology is further developed and tested.

### Practical Applications:

*Enhancing Communication, Control, and Entertainment*

Given the progress made by Neuralink, its applications are not only confined to medical and communication domains but also extend to defense, cognitive enhancement, and entertainment.

These areas present limitless possibilities for how neural interfaces could redefine human capabilities and interactions.

**Brain-to-Brain Communication and Remote Control**

One of the most exciting practical applications is brain-to-brain communication over the internet. Neuralink could facilitate direct thought transmission between individuals, bypassing language barriers and enabling faster, more intuitive communication. This technology could also be adapted for controlling advanced systems and devices, such as drones, robots, or even weapons. By leveraging thought commands instead of traditional control mechanisms, response times could be drastically reduced, offering a significant tactical advantage in high-stakes environments like military operations.

For instance, a soldier equipped with a Neuralink device could control a fleet of drones, deploying them with precise thought commands without the need for a physical interface. This level of control would not only enhance efficiency but also reduce the cognitive load required for operating multiple systems simultaneously, allowing for more complex and coordinated actions.

**Enhanced Cognitive Abilities**

Another promising application lies in the enhancement of human cognitive abilities. Neuralink could potentially boost memory retention, processing speed, and learning capabilities by directly interfacing with brain regions responsible for these functions. Imagine a scenario where individuals can instantly access and process vast amounts of information, perform complex calculations, or learn new skills at an accelerated rate—all by simply thinking.

This cognitive enhancement could revolutionize education, research, and problem-solving, creating a new class of "super learners" capable of tackling challenges that are currently beyond human capability. The implications of such advancements could lead to a profound shift in how society values and utilizes intellectual resources.

**Entertainment and Immersive Experiences**

The entertainment industry stands to benefit significantly from Neuralink's potential. With the advent of neural interfaces, video games could evolve from mere visual and auditory experiences to fully immersive environments where players interact with the game world using their thoughts alone. This would eliminate the need for physical controllers or VR headsets, as the neural interface could directly simulate actions such as walking, jumping, or even complex gestures within the game.

In this scenario, traditional gaming devices like joysticks or multidirectional treadmills would become obsolete, as players could seamlessly navigate virtual environments with their minds. This level of immersion could open up new opportunities in game development, allowing for the creation of experiences that were previously limited by the constraints of current technology.

Games could become more interactive and emotionally engaging, as players would have a more direct connection to the virtual worlds they inhabit.

Additionally, the entertainment industry could explore new forms of media where neural inputs are used to create personalized content. For example, movies or virtual experiences could adapt in real-time to a viewer's emotional state or preferences, creating a truly customized and immersive experience.

**Internet Protocols and Infrastructure**

For this vision to become a reality, existing internet infrastructure and protocols would need to support the vast amounts of data generated by neural interfaces. Technologies such as 5G and fiber-optic networks will play a crucial role in ensuring low-latency, high-speed connections necessary for real-time neural communication.

Protocols like WebRTC, which currently enables real-time video, voice, and data sharing, could be adapted for neural data transmission. Additionally, the development of new protocols specifically designed to handle neural data will be essential for ensuring efficient and secure communication.

**Security and Ethical Considerations**

The integration of Neuralink with the Internet introduces significant security and ethical challenges. Protecting neural data from cyber threats is paramount. Advanced encryption methods, possibly building on current standards like TLS, will be needed to safeguard the privacy and integrity of users' thoughts and neural inputs.

Moreover, ethical guidelines must be established to regulate the use of neural interfaces. Issues such as consent, data ownership, and the potential for misuse of technology must be carefully considered and addressed to prevent harm and ensure that the benefits of this technology are accessible to all.

The ongoing advancements in Neuralink, combined with the power of the internet, offer a practical and innovative future application that could transform how we communicate, collaborate, and learn. As Neuralink progresses through human trials and continues to evolve, the integration of this technology with global internet infrastructure holds the promise of making brain-to-brain communication and enhanced remote collaboration a reality in the near future. Moreover, the potential applications in defense, cognitive enhancement, and entertainment open up limitless possibilities for human interaction, creativity, and control, heralding a new era of technological evolution. This vision can become a cornerstone of the next generation of Internet applications by addressing the associated security and ethical challenges.

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**Contributions:**

Aditya Aggarwal  (2022028): History of the Internet
Aaradhya Verma (2022004): India and Internet
Aarav Mathur (2022005): IIITD LAN & its uses
Mehul Pahuja (2022295): Innovative application of Internet
Note: Every group member was actively involved in the discussion and research which was required to complete each part of the assignment. The above contributions refer to the members summarizing the different parts of the solutions.