Network Technologies

Telephone Networks
  IP Networks
  ATM Networks

Three Network Technologies

• Telephone Network
  – The largest worldwide computer network, specialized for voice
  – Switching technique: Circuit-switching

• Internet
  – A new global and public information infrastructure
  – Switching technique: Datagram packet switching

• ATM
  – Was intended to replace telephone networks and data networks, but lost momentum due the success of the Internet
  – Switching technique: VC packet switching
Telephone Networks

- Starting in 1876, the public switched telephone network (PSTN) has become a global infrastructure for voice communications

Central Office and Local Loop

- Each phone user (subscriber) has a direct connection to a switch in the central office. This is called the **local loop**
- The local loop has a length of 1 - 10 km
- The switches in the central office are called **local exchange**
- A company which provides local telephone service is called a **local exchange carrier** or **LEC** (e.g., Bell Atlantic)
**PBX**

- A **PBX (Private Branch Exchange)** is a telephone system within an enterprise that switches calls within the enterprise on local lines, while allowing all users to share a certain number of external lines to the central office.
- The main purpose of a PBX is to save the cost of requiring a line for each user to the telephone company's central office.

**The long-haul network**

- Toll or backbone switches provide long-distance connectivity over long-distance trunks.
- There are only about 500 toll switches in the United States. Each toll switch can run more than 100,000 simultaneous phone calls.
Addressing and Routing

- Each subscriber has an address (telephone number)
- Addresses are hierarchical
- **Example**: Domino’s Pizza in downtown Charlottesville

```
1  804  979  2656
```

- The information contained in a telephone address is exploited when establishing a route from caller to callee

How is voice transmitted?

- Voice can be transmitted in two ways:
  - **Analog voice transmission**: Each voice channel is allocated a bandwidth of 3.5 kHz
  - **Digital voice transmission**: Analog voice stream is converted in a digital stream:
    - Standard scheme for a voice call: Obtain 8000 samples per second, each with length 8 bit
      (We will learn more details later)
How is voice transmitted?

- **Until 1960s:**
  - Entire telephone network is analog

- **Today:**
  - The local loop is analog.
  - The rest of the network is digital.

- **When do we get an all digital network?**
  - This is ISDN
  - It is available since many years, but no one seems to want it, at least in the US. ISDN is in wide-spread use in Europe.

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All analog telephone network

- The telephone switch bundles (multiplexes) multiple voice calls on a high-bandwidth link
- Each call receives a fixed bandwidth. The frequency of each call is shifted, so that multiple calls do not interfere. This is called **Frequency-Division-Multiplexing (FDM).**
• The first telephone switch digitizes a voice call (8000 8-bit samples per second)
• Switch bundles multiple calls, by interleaving samples in time. Each call receives one 1-byte slot every 125 µs
• This is called **Time-Division-Multiplexing (TDM).**

• The telephone at the subscriber digitizes voice and sends one 8-bit samples every 125 µs
Signaling

- Signaling refers to the control functions performed to setup a phone call.
- Signaling between users and the local exchange in the central office is quite simple: dial-tone, punch numbers, put phone down, etc.
- Signaling between exchanges is more complicated and is done via a separate network, which uses packet switching.

Other Topics on Telephone networks

- Toll-Free numbers
- Cellular telephone networks
- ISDN (Integrated Services Digital Networks)
- Billing
The Internet

- The Internet has become a global information infrastructure
- The Internet is a datagram packet-switching network
  - Station or Endsystems are called **Hosts**
  - Nodes are called **Routers**

History of the Internet

**End 1969s:** ARPA sponsors the development of a packet-switching network, called the **ARPANET**. First four nodes are UCLA, SRI, U. Utah, UCSB

**1974:** The TCP/IP protocols are being proposed by Vint Cerf and Bob Kahn

**1983:** ARPANET adopts TCP/IP. At this time, the ARPANET has 200 routers.

**1984:** NSF funds a TCP/IP based backbone network. This backbone grows into the **NSFNET**, which becomes the successor of the ARPANET.

**1995:** NSF stops funding of NSFNET. The Internet is completely commercial.

**Since 1998:** Number of hosts on the Internet double every year
Main Applications of the Internet

- Traditional core applications:
  - Email
  - News
  - Remote Login
  - File Transfer
- The killer application:
  - World-Wide Web (WWW)
- Future applications:
  - Videoconferencing and Telephony
  - Multimedia Services
  - Internet Broadcast

Recent Growth of the Internet

- Latest data (Fall 98):
  - Jul 98: 36,739,000 Hosts
  - Jan 98: 29,670,000 Hosts
- Latest data:
  - Jul 99: 56,218,000 Hosts
  - Jan 99: 43,230,000 Hosts
The Internet - A Network of Networks

• The Internet is a loose collection of networks
• Networks are organized in a (loose) multilayer hierarchy

Internet Service Provider

• An **ISP (Internet Service Provider)** or **ISP (Internet Access Provider)** is a company which provides access to the Internet
  – There are about 7,500 ISPs worldwide
  – Local ISPs connect to regional network (can belong to the same organization)

• The location which provides access to the Internet is called a **POP (point-of-presence)**. A POP has a unique Internet address. An ISP has at least one POP.
Network Access Points

- **Network Access Point (NAPs)** are public network exchange facility where ISPs connect with one another
- NAPs are the crossroads of the Internet, and the locations of most congestion

What defines the Internet?

- Use of a globally unique address space (**Internet Addresses**)
- Support of the **Transmission Control Protocol/Internet Protocol (TCP/IP)** suite for communications
Internet Addresses

- Each network interface on the Internet has a unique global address, called the IP address.
- An IP address:
  - is 32 bits long.
  - encodes a network number and a host number

- IP addresses are written in a dotted decimal notation:
  - **128.143.137.144** means
    10000000 in 1st Byte
    10001111 in 2nd Byte
    10001001 in 3rd Byte
    10010000 in 4th Byte

Domain Names and IP Addresses

- Users and applications on the Internet normally do not use IP addresses directly. No one says:
  - **http://128.143.137.29/**
- Rather users and applications use domain names:
  - **http://www.cs.virginia.edu**

- A service on the Internet, called the Domain Name System (DNS) performs the translation between domain names and IP addresses
Domain Name System (DNS)

- The DNS can be thought of as an Internet-wide database, which translates between Domain names and IP addresses

![Diagram of DNS resolution](image)

- Applications (browser, telnet) can work with both domain names and IP addresses
- The TCP and IP protocols only work with IP addresses

Data Transport on the Internet

- The Internet is a datagram packet switching network
- All information is carried as packets, which are called IP datagrams.
- Each router does store-and-forward packet switching

![Diagram of data transport on the Internet](image)
ATM Networks

- **Asynchronous Transfer Mode (ATM)** is a packet-switching technology which emerged in the 1980s.
- ATM is based on virtual circuit packet switching

ATM emerged from an effort to replace all existing networks (telephony networks, Cable TV network, data networks) with a single network infrastructure. The effort was called **B-ISDN** (**Broadband Integrated Services Digital Networks**)

Traditional Network Infrastructure

Diagram showing the traditional network infrastructure with Company A, Company B, Telephone network, Data network, Video network, and Residential user.
ATM’s Key Concepts

- **ATM uses Virtual-Circuit Packet Switching**
  - ATM can reserve capacity for a virtual circuit. This is useful for voice and video, which require a minimum level of service.
  - Overhead for setting up a connection is expensive if data transmission is short (e.g., web browsing).

- **ATM packets are small and have a fixed size**
  - Packets in ATM are called *cells*.
  - Small packets are good for voice and video transmissions.

Cell is 53 byte long
ATM Virtual Connections

• Before ATM cells can be sent, an ATM virtual connection connection must be established
• Users can reserve link capacity for each connection

Which Technology will prevail?

• Right now the various technologies (Telephone Networks, Internet, ATM, Frame Relay, and more) compete with each other, and co-exist at the same time.
• This is a network scenario which you could find today: