Three Network Technologies

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

- **Internet**
  - The global public information infrastructure for data
  - Switching technique: Datagram packet switching

- **ATM**
  - Was intended to replace telephone networks and data networks, but lost momentum due to 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).
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.
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

How is voice transmitted?

- **Until 1960s:**
  - Entire telephone network is analog
  - Frequency-division multiplexing

- **Today:**
  - The local loop is analog.
  - The rest of the network is digital (based on TDM)

- **All digital: When do we get an all digital network?**
  - ISDN (Integrated services Digital Network) is an all digital circuit-switching technology. ISDN is available since the early-1990s (in Europe) or mid-1990s (US). No wide deployment in US
  - Another all digital –but not circuit-switched – telephony solution is IP telephony.
All analog telephone network

- The telephone switch bundles (multiplexes) multiple voice calls on a high-bandwidth link
- The multiplexing method is FDM.

Analog local loop / digital network

- The first telephone switch digitizes a voice call (8000 8-bit samples per second)
- Switching method is TDM.
  - Switch bundles multiple calls, by interleaving samples in time. Each call receives one 8-bit slot every 125 $\mu$s
All digital telephone network

- The telephone at the subscriber digitizes voice and sends one 8-bit samples every 125 $\mu$s

Digital Multiplexing

- Digital Signaling (DS) transmission hierarchy used in the US for multiplexing digital voice channels

<table>
<thead>
<tr>
<th></th>
<th>Number of voice circuits</th>
<th>Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>DS0</td>
<td>1</td>
<td>64 kbps</td>
</tr>
<tr>
<td>DS1</td>
<td>24</td>
<td>1.544 Mbps</td>
</tr>
<tr>
<td>DS2</td>
<td>96</td>
<td>6.312 Mbps</td>
</tr>
<tr>
<td>DS3</td>
<td>672</td>
<td>44.736</td>
</tr>
</tbody>
</table>
Addressing and Routing

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

![Telephone Address Example]

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

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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-switches is more complicated and is done via a separate network, which uses packet switching
Switching in the Telephone Network

- Telephone switch has two parts:
  - Switch controller responsible for signaling (control plane)
  - Switching hardware responsible for handling voice data (data plane)

Signaling Network

- Signaling between switch controllers is done over a (packet switching) network that is separate from the data plane
- This is called out-of-band signaling.
- Packet network is called **Signaling System 7 (SS7)**. SS7 has a complete protocol stack.
Other Topics on Telephone networks

- Toll-Free numbers
- Cellular telephone networks
- ISDN (Integrated Services Digital Networks)
- Billing
- VoIP (Voice over IP networks)