Overview of Telephone Plant

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Telephone Communication Circuits

2 phones - 1 circuit

3 phones - 3 circuits

Fully meshed networking
10 phones ? Circuits
101 phones ? Circuits

4 phones - 6 circuits
CIRCUIT SWITCHING
Operator CordBoard
Step-by-Step Switch
Step-by-Step Switch
THE CIRCUIT SWITCHED CONCEPTS

• The end to end connection is maintained for duration of “session” or telephone call.
• Various means of signaling and supervision of call.

Figure 10.2 Example Connection Over a Public Circuit-Switching Network
Crossbar Switch
Basic Telephone Components
The Big Picture

Phones
Loop/Line
Class 5 Switch
DSL
Trunks
Class 4 Switch
ISP
Toll Switches and IC Network
PSTN
SS7 Network
IC POT
DSL
DSL
DSL
Telephone Services
Switched Access

- Switching functions are performed.
- Billed to an access customer at variable and flat monthly rates
- State and Interstate Traffic, PIU
Switches

DMS10
2500 - 7500 lines

Panel switch

Nortel CS1500 Softswitch
Softswitch

Figure 4. IMS architecture
Telephone Services
Special Access

- No switching function is performed.
- Facility is dedicated from CDP to CDP
- Billed to an access customer at a flat monthly rate
- State and Interstate Services
## Basic Concepts

- **Shorthand Notation**

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Power of 10</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kilo</td>
<td>3</td>
<td>1,000</td>
</tr>
<tr>
<td>Mega</td>
<td>6</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Giga</td>
<td>9</td>
<td>1,000,000,000</td>
</tr>
<tr>
<td>Tera</td>
<td>12</td>
<td>1,000,000,000,000</td>
</tr>
<tr>
<td>Peta</td>
<td>15</td>
<td>1,000,000,000,000,000</td>
</tr>
<tr>
<td>Exa</td>
<td>18</td>
<td>1,000,000,000,000,000,000</td>
</tr>
<tr>
<td>Zetta</td>
<td>21</td>
<td>1,000,000,000,000,000,000,000</td>
</tr>
<tr>
<td>Yotta</td>
<td>24</td>
<td>1,000,000,000,000,000,000,000,000,000</td>
</tr>
</tbody>
</table>
Basic Networking Technologies

LEC Transmission
Analog and Digital
Basic Networking Technologies

- Transmission
  - Channels
    - Metallic
    - Fiber
    - Radio
  - Direct...Point to point
- Analog Multiplexing
- Digital Multiplexing
Distribution Plant

- CO Main Frame
  - Cable Vault

- Feeder Cable
  - Underground
  - Serving Area Interface (SAI)/Carrier Serving area (CSA)

- Distribution Cable
  - Aerial
  - Buried
  - Distribution Access Point

- Drop
  - Aerial
  - Buried
  - NID
Switchboards 1880 - 2002
The telephone plug (the jack* is the receptacle) traditionally had three leads—TIP, RING, and SLEEVE. Modern two wire phone systems may or may not use the local sleeve as a ground or shield.

Usually the TIP is the positive side of the 48 volt DC feed from the Central Office, and the RING is negative.

*The derivation of the word “jack” for a receptacle is unclear. One theory is that it comes from the design of detent mechanism of the “jack knife”. “Jack” is an old slang word for boy, as jack knives were carried by boys in the 1920s and 30s.
THE LOCAL LOOP

- Aerial Service Terminal
- Aerial Drop Wire
- Cable Vault
- The Main Distribution Frame

- F2 or Distribution Cable. Can be above or below ground.
- Serving Area Interface (A cross-connect box)
- F1 or Main Feed. There will actually be several F1s to serve different neighborhoods.
Cable Vault
MAIN DISTRIBUTING FRAME
Distribution Plant

- CO Main Frame
Loop Plant

- Twisted Pair
  - Cable Closures
  - Splicing
  - Load Coils
  - Loop Electronics & Range Extenders
- COAX
- Fiber
  - Passive optical Networks
  - FTTP
- Radio
ILEC Exchange

Central OFFICE

Cable Plant
- Aerial
- Buried
- Underground

Feeder Cable

Distribution Cable

Drop

CSA/SAI

Pedestal

NID

Cable Vault
Fiber vs Copper Facility
CWDM Wavelength Grid

- O-band: 1260-1360 nm
- E-band: 1360-1460 nm
- S-band: 1460-1530 nm
- C-band: 1530-1565 nm
- L-band: 1565-1625 nm

DWDM WaveLength Grid

- Standard - ITU G.694.2: 1530.33
- ITU-T G.652 fiber
- Water peak
CWDM Wavelength Grid

DWDM WaveLength Grid

O-band 1260-1360

S-band 1460-1530

C-band 1530-1565

Water peak

Upstream POTs and Data & G.983.1

Downstream POTs and Data & G.983.3

APON RF Video & G.983.3

Standard - ITU G.694.2
1530.33

GPON Video & G.983.3
1558.33
1560.33
1561.42

Fiber attenuation (dB/km)

Wavelength (nm)
Field Terminal
Field Terminals
Field Terminal
Carrier System/DSLAM
Field and Customer Premises
TWISTED PAIR PUNCHDOWN BLOCK

University of Colorado Telecommunications Main PBX Location © 2005 Michael H. Borsuk
COAXIAL CABLE

• COMES IN VARIOUS TYPES (OLD “RG” DESIGNATION WAS MILITARY BUT NAME STILL WIDELY USED)

• MANY IMPEDANCES, DIAMETERS, DEGREE OF SHIELDING, EVEN LEAKY COAX TYPES FOR CONTINUOUS ANTENNAS

• USED FOR COMPUTER NETWORKS, RADIO, TELEPHONY LONG HAUL, CELL PHONE AUTO INSTALLATION

• EXPENSIVE DEPENDING ON SHIELDING, CONSTRUCTION, INSULATION, DIAMETER
Basic Networking Technologies

- Transmission Impairments
  - Attenuation
  - Noise and Crosstalk
  - Distortion
  - Echo
  - Delay
Basic Networking Technologies

- Improving Analog Transmission
  - Amplification
  - Equalization
  - Modulation
  - Multiplexing
  - Digital Coding
Basic Networking Technologies

- Three basic methods for transmission of electrical signals
  - Direct
  - Analog Carrier
  - Digital Carrier
Basic Networking Technologies

- Physiology, Psychology & Physics
Basic Networking Technologies

- Carbon Transmitter
Voice Communications

Direct Transmission
Voice Communications

- Characteristics of Analog Communications

1. Amplitude
   (Signal Strength)

   ![Graph showing amplitude over time with two examples: 1 second, 6 cycles at 6 Hz and 1 second, 3 cycles at 3 Hz.]

2. Frequency

   - 1 second, 6 cycles
     Frequency = 6 Hz
   - 1 second, 3 cycles
     Frequency = 3 Hz
Voice Communications

- Characteristics of Analog Communications

1. Amplitude (Signal Strength)
2. Frequency
3. Phase
Voice Communications

Single Tone

![Waveform diagram showing amplitude over time and frequency](image-url)
Voice Communications

Complex Tone

Time

Frequency
Voice Communications

Bandwidth

Voice Frequency

Television Frequency
Voice Communications

Direct Transmission
Distortion
Voice Communications

Direct Transmission
Distortion

load coils
In 1899, Michael Pupin of Columbia University and George Campbell of AT&T independently developed the theory of loading coils. Loading coils made it possible to build longer telephone lines. Typical 3 kHz distances to local COs remain at 13 kilo-feet (ok, 2 ½ miles) for voice connections without additional amplification or conditioning.

The placement of inductors along the telephone lines were said to “cancel out” the substantial capacitance between conductors and thus extend the useable distance for voice transmissions. We recognize now that loading the phone line is really just “tuning” it for the voice bandwidth.
Voice Communications

Direct Transmission

Loss
Voice Communications

Direct Transmission
Loss
Repeater/Amplifier

Amplifier/Repeater
Loop/Line Network Components (cont’d)

- **Repeater** - a device placed along a circuit to amplify signal energy
  - Used for **analog** transmission
  - Amplifies Analog Signal
Loop/Line Network Components (cont’d)

- **Repeater** - Continued
  - Amplifies both wanted and unwanted Analog Signal
Voice Communications

- Analog Signal Treatment
  - Amplitude Modulation
  - Multiplexing
Voice Communications

Two Voice Signals

Voice Frequency 1

Voice Frequency 2
**Voice Communications**

Single Tone Modulation

At

\[ A_t \]

\[ f_t \]

300 – 3200 Hz (4KHz)

\[ f_c \]

Bandpass Filter

\[ A_c \]

\[ \frac{A_t}{2} \]

\[ f_{c-} \]

\[ f_c \]

\[ f_{c+} \]
Voice Communications

Voice Modulation

Modulator Input

Voice Frequency

200 Hz 3200 Hz

Carrier Frequency

f_c

Modulator Output

f_c - 3200 f_c - 200 f_c + 200 f_c + 3200
Voice Communications

2 Voice Frequencies Modulating two carrier frequencies
Voice Communications

Analog Carrier Group – 12 Channels

Frequency KHz
Voice Communications

Analog Carrier Systems

Chan 1 → $f_1$
Chan 2 → $f_2$
Chan 3 → $f_3$
Chan 4 → $f_4$
Chan n → $f_n$

Carrier Line

Combiner
Voice Communications

- Wideband Carrier Systems
- FDM Hierarchy
  - Voice Frequency 200 – 3200 Hz
    - 1925 C-Carrier 3 Channels on Open Wire between Pittsburgh and St. Louis
  - Group 12 VG Channels
    - 1937 K-Carrier Between Toledo and South Bend on cable
    - 1938 first Open Wire J-Carrier System Dallas – San Antonio
  - Supergroup 60 VG Channels
  - Mastergroup 600 VG Channels
  - Jumbogroup 10,800 VG Channels
Voice Communications
Analog Carrier Systems

12 Voice

MUX

Repeaters

MUX

Channel Banks

Channel Banks

1

n

n
Voice Communications

- Analog Carrier Systems
  - Highly Accurate System Components
    - Repeaters
    - Frequency Sources
    - Bandpass Filters
  - Cumulative Noise
  - Bandwidth Efficiency
    - 4KHz per voice channel
Analog to Digital Systems

- Digital Carrier Systems
  - Two basic concepts
    - Sampling
    - Coding
Voice Communications

Analog Transmission

Digital Transmission

Regenerator
**Voice Communications**

**Digital Systems**

- **Regenerator** - A device that will filter then regenerate and re-transmit a *digital* stream
  - As the signal passes through the circuit it can lose shape and become distorted
  - Re-shapes as it strengthens the signal
  - Used for electrical or fiber transmissions
Voice Communications
Digital Systems

Time Division – Pulse Amplitude Modulation

1/8000 Second
125 micro Seconds
Voice Communications
Digital Systems

Time Division – Pulse Amplitude Modulation

1/8000 Second
125 micro Seconds

Analog
PAM
Voice Communications
Digital Systems

Time Division – Pulse Amplitude Modulation

1/8000 Second
125 micro Seconds

Channel 1
Channel 2
Voice Communications
Digital Systems

Time Division – Pulse Code Modulation

1/8000 Second 125 micro Seconds

Each PAM Sample coded with 8 bits

Time

PAM

+128

-128

1110110010110111

5.2 us 5.2 us
Voice Communications
Digital Systems

- Pulse Code Modulation
  - Quantizing Errors
  - Input 4 KHz Bandwidth
  - 8000 Samples per Second
  - 8-Bit word
  - 64,000 Bits per Second
  - Equivalent to 32,000 KHz
Voice Communications
Digital Carrier Systems
Voice Communications
Digital Systems

- Digital Time Division Multiplex System
  - DS1  24  DS0s  1.544 Mbps
  - DS1C  48  DS0s  3.152 Mbps
  - DS2  96  DS0s  6.312 Mbps
  - DS3  672  DS0s  44.736 Mbps
  - DS4  4032  DS0s  274.176 Mbps

Note: DS0 = 64Kbps, or one 4 KHz Voice Channel
**Voice Communications**

**International Comparison**

- **Digital TDM Transmission Rates - Mbps (DS0s)**

<table>
<thead>
<tr>
<th></th>
<th>USA</th>
<th>Europe</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.544(24)</td>
<td>2.048(30)</td>
<td>1.544(24)</td>
<td></td>
</tr>
<tr>
<td>6.312(96)</td>
<td>8.448(120)</td>
<td>6.312(96)</td>
<td></td>
</tr>
<tr>
<td>44.736(672)</td>
<td>34.368(480)</td>
<td>32.064(480)</td>
<td></td>
</tr>
<tr>
<td>274.176(4032)</td>
<td>139.264(1920)</td>
<td>97.728(1440)</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>564.992(7680)</td>
<td>397.200(5760)</td>
<td></td>
</tr>
</tbody>
</table>

*Note: DS0 = 64Kbps, or one 4 KHz Voice Channel*
## Synchronous Transport Signal

<table>
<thead>
<tr>
<th>Optical Carrier</th>
<th>DS0s* (Voice)</th>
<th>Line Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>OC1(STS-1)</td>
<td>672</td>
<td>51.840 Mbps</td>
</tr>
<tr>
<td>OC3(STS-3)</td>
<td>2,016</td>
<td>155.520 Mbps</td>
</tr>
<tr>
<td>OC12(STS-12)</td>
<td>8,064</td>
<td>622.080 Mbps</td>
</tr>
<tr>
<td>OC48(STS-48)</td>
<td>32,256</td>
<td>2.48832 Gbps</td>
</tr>
<tr>
<td>OC192(STS-192)</td>
<td>129,024</td>
<td>9.95328 Gbps</td>
</tr>
<tr>
<td>OC769(STS-768)</td>
<td>516,096</td>
<td>39.81312 Gbps</td>
</tr>
</tbody>
</table>

*DS0 = 64 Kbps, or one 4KHz Voice Channel, Time Division Multiplex (TDM)
# Ethernet Transport International Comparison

- **Digital Transmission Rates - Mbps**

<table>
<thead>
<tr>
<th>USA</th>
<th>Europe</th>
<th>Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>1,000 (1 Gbps)</td>
<td>1,000 (1 Gbps)</td>
<td>1,000 (1GBPS)</td>
</tr>
<tr>
<td>10 Gbps</td>
<td>10 Gbps</td>
<td>10 Gbps</td>
</tr>
<tr>
<td>40 Gbps</td>
<td>40 Gbps</td>
<td>40 Gbps</td>
</tr>
<tr>
<td>100 Gbps</td>
<td>100 Gbps</td>
<td>100 Gbps</td>
</tr>
</tbody>
</table>
Basic Network Components Signaling

- Signaling - Technology network components uses to communicate with each other
  - Supervision
  - Alerting
  - Addressing
  - Call set-up
Basic Network Components Signaling (cont’d)

- **In-Band Signaling** - Signals are sent on same path and frequency as the voice, data or video signal
  - Request for service
  - Dialing
  - Disconnect
Basic Network Components Signaling (cont’d)

- **Out-of-Band Signaling** - Signals that are sent outside of the call path

- **Signaling System 7 (SS7)** - Used for control and status functions

- Allows access to intelligent databases
  - Advanced intelligent Network features
  - 800 call routing
  - Local number portability
**SS7**

SSP = Service Switching Point
STP = Signaling Transfer Point
SCP = Signaling Control Point

Basic Network Components Signaling (cont’d)
Basic Network Components
The Internet

- A loose confederation of separate networks forming one virtual network
  - Initially distributed among military and academic institutions
  - World Wide communications
  - Interconnect via TCP/IP
Telephone Services

Broadband Technologies

- **Broadband** - High bandwidth (speedy) connections to networks

  - Technologies
    - Internet
    - DSL
    - ATM
    - SONET
    - Ethernet Wireless
    - Cable TV
    - Satellite
    - Power lines
Telephone Services
Digital Subscriber Line

Diagram:
- Modem
- DSLAM
- Filter
- Copper Loop
- Splitter
- NID
Converged Communications

ILEC
Broadband Network
DSLAM

Mobile Switching Centre

HLR
HSS
SCP

Fixed Mobile Convergence Handover
DSL/WiFi
Femtocell
DOCSIS/WiFi
Converged Networks

INTERNET CLOUDS

IP/MPLS/ATM/FR

IMS HSS*

SS7/IS41/ IP

Mobile Switching Center

Data Center

Internet IP

TCP/IP

STP

HLR/VLR

Mobile Base Station

Mobile Switching Center

Internet

Wireless Data

VoIP

Data

Video

SCP

Hot Spots

802.11 Network

Mobile Units

DSL

Fixed Wireless

PSTN

802.16

802.11 LANs

IP Phones

802.11

PBX

STP

CO

BX

Internet IP

* IP Multimedia Subsystem Home Subscriber Server
Apportionment of Costs for Nonregulated Services Including Digital Subscriber Line (DSL) and Video Services

Separations Treatment of ADSL & SDSL Services

Soft Switch Technology In Access

Wireline Broadband Internet (WBI) Access Transmission Allocation Methods - Reporting Guidelines

Integrated Network Interface Device (INID)

Basic Exchange Loop Count for Bonded Pairs

Categorization of Wideband and Special Access Services

Providing Local Exchange Telephone Service Using Voice over Internet Protocol (VoIP) Technology - Reporting Guidelines

Separations Cost Issue 4.9, Wireless Technology in Loop Facilities
Overview of Telephone Plant

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