Introduction to
Digital Subscriber's Line (DSL)

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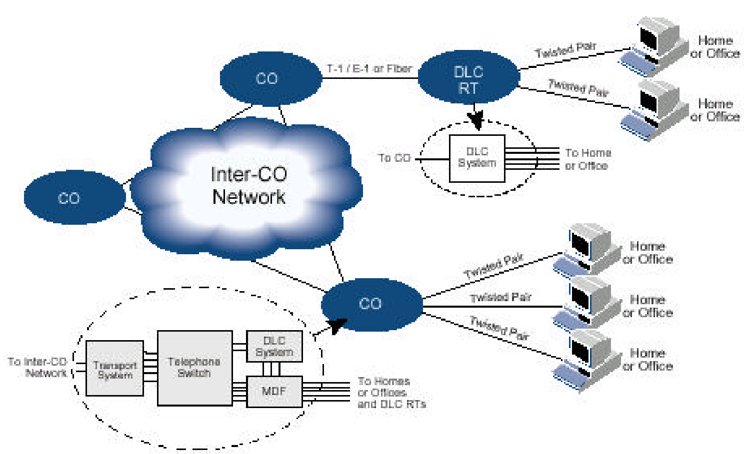
Chapter 2 Telephone Infrastructure

- Telephone line dates back to Bell in 1875
- Digital Transmission technology using complex algorithm based on DSP and VLSI to compensate impairments common to phone lines.
- Phone line carries the single voice signal with 3.4 KHz bandwidth, DSL conveys 100 Compressed voice signals or a video signals.

- 15% phones require upgrade activities.
- Phone company spent approximately 1 trillion US dollars to construct lines;
- 700 millions are in service in 1997, 900 millions by 2001.
- Most lines will support 1 Mb/s for DSL and many will support well above 1Mb/s data rate.

Typical Voice Network



THE ACCESS NETWORK

- DSL is really an access technology, and the associated DSL equipment is deployed in the local access network.
- The access network consists of the local loops and associated equipment that connects the service user location to the central office.
- This network typically consists of cable bundles carrying thousands of twisted-wire pairs to feeder distribution interfaces (FDIs).

Two primary ways traditionally to deal with long loops:

- *1.*Use loading coils to modify the electrical characteristics of the local loop, allowing better quality voice-frequency transmission over extended distances (typically greater than 18,000 feet).
- ***Loading coils are not compatible with the higher frequency attributes of DSL transmissions and they must be removed before DSL-based services can be provisioned.***

Two primary ways traditionally to deal with long loops

- *2.* Set up remote terminals where the signals could be terminated at an intermediate point, aggregated and backhauled to the central office. The backhaul to the CO or SWC via T1/E1 circuits may be based on copper or fiber-based technologies.
- ***One advantage of terminating the loops at the DLC remote terminal is that it reduces the effective length of the copper line, thus improving the reliability of the service.***
- ***An additional benefit is that Plain Old Telephone Services (POTS) can be multiplexed into a higher-speed T1 format for transmission to a central office over a single fiber optic or four-wire circuit.***

Two primary ways traditionally to deal with long loops:

- ***while the RT architecture solves many problems for POTS, it introduces complexities relative to the provisioning of DSL-based services.***
- ***DSL transmissions can only be supported over contiguous copper wire loops.***
- ***The use of DLCs varies by telephone company and typically ranges from almost none to as high as 30 percent of the local loops within a given telephone company's access network.***

Public Switched Telephone Network (PSTN)

- Current projections estimate that nearly 700 million copper wire access lines connect homes and business customers to PSTN.
- More than 95 percent of the local access loops consist of a single-pair twisted wire supporting POTS.
- POTS is designed to carry a voice conversation, which requires the lines to handle frequencies up to about 3,400 Hz.
- This narrow-band service has supported only voice calls or analog modem transmissions at speeds ranging from 9.6 to 33.6 kilobits per seconds (Kbps), and more recently approaching the 56 Kbps range.

Basic Rate Interface Integrated Services Digital Network

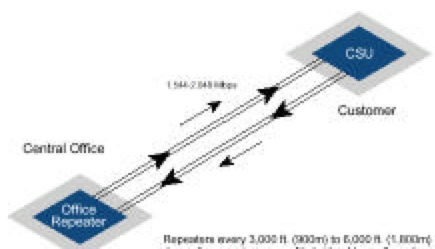
- A very small percentage of the PSTN connections are provisioned with Basic Rate Interface (BRI) Integrated Services Digital Network (ISDN) services.
- Customers have either two B-channels (Bearer channels) for one voice & one data, two voice, or two data (64 Kbps each); or 128 Kbps for data.
- BRI ISDN also provides a 16 Kbps D-channel (Data channel) that supports signaling for the B-channel and is capable of carrying packet data.

DEDICATED T1/E1 ACCESS USING LOCAL LOOP

- Same physical copper wire lines that are used to provision POTS and ISDN can be engineered & conditioned to provision T1/E1;
- In cases that copper wire loops cannot be reliably engineered for T1/E1, T1/E1 services are provisioned using fiber optic cables.
- Telephone companies have charged higher recurring monthly service charges for T1/E1.

DEDICATED T1/E1 ACCESS USING LOCAL LOOP

- Traditional T1 and E1 modulation can only be supported over relatively short distances.
- T1/E1 over longer loops requires multiple stages with repeaters at intermediate points.
- Repeaters placed within 2-3 Kft of endpoints, not more than 3-6K feet between repeaters,

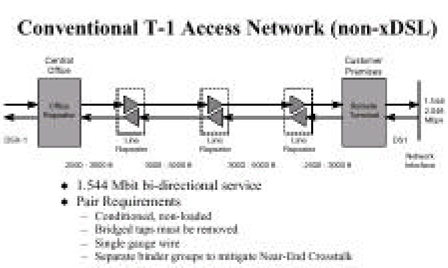


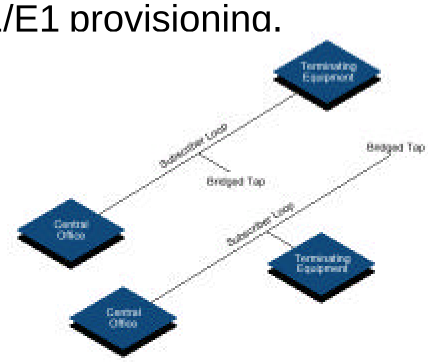
DEDICATED T1/E1 ACCESS USING LOCAL LOOP

- ***T1 is a digital service***
- ***In T1 AMI coding scheme, each bit is transmitted over the copper wire loop using an analog waveform that is modulated to a 1 or 0.***
- ***transmission of 1,536 Kbits of info payload, plus associated framing and overhead info (a total of 1,544,000 bits/sec) needs spectrum to 1,544 KHz, with one bit each baud or frequency cycle.***
- ***the distance limitation of less than 6,000 feet of 22-gauge wire between repeaters.***

DEDICATED T1/E1 ACCESS USING LOCAL LOOP

- Traditional T1 and E1 can’t operate on loops that have bridged taps. All bridged taps have to be removed before T1/E1 provisioning.





PRIVATE/CAMPUS NETWORKS

- A significant market based on private copper wire networks that are isolated to a self-contained campus environment.
- Private/campus networks: carrier-like architecture, where a single building or location on the campus acts as the hub (CO) and the remaining locations connected with embedded copper wire on campus.
- ***DSL technologies can dramatically improve operations within this environment***.

Mid-Chapter Summary

- *Telephone network structure was primarily designed for voice-grade services.*
- *The use of fiber optics to increase the Quality and capacity while reducing expense has resulted in high-capacity service capabilities between COs, but not necessarily within the local access network.*
- *DSL technology is a local access network technology.*

Mid-Chapter Summary (Cont)

- *Use of remote terminals reduces effective length of the line and improves reliability.*
- *Historically, distance limitations in the local loop have required the use of repeaters and the removal of unused-bridged taps to support high-speed data. DSL technology overcomes these limitations.*
- *Beyond the boundary, the private/campus network environment is well suited for deployment of DSL-based services.*

Twisted-Pair Transmission

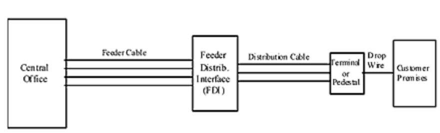
- Origins
  - Started 1877 with Bell connected phone via single iron line with the earth as return path, but SNR is low.
  - Later used a pair of bare wires, which resulted in coupling with adjacent pairs.
  - Soon realized that the cross talk can be reduced by periodically swapping the position of left and right conductors.

Twisted-Pair Transmission

- Origins (Continued)
  - Bell invented in 1881 the twisted wire pairs of individually insulated conductors twisted together.
  - Modern phone cables are only slightly different in twist rates.
  - Copper is used to minimize signal attenuation due to electrical resistance.

Telephone Network and Loop Plant Characteristics

- POTS is provisioned to customers by routing twisted wire pairs between the CO and the customer premises (CP) location.
- The twisted wire pair that connects the CO to the CP is the subscriber loop, which may consist of sections of copper twisted wire pairs of one or more different gauges.
- Loop refers twisted-pair copper line from CO to customer.



Feed Plant

- COs: serve over 100,000 lines, terminating at main distributing frame (MDF);
- Feeder plant cables: connect CO to serving area interface (SAI), serving up to 10,000 wire-pairs per cable.
- SAI: is at most 3,000 ft away from customers' premises, serves 1,500 t o 3,000 lines, contains only a wire cross-connect field, no active electronics.
- Loops emanating from the SAI to customers are also called "distribution plant".

Loop plant - design rules

- Loop resistance is not to exceed 1,500 Ohms.
- Inductive loading is to be used whenever the sum of all cable lengths, including bridged taps, exceeds 15 kft.
- For loaded cables, 88-mH loading coils are placed at 3 kft from the CO and thereafter at intervals of 6 kft.
- For loaded cables, the total amount of cable, including bridged taps, in the section beyond the loading coil furthest from the CO should be between 3 kft and 12 kft.
- There are to be no bridged taps between loading coils and no loaded bridged taps.

CSA Design Rules

- There should be only nonloaded cable.
- Multigauge cable is restricted to two gauges.
- Total bridged-tap length may not exceed 2.5 kft, and no single bridged tap may exceed 2.0 kft.
- The 26 AWG cable may not exceed a total length of 9 kft, including bridged taps. For single gauge or multigauge cables containing only 19, 22, or 24 AWG cable, the total cable length may not exceed 12 kft, including bridged taps.
- The total cable length including bridged taps of a multi-gauge cable that contains 26-gauge wire may not exceed where L_{26} is the total length of 26 gauge wire in the cable (excluding any 26 gauge bridged tap) and L_{Btap} is the total length of bridged tap in the cable. All lengths are in kft.

Digital Loop Carrier (DLC)

- DLC: electronic multiplexing device resides at SAI to multiplex up to 96 lines into a few T1 carrier feeder lines to the CO.
- DLC: replaces the large number of copper pairs in the feeder with MUX.
- Future: Next Generation of DLC (NGDLC) will be fiber-fed, terminated up to 2,000 lines.
- Only 15% lines are served via DLC.
- DLC does not eliminate the copper loops but making them shorter, which are idea for DSL.

Distribution Plant (D-Side)

- Distribution cable (D-Side) contains 25 to 1000 pairs
- Distribution cable (D-Side) leads to the drop wires, via a wiring pedestal (distribution terminal), serving four to six living units.
- A wiring pedestal (distribution terminal) serves four to six living units, 50% have a network interface device (NID, including an over-voltage protector and test access jack) inside.
- Both feeder and distribution cable are bundled into binder group of 25, 50, or 100 pairs.

Wire Gauge

- 1300-ohm resistance design rule: first 10000 ft is 26 AWG, beyond this point heavier gauge wires (24 AWG in most cases, and 22 AWG, or 19 AWG for excessively long loops).
- Wire spools are 500 ft long, so a loop may use up 22 splices.
- Signal will reflect when different gauge wires are spliced.
- DSL will echo canceler will tolerate the gauge change.

Bridged Tap

- A Bridged Tap is a branching connection of a pair length that is connected to a loop at one end and is unterminated at the other, to permit the pairs to be used or re-used to serve the customers along the cable route.
- 80% US loops have bridged taps.
- The reflection of signal from unterminated bridged taps result loss. A heavy gauge tap of one quarter wavelength causing 3 to 6 dB losses.
- The adaptive equalizer and echo canceler can reduce this.

Loaded Loop

- For loops beyond 5.5 km (18 kft), the signal loss at frequencies above 1 kHz is excessive.
- Loaded loop: Series inductors (88mH) place at 1.8 km (6 kft) to flatten frequency across voice band at expense of higher frequency.
- DSL will not operate on loaded loop.

Loop Length Distribution

- Central offices are positioned in the center of population.
- 50% of customers have loops shorter than 2 km (6.6kft)
- Business loops tend to be shorter, and residential tend to be longer.
- Variations are expected.
- DLCs make effective loop length shorter, but farther way constructions offset this.

Customer Premise Configuration

- Anything goes:
  - type of wires,
  - topology, and
  - appliances.
- DSL transceiver should be close to the entry but may not be convenient, sometime new wire (e.g. Category 5 UTP Wire) may be needed.
- DSLs are point to point: one line one device. Local Area Network (LAN) can be used.

Line Powering

- Mid-span repeaters are line-powered since no sources are available at mid-span repeater side.
- Customer end units of HDSL and ISDN are line-powered.
- Negative DC from CO and ground are used.
- Devices should automatically enter the “idle” (low power) mode.

Sealing Current

- Sealing current (wetting current) from line power is applied to preventing oxidation.
- DSL without line power can be subject to splice oxidation.

Voice Band Modem

- Introduced in late 1950s for Public Switch Telephone Network (PSTN);
- Convey the data from 200 Hz to 3.4 KHz;
- Fax machines use voice band modem;
- Modem History Review:
  - AT&T Bell 103 at 300 b/s using FSK, in 70s
  - Vadic VA 34000 1200 b/s using PSK, in 80s
  - V.32 9600 b/s using FDM
  - V.90 56000 b/s using PCM, 1996

Voice Band Modem (Cont)

- Practical limits to 50 Kb/s due to transmitted power. Line impairment, etc.
- Fundamental limit: Voice Codec limits a conversion up to 64 Kb/s for PCM.
- Potentials:
  - Not PCM?
  - More compression?