CISC452-00W
Telecommunications Systems

Lesson 1
Local Access Technologies

Transmission

Definition

Electrical transfer of a signal, message, or other form of intelligence from one location to another

Co-exists with *switching* as being one of the two major disciplines of telecommunication

Transmission

Switching

Establish a connection from point X to some distant point Y

Transmission and switching are almost one in-the-same in modern PSTN equipment

Baseband Transmission

Definition

The transmission of a raw electrical signal

Severe distance limitations

Voice transmitted from a standard telephone set will become inaudible <30km

Solution

Use *carrier* or *radio* transmission

Modulation

IEEE definition

“a process whereby certain characteristics of a wave, often called the carrier, are varied or selected in accordance with a modulation function”

English definition

The process of impinging useful information on a carrier

Carrier

- Generated by the transmitting side of a telecommunication link
- Characterized by a frequency
- By itself, it contains no useful information
- Carrier transmission
  - Implies the use of a conductive medium
- Radio transmission
  - Implies the radiation of a signal in the form of an electromagnetic wave

Modulating Function

Three generic forms include

- Amplitude modulation (AM)
- Frequency modulation (FM)
- Phase modulation (PM)

Modulation

Amplitude Modulation

The carrier is varied in amplitude in accordance with the baseband signal

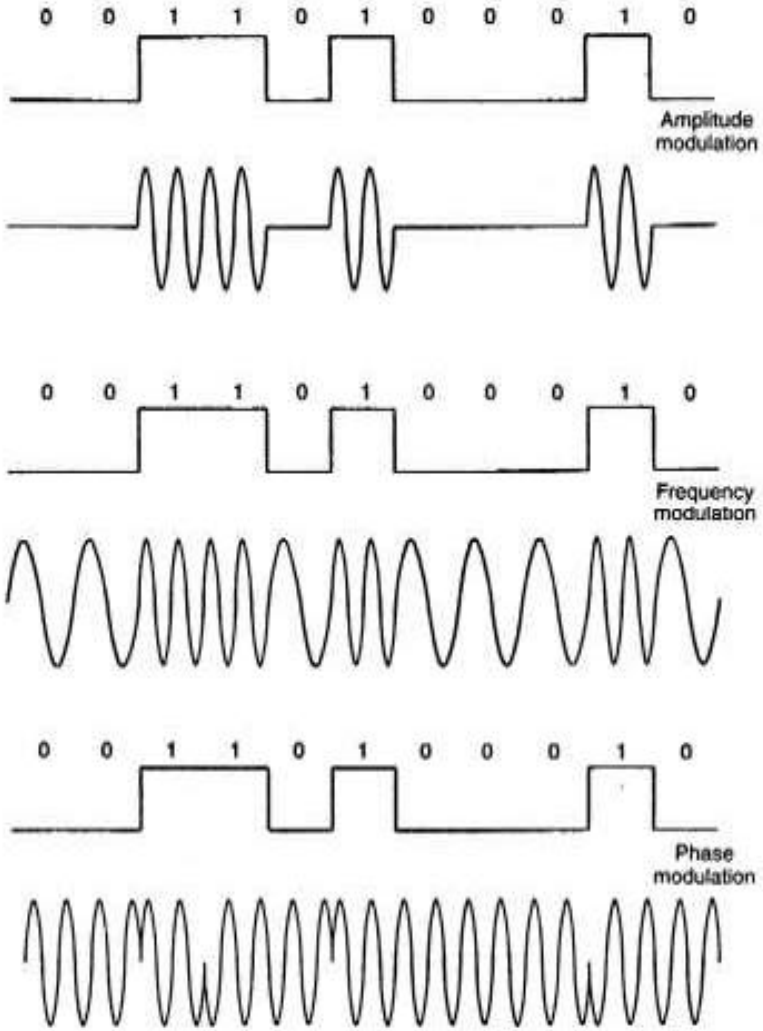
Frequency modulation

The carrier is varied in frequency in accordance with the baseband signal

Phase modulation

The carrier is varied in phase in accordance with the baseband signal

Modulation


0 0 1 1 0 1 0 0 0 1 0
Amplitude modulation
0 0 1 1 0 1 0 0 0 1 0
Frequency modulation
0 0 1 1 0 1 0 0 0 1 0
Phase modulation

Analog Transmission

Continuous signal

Information content is conveyed by the value or magnitude of one or more characteristics of the signal

- **Amplitude, frequency, or a phase of a voltage**
- **Amplitude of duration of a pulse**
- **Angular position of a shaft**
- **Pressure of a fluid**

Digital Transmission

Discrete states

- Presence or absence of a voltage
- State of a contact (open or closed)
- Presence of absence of a magnetized particle (magnetic disks)

Meaning is determined by assigning numerical values to the various combinations of the discrete states of the signal

Transporting Electrical Signals

Common types of transmission media

- Wire pair
- Coaxial cable
- Fiber optic cable
- Radio

Wire Pair

- Typically use a copper conductor
- Attenuation (loss)
  - Dissipation of signal strength as it travels along a transmission medium
  - Typically expressed in decibels (dB)
    - $L_{db}=10\log(P_1/P_2)$, where P_1 is the power of the signal where it enters the wire and P_2 is the power at the distant end

Wire Pair

Attenuator

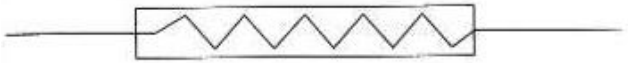
Device that is put in a circuit to cause loss

Amplifier

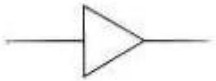
Provides gain; increases a signal’s intensity

Wire Pair

Attenuator Symbol



Amplifier Symbol



Wire Pair

Crosstalk

- Noise induced in a pair of wires from nearby wire pairs
- Commonly occurs when wires are placed closed together such as in a telephone cable
- Problem is remedied by twisting the pairs together; hence the term *twisted pair*

Wire Pair

Delay distortion

- Varies directly with the length of the line
- Little effect on voice transmissions
- Restricts data rate for digital/data transmissions
- Caused by the *capacitance* between
  - One wire and the other of a pair
  - Between each wire and ground
  - Between each wire and shield (if present)

Capacitance

Affects alternating current circuits

Capacitor

- Defined as two conductors separated by an insulator; ie – a wire pair

The capacitance of two parallel open wires of great length contain a sufficient amount of capacitance

Bandwidth

IEEE definition

"the range of frequencies within which performance, with respect to some characteristic, falls within specific limits"

Bandwidth of twisted pair

PSTN subscriber access provides 2MHz over 1 mile of length

Category 5 twisted pair only has a 67dB loss at 100MHz at lengths of 1000 feet

Coaxial Cable Transmission

Conducting pair consists of a cylindrical tube with a single wire conductor at its center – all held in place with a surrounding insulator

Used primarily high frequency radio applications

Coaxial Cable

Typical uses include

- RF transmission lines
- Cable TV plants; particularly during the “last mile”

Used to be used for long-distance, multichannel transmission

- The advent of fiber, which has a relatively flat frequency response, has made this use obsolete

Impedance

Definition

The combined effect of a circuit's resistance, inductance, and capacitance

Expressed in *ohms* Ω

Common impedance levels are 75 & 50

Equalization

Frequency response of coaxial cable is exponential

- At 100kHz loss ~ 1dB; at 10MHz loss ~ 12dB

Equalization levels out this frequency response

- What is it????

Fiber Optic Cable

- **Uses include**
  - **Wideband terrestrial links**
  - **Cable television**
  - **Data network backbones**
- **Very high bandwidth; measured in terahertz**
  - **The entire usable radio frequency spectrum can be carried by a single strand**

Fiber Optic Systems

Two major types of limitations

- Loss limited
- Dispersion limited

Fiber Optic Systems

Loss limited

As the link is extended in distance the signal will dissipate to a point at which it becomes unusable

Maximum loss is a function of

- Type of fiber
- Wavelength of the light signal
- Bit & error rate
- Power output of transmitter
- Sensitivity of the light detector

Fiber Optic Systems

Dispersion limited

- Link's length is limited by signal corruption
  - As length is increased a point may be reached where the bit error rate is too high
  - Energy elements of a light pulse become delayed – confuses the detector
    - *Modes* of a pulse may arrive at different times
    - Different frequencies may arrive before others

Fiber Optic Systems

Maximum length can range from 20 miles to several hundred miles before requiring a repeater

- **Typical amplifiers/repeaters can boost the signal 20-40dB**
- **The signal is detected, demodulated, and remodulated**

Radio Transmission

Based on radiated electromagnetic energy

Unguided transmission – no conductors

Radio Transmission

Necessary components

- Transmitter for generating & modulating a high-frequency carrier wave with an information baseband
- Transmitting antenna that will radiate the modulated signal energy in a particular direction
- Receiving antenna that will receive the radiated energy
- Receiver to select the desired carrier wave, amplify it, and detect or separate it from the carrier

Radio Transmission

Radio link capacities

Line-of-sight microwave

2,5,10,20,30,40, or 60MHz

SCADA (system control and data acquisition)

up to 12kHz in the 900MHz band

Satellite communications

500Mhz or 2.5GHz bandwidths broken down into 36MHz and 72MHz segments

Radio Transmission

- Cellular radio
  - 25MHz bandwidth in the 800/900MHz band
  - 25MHz band is split into two 12.5MHz segments for competitive providers
- Personal communication services (PCS)
  - 200MHz band just below 2.0GHz, broken down from there into segments such as licensed and unlicensed users

Radio Transmission

- **Cellular/PCS by satellite**
  - **10.5MHz bandwidth in the 1600MHz band**
- **Local multipoint distribution system (LMDS)**
  - **28/38GHz**
  - **1.2GHz bandwidth for CATV, Internet, data, and telephony services**

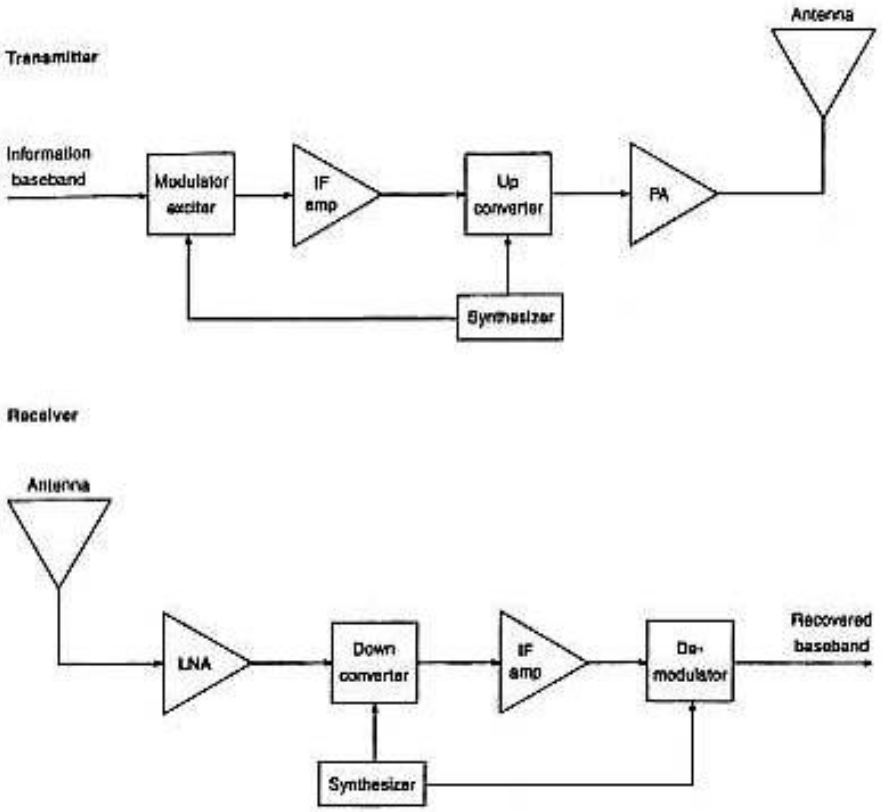
Radio Transmission

Bandwidth determined in most cases by the FCC for a particular service

Capacity is increasing through techniques such as *bit packing*

- **Allows the capacity of a unit of bandwidth to be greater than 1 bit per Hz of bandwidth**
- **Typical line-of-sight microwave transmissions are 5-8 bits per Hz**

Radio Transmission



Signaling

IEEE Definition

“Exchange of information specifically concerned with the establishment and control of connections and the transfer of user-to-user and management information in a telecommunication network.”

Types of Signaling

- **Supervisory**
- **Address**
- **Call progress audible-visual**
- **Can also be broken into**
  - **Subscriber signaling**
  - **Interswitch signaling**

Supervisory Signaling

Provides information about the line condition

Tells a switch whether an internal circuit or an external trunk is busy or idle

Whether a called party is on/off-hook

Whether a calling party is on/off-hook

Address Signaling

Routes a call from the calling party to the called party

Originates from CPE; usually as dialed digits or pushbuttons

The local switch receives these digits and determines if more than one switch will be needed to complete the call

Address Signaling

Address signaling between switches is known as interregister signaling

Interregister signaling consists of both address and supervisory signaling

Call Progress

Forward direction

Consists of alerting the called subscriber in some way (bell, buzzer, light)

Backward direction

Ringback – tells the calling party that the remote phone is ringing

Busyback – tells the calling party that the called line is busy

Call Progress

ATB (All Trunks Busy)

Too much traffic being routed. I.E. – switch capacity has been exceeded

Loud warble on CPE – timeout

Occurs when a telephone has unintentionally been left off-hook

Conveying Signal Information

Duration of pulses

Combination of pulses

Frequency of signal

Combination of frequencies

Presence or absence of a signal

Binary code

Direction or voltage of transmitted current

Local Loop Signaling

Terminology

- Refers back to old manual switchboards and the connections on the plugs and jacks
- Tip
- Ring
- Sleeve
  - Typically grounded and has no effect electrically anymore

Local Loop Signaling

Loop-start signaling

Occurs when a telephone goes off-hook and a switch is closed thus allowing current to flow in the loop

This tells the local switch that service is being requested on that line. As a result a dial tone is returned to the subscriber

Local Loop Signaling

Glare

- Occurs with loop-start signaling
- Results from the attempt to seize a subscriber's loop from both directions; such as when an outgoing call and incoming call are made nearly at the same time
- Less likely to happen to individual subscriber loops than on a PBX

Local Loop Signaling

Ground-start signaling

- Prevents *glare* from occurring in PBX systems
- From local switch to PBX
  - The local switch grounds the conductor tip in order to seize the line
  - After a few seconds delay, ringing voltage is applied to the line
  - The PBX then detects the grounded tip conductor and will not allow an outgoing call to occur

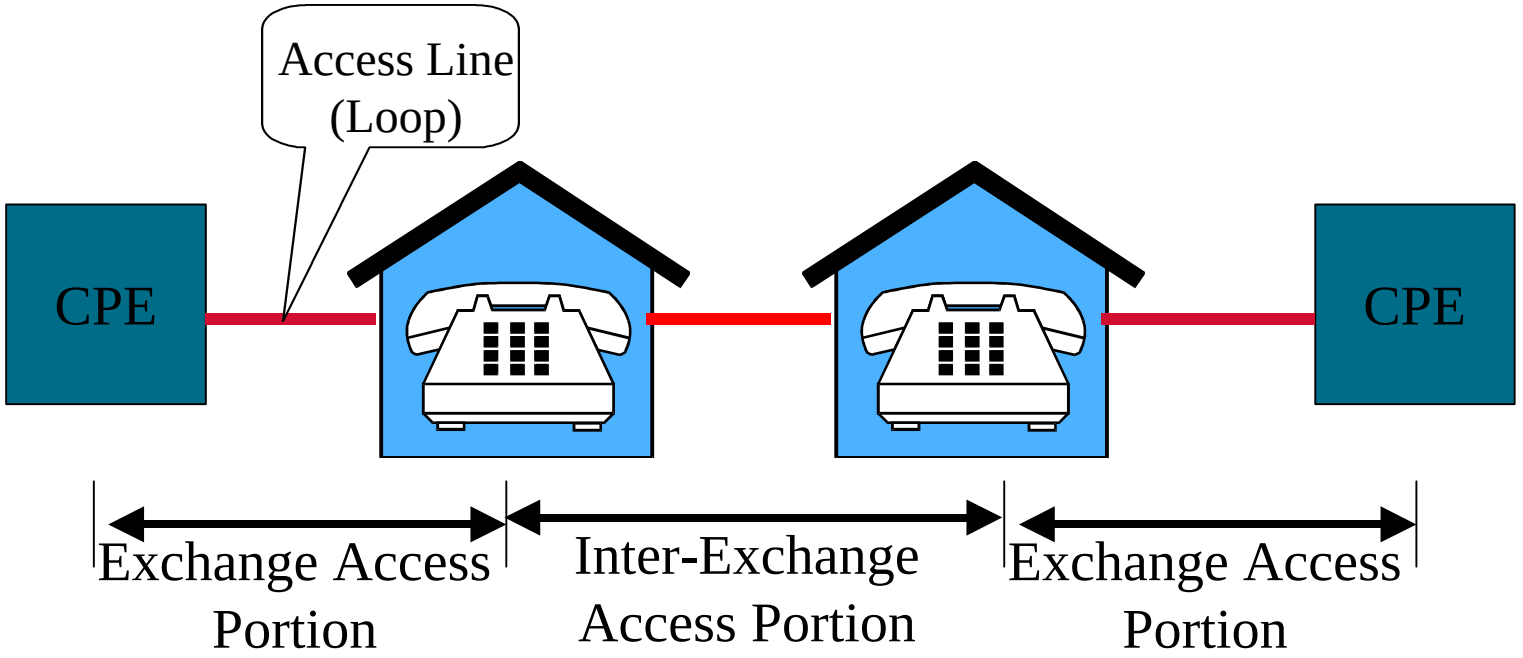
Local Loop Signaling

Ground-start signaling

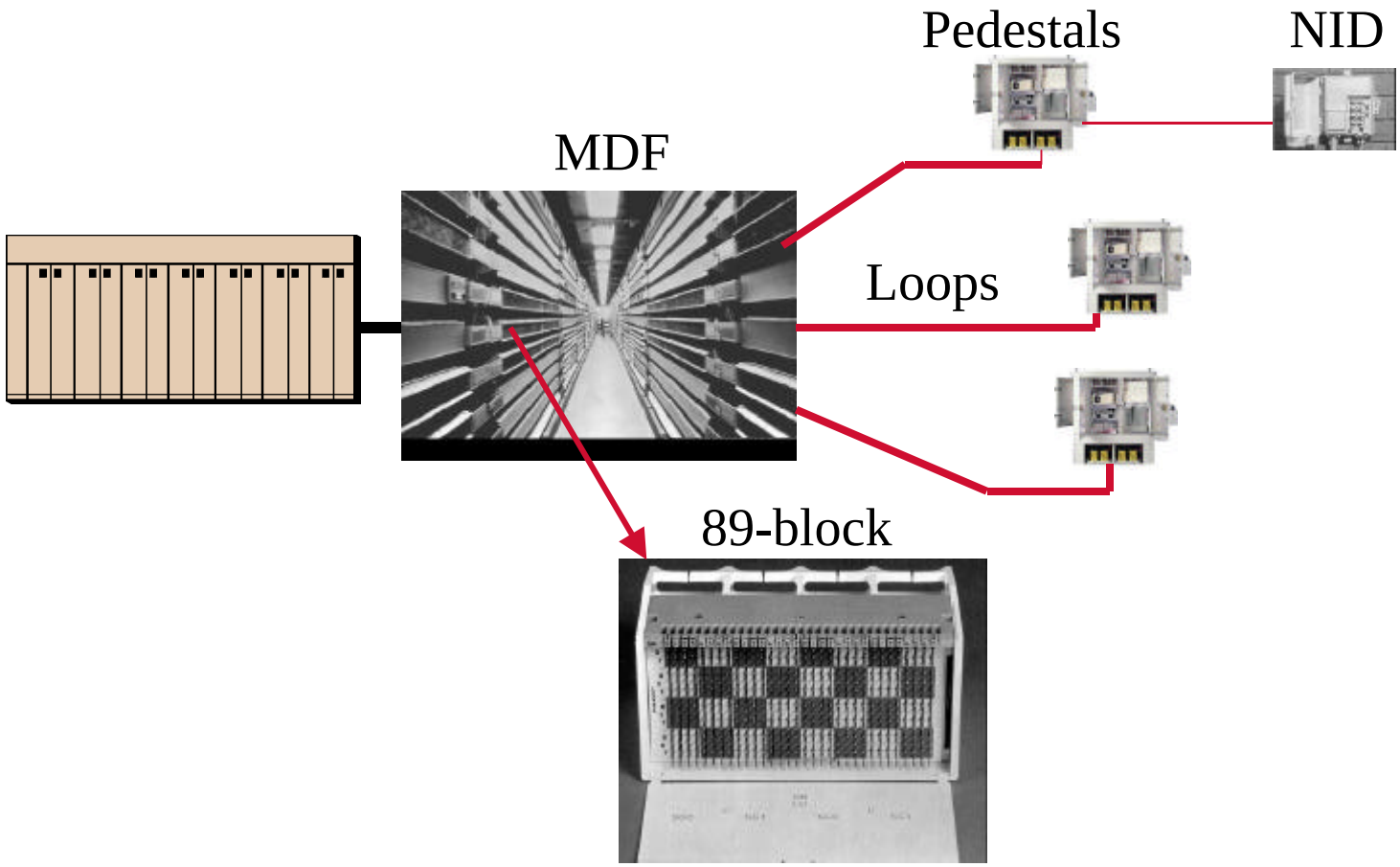
From PBX to local switch

- The PBX grounds the ring conductor, thus seizing the line
- At this point the serving switch recognizes the line as being busy, so it will not allow calls to terminate to it
- The switch at this point grounds the tip conductor and returns a dial tone
- It is possible for a double seizure of the line to occur in this case; at this point programming in one of the switches will force one of them to back down

Exchange Access Channel



Local Loops



Line Circuit Functions

- Terminate loop in a balanced 900Ù circuit
- Supplies DC loop current from CO battery
- Supervises loop currents
- Receives dialed address
- Isolates foreign potentials
- Applies ringing voltage to the loop
- Supplies call progress tones as needed
- Converts 2-wire loop into 4-wire internal path
- Provides A/D and D/A conversion (digital COs)
- Provides test access

BORSCHT

Battery

Overvoltage protection

Ringing

Signaling

Coding

Hybrid

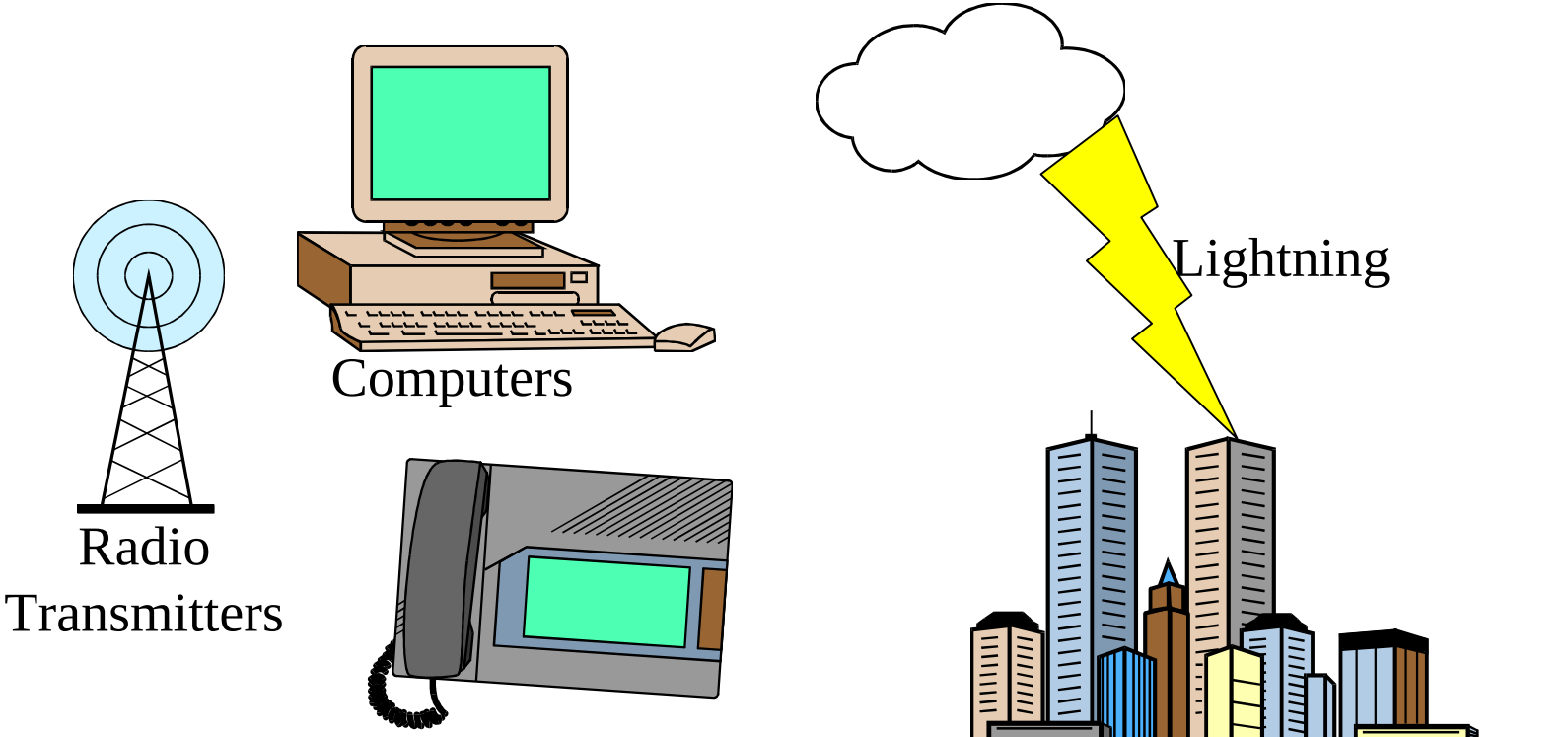
Test

Local Access

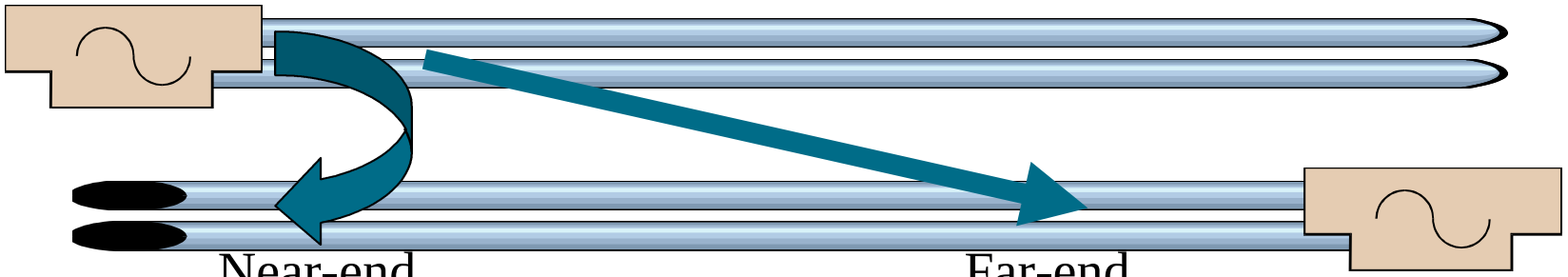
Attenuation of signals limits effective distance for many services

Effects of noise and cross-talk especially adverse to digital service

Noise Sources in Outside Plant



Crosstalk



Near-end
Crosstalk
NEXT

Far-end
Crosstalk
FEXT

Measurement of Circuit Noise

Measured in dB relative to a reference with a specified bandwidth

dBrnC - noise relative to a picowatt (-90 dBm) of 1000 Hz tone, C-message filter

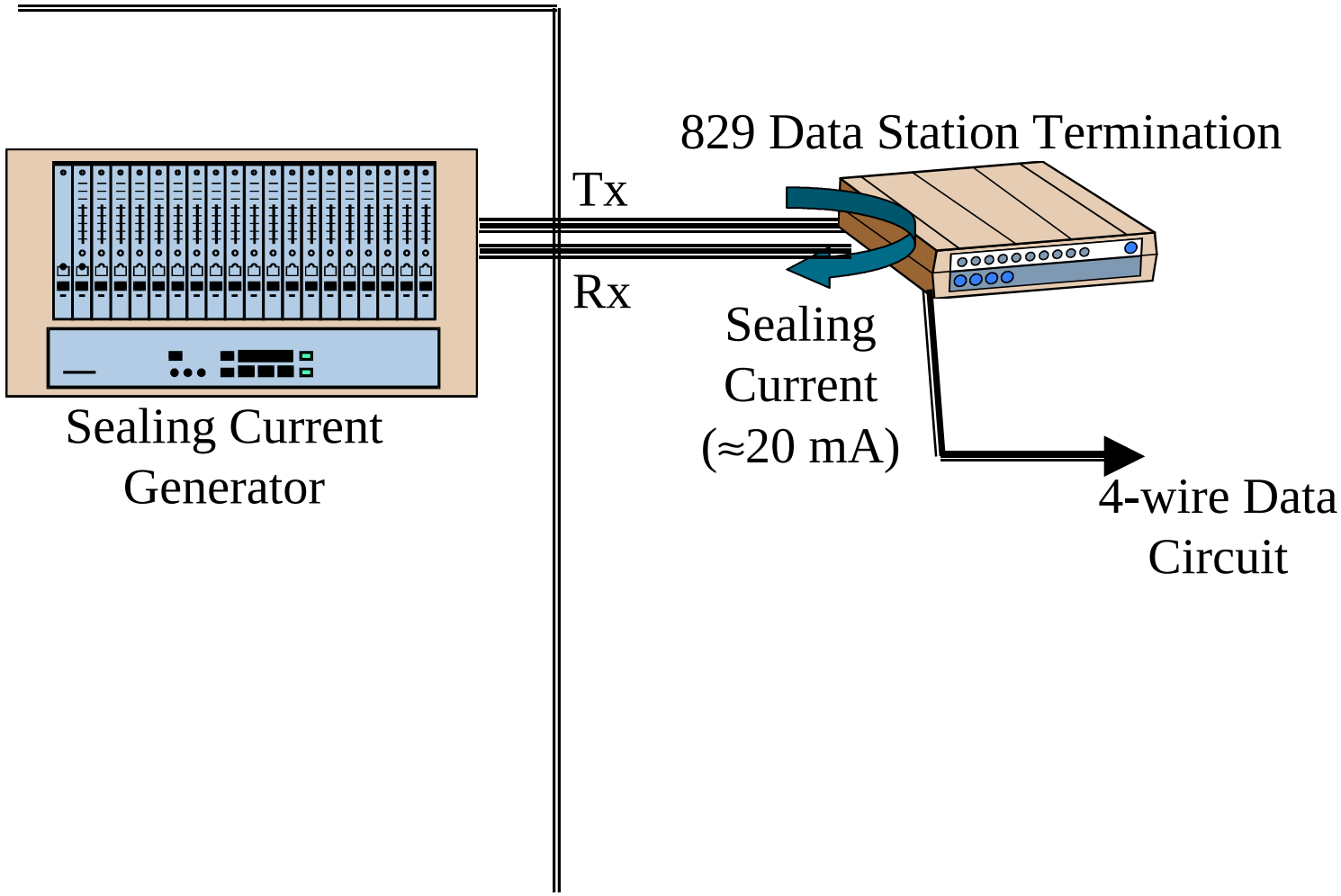
Other filters

- **3 kHz flat**
- **Program**
- **15 kHz flat**

Why do data lines get noisier with time?

- Voice telephone pairs have current (>20 mA) flowing whenever off-hook
- Metals tend to oxidize over time, causing high resistance films to develop
- Loop current tends to clean these films
- Dry data loops have negligible loop currents, hence the tendency to get noisy over time

Sealing Current



Loop Limits
Analog Telephone Service

Limited to 8 dB loss at 1000 Hz.

Loss dependent upon

Wire gauge

Temperature

Representative low-cap cable at 25^{o} C.

Gauge	Loss/1000 ft (dB)	Loop Length, kft
26	0.51	15.68
24	0.41	19.51
22	0.32	25.00
19	0.21	38.09

Temperature Effects

Temp °F	19 AWG	22 AWG	24 AWG	26 AWG
55	1.24	1.78	2.26	2.88
100	1.30	1.87	2.37	3.02
140	1.35	1.95	2.47	3.15

dB loss per mile; 1000 Hz signal
Unloaded PIC

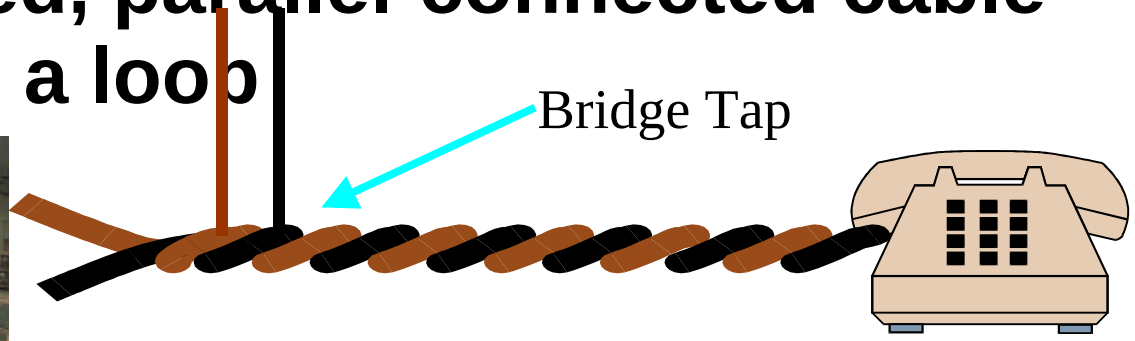
Properties of Conductors

AWG	Mutual Cap.	Loading Coils	Attenuation	Max Loop Length
No.	nF/km	mH	dB/km	kft
26	40	none	1.61	16.30
	50	none	1.79	14.66
	40	D66	1.25	21.00
	50	D66	1.39	18.88
	40	H88	1.09	24.08
	50	H88	1.21	21.69
24	40	none	1.27	20.67
	50	none	1.42	18.48
	40	D66	0.79	33.22
	50	D66	0.88	29.83
	40	H88	0.69	38.04
	50	H88	0.77	34.09
19	40	none	0.71	36.97
	50	none	0.79	33.22
	50	D66	0.29	90.51
	50	H88	0.26	100.95

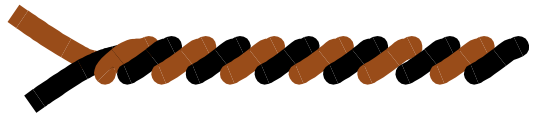
Terminology

AWG - American Wire Gauge

Bridge Tap - an unused, open-circuited, parallel-connected cable pair on a loop



Cable Color Codes



Pair (2 wires)

Binder (25 pair)

Super Unit Binder (24 Binders)

1-600	White
601-1200	Red
1201-1800	Black
1801-2400	Yellow
2401-3000	Violet
3001-3600	Blue
3601-4200	Orange

Pair No.	Color	Pair No.	Color
1	White-Blue	14	Black-Brown
2	White-Orange	15	Black-Slate
3	White-Green	16	Yellow-Blue
4	White-Brown	17	Yellow-Orange
5	White-Slate	18	Yellow-Green
6	Red-Blue	19	Yellow-Brown
7	Red-Orange	20	Yellow-Slate
8	Red-Green	21	Violet-Blue
9	Red-Brown	22	Violet-Orange
10	Red-Slate	23	Violet-Green
11	Black-Blue	24	Violet-Brown
12	Black-Orange	25	Violet-Slate
13	Black-Green		

Cable Construction

Sheath

- Armored (gopher protection) - lead/steel
- Dielectric

Fill

- Air filled (pressurized?)
- Gel-filled (icky-PIC)

Insulation

- Paper pulp
- Plastic

Loading Coils

Used to extend useful length o for voice service

Counteracts the effects of cable capacitance

BAD NEWS for high-speed digital services - causes excessive attenuation at frequencies above voice-band

Loading Coil Design Rules

Types of Loading

D66 - 66 mH coils spaced 4500 ft

H88 - 88 mH coils spaced 6000 ft.

First coil is located half-section out from CO

Loading Coil Design Rules

Only used on loops > 18,000 ft. (19,22,24 AWG) or 15,000 ft. (26 AWG)

Never used on high speed (>9600 bps) data services

- **Envelope delay distortion**

Subscriber never installed between loading coils

Loop Design Philosophies

Revised Resistance Design (RRD)

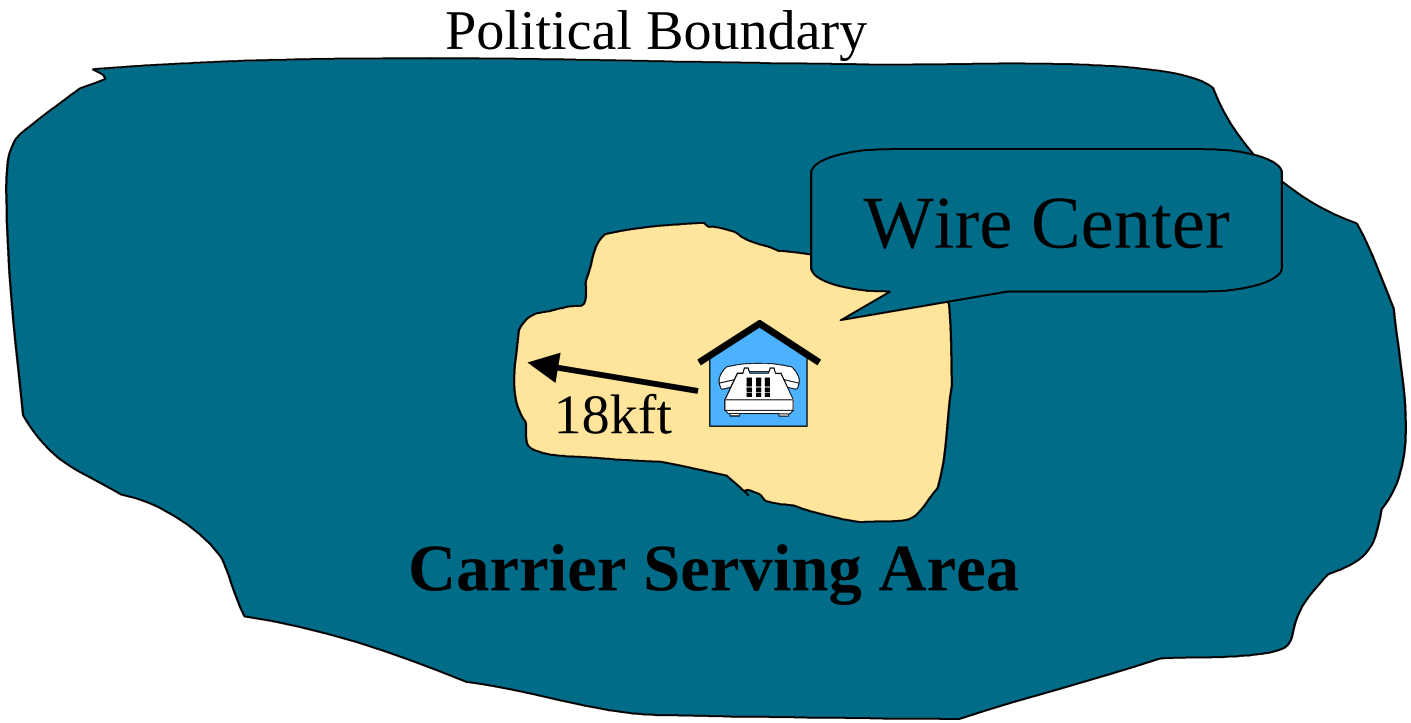
Design Parameter	Revised Resistance Design
Loop Resistance	0-18 kft: 1300 ohms max.
	18-24 kft: 1500 ohms max.
Loading	88 mH > 18 kft
Cable gauge	Two-gauge combinations
	22-, 24-, 26-AWG preferred
Bridged Tap	Total BT length 6 kft max.
Limitations	No digital services > 18 kft

Loop Design Philosophies

Modified Long Route Design (MLRD)

Design Parameter	Modified Long Route Design
Loop Resistance	1501-2800 ohms
Loading	88 mH
Cable gauge	Two-gauge combinations
	22-, 24-, 26-AWG preferred
Bridged Tap	Total BT length 12 kft max.
Limitations	No digital services; range extenders

Wire Centers and Cable Plant



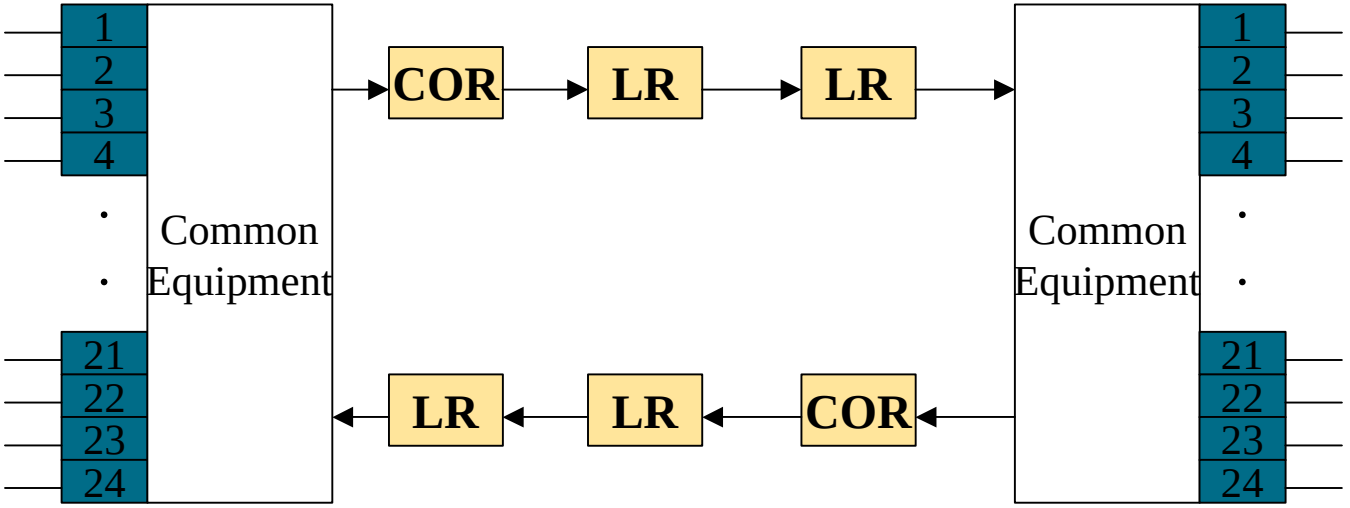
Carrier Systems

Digital Repeater

How do we serve customers outside the loop limits?

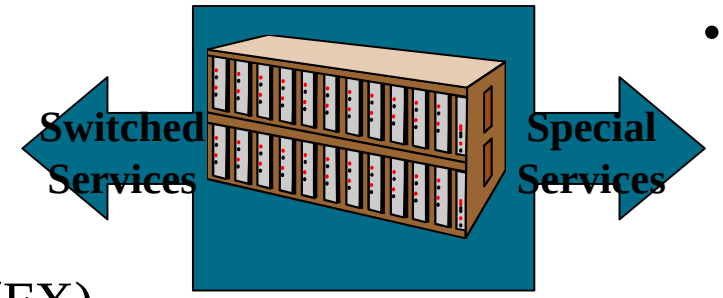
- Range extenders
- Carrier systems (Subscriber Loop Carrier)
  - Analog (frequency division multiplexing)
  - Digital (time division multiplexing)

DLC Block Diagram



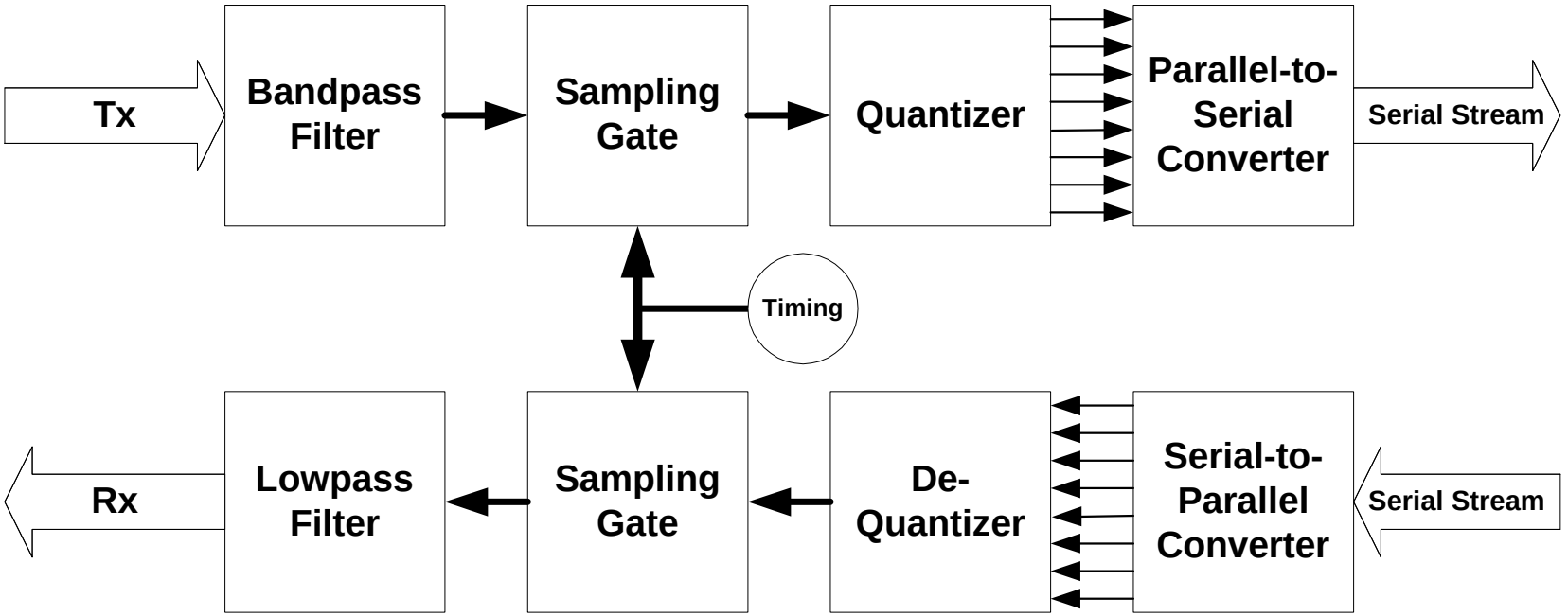
Digital Loop Carrier Applications

- Single-party line
- Multi-party line
- Coin
- 4W E&M
- 2W E&M
- Foreign Exchange (FX)
- Electronic business set
- Basic-rate ISDN
- Direct Inward Dial

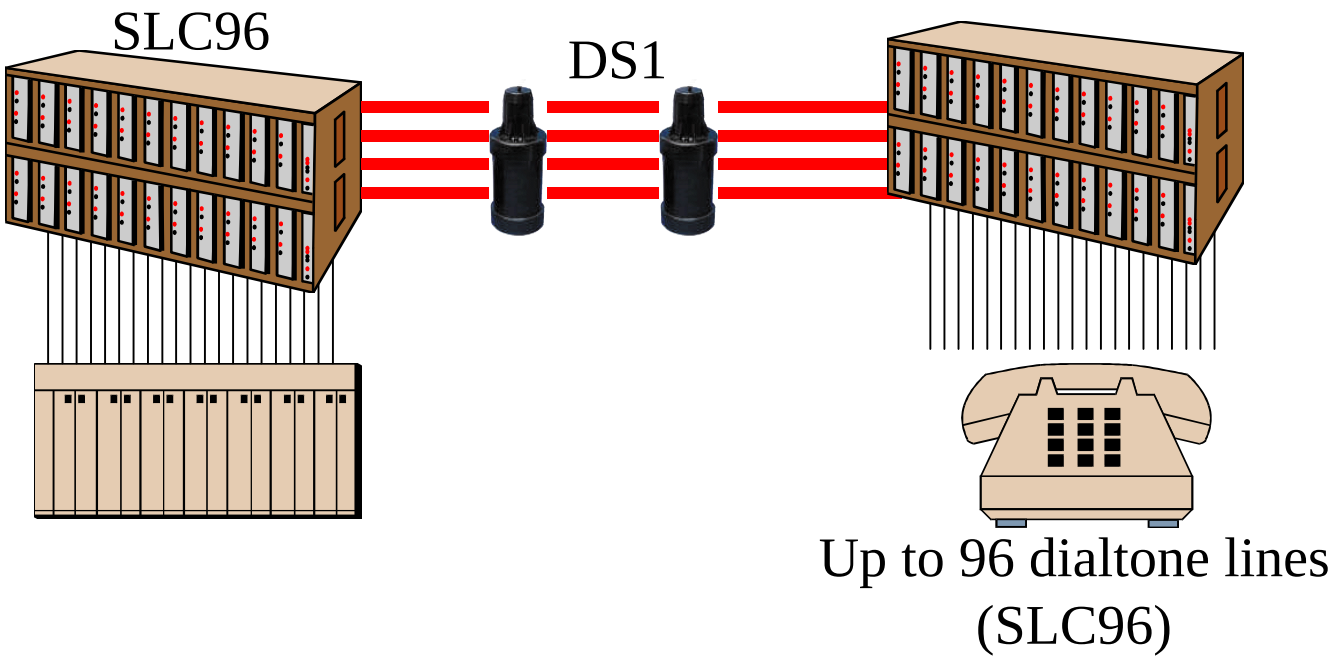


- Digital Data Service
- 2W/4W Analog PL
- Fractional T1
- Switched 56

Channel Bank A-D Conversion



DLC Usage (TR08)



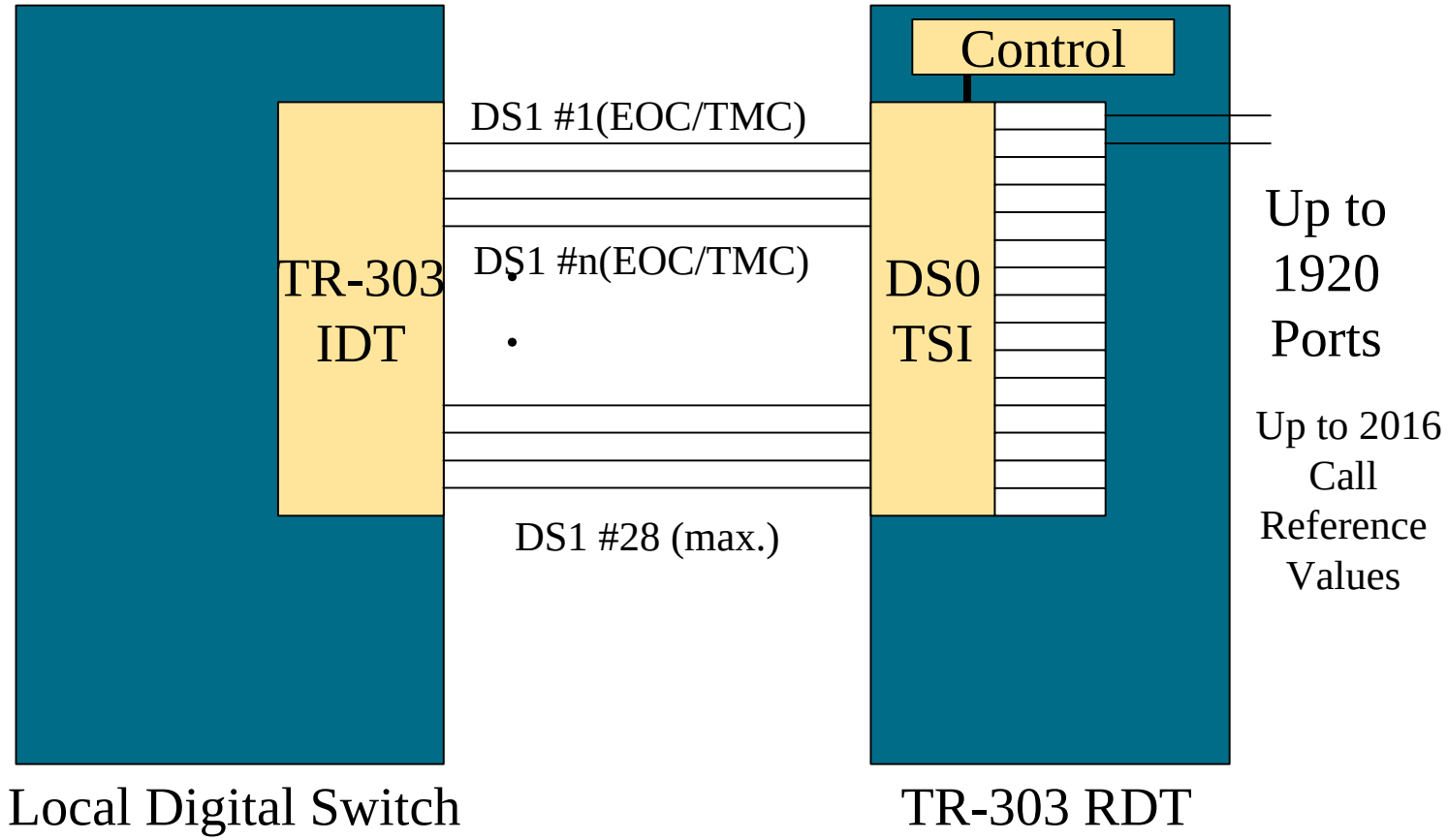
Getting Higher Utilization in a DLC

Over-subscription of bandwidth from DLC to CO switch

Typically 2-4:1 ! (CCI uses 3:1 and then monitors utilization)

Bellcore TR-303 standard

TR-303 Interfaces



Timeslot Management Channel

Controls DS0 time slot interchange of the Remote Digital Terminal (RDT)

DS1/DS0 Assignments

Redundant assignments; DS0 #24 of DS1 #1 and **DS0 #24 of some other DS1**

Embedded Operations Channel

Operational control - I.e., protection switching

Provisioning using CMISE

Redundant DS0 links - DS0 #12 of DS1 #1 and DS0 #12 of another DS1

TR-303 Call Processing

Subscriber goes off-hook

RDT sends “SETUP**” over the TMC to the IDT**

IDT sends “CONNECT**” over the TMC to the RDT**

RDT sends “CONNECT ACK**” back to the IDT over the TMC**

DS0 cross-connected from the feeder DS-1 to the appropriate port

TR-303 Call Processing

Dial tone sent from switch to subscriber

Other signaling sent via ABCD signaling bits

Subscriber goes on-hook

RDT sends “DISCONNECT**” over the TMC to the IDT**

TR-303 Multi-hosting