


18-345 – Fall 08

Lecture 7

Circuit-Switching Networks 1

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Reading: Chapter 4



1

Topics


- Multiplexing
- SONET
- Transport Networks
- Circuit Switches
- Telephone Network



2

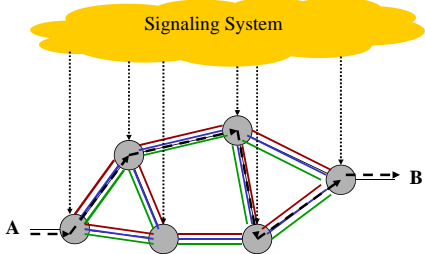
Circuit Switching Networks

- End-to-end dedicated circuits between clients
 - Client can be a person or equipment (router, switch)
 - E.g., Telephone network
- Circuit can take different forms
 - Dedicated path for the transfer of electrical current
 - Dedicated time slots for transfer of voice samples
 - Dedicated frames for transfer of $N \times 51.84$ Mbps signals
 - Dedicated wavelengths for transfer of optical signals
- Circuit switching networks require:
 - Multiplexing & switching of circuits
 - Signaling & control for establishing circuits




3

A Circuit Switched Network



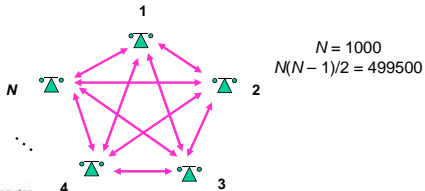
No address attached to data!



4


Why use switching?

- For N users to be fully connected *directly*
- Requires $N(N-1)/2$ connections
- Requires too much space for cables
- Inefficient & costly since connections not always on

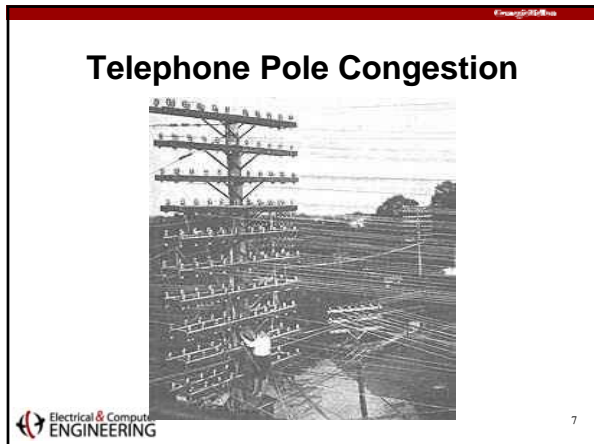


5

Multiplexing



6



Multiplexing

- Multiplexing involves the sharing of a transmission channel (resource) by several connections or information flows
 - Channel = 1 wire, 1 optical fiber, or 1 frequency band
- Significant economies of scale can be achieved by combining many signals into one
 - Fewer wires/pole; fiber replaces thousands of cables
- Implicit or explicit information is required to demultiplex the information flows.

(a)

(b)

8

Frequency-Division Multiplexing

- Channel divided into frequency slots

Individual signals occupy W_u Hz

↓

Combined signal fits into channel bandwidth

- Guard bands required
- AM or FM radio stations
- TV stations in air or cable
- Analog telephone systems

9

Time-Division Multiplexing

- High-speed digital channel divided into time slots

(a) Each signal transmits 1 unit every $3T$ seconds

- Framing required
- Telephone digital transmission
- Digital transmission in backbone network

(b) Combined signal transmits 1 unit every T seconds

10

Time versus Frequency Division Multiplexing

11

T-Carrier System

- Digital telephone system uses TDM.
- PCM voice channel is basic unit for TDM
 - 1 channel = 8 bits/sample x 8000 samples/sec. = 64 kbps
- T-1 carrier carries Digital Signal 1 (DS-1) that combines 24 voice channels into a digital stream:

Bit Rate of T-1 carrier = 8000 frames/sec. x (1 + 8 x 24) bits/frame = 1.544 Mbps

12

North American Digital Multiplexing Hierarchy

- DS0, 64 Kbps channel
- DS1, 1.544 Mbps channel
- DS2, 6.312 Mbps channel
- DS3, 44.736 Mbps channel
- DS4, 274.176 Mbps channel

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CCITT Digital Hierarchy (Europe)

• CCITT digital hierarchy based on 30 PCM channels

- E1, 2.048 Mbps channel
- E2, 8.448 Mbps channel
- E3, 34.368 Mbps channel
- E4, 139.264 Mbps channel

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Clock Synch & Bit Slips

- Digital streams cannot be kept perfectly synchronized
- Bit slips can occur in multiplexers

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Pulse Stuffing

- Pulse Stuffing: synchronization to avoid data loss due to slips
- Design Multiplexer output rate $> R1+R2$
 - e.g. DS2, 6.312Mbps=4x1.544Mbps + 136 Kbps
- Pulse stuffing format
 - Fixed-length master frames with each channel allowed to stuff or not to stuff a single bit in the master frame.
 - Redundant stuffing specifications
 - Signaling or specification bits (other than data bits) are distributed across a master frame.

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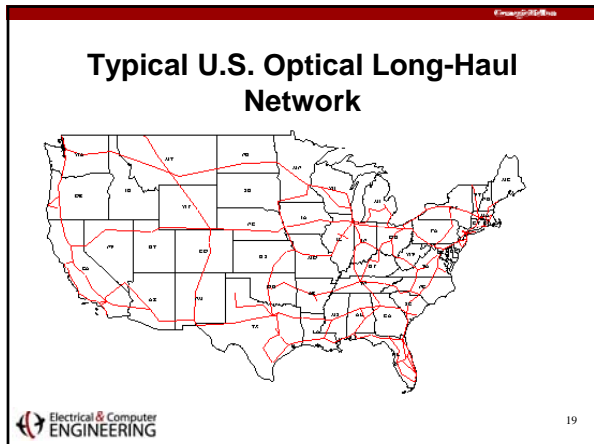
Wavelength-Division Multiplexing

- Optical fiber link carries several wavelengths
 - From few (4-8) to many (64-160) wavelengths per fiber
- Imagine prism combining different colors into single beam
- Each wavelength carries a high-speed stream
 - Each wavelength can carry different format signal
 - e.g. 1 Gbps, 2.5 Gbps, or 10 Gbps

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Example: WDM with 16 wavelengths

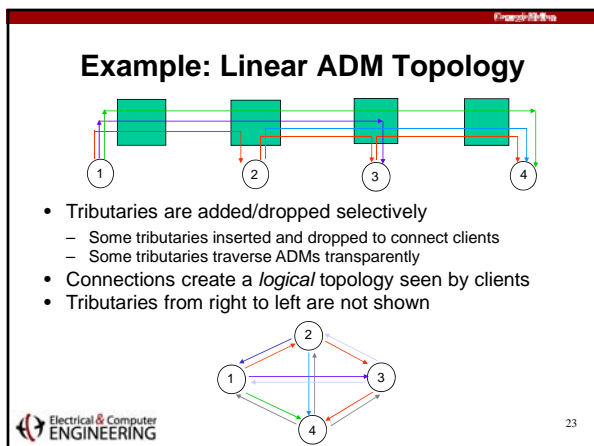
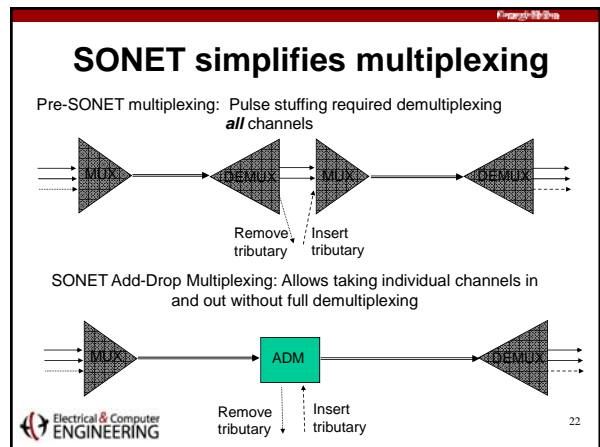
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SONET

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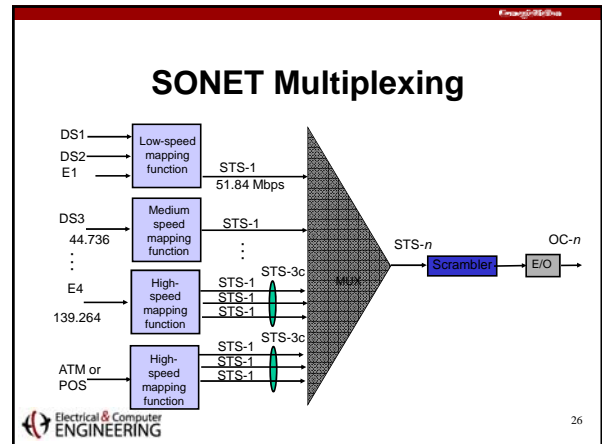
- ### SONET: Overview
- Synchronous Optical NETWORK
 - North American TDM physical layer standard for optical fiber communications
 - 8000 frames/sec. ($T_{\text{frame}} = 125 \mu\text{sec}$)
 - compatible with North American digital hierarchy
 - SDH (Synchronous Digital Hierarchy) elsewhere
 - Needs to carry E1 and E3 signals
 - Compatible with SONET at higher speeds
 - Greatly simplifies multiplexing in network backbone
 - OA&M support to facilitate network management
 - Protection & restoration
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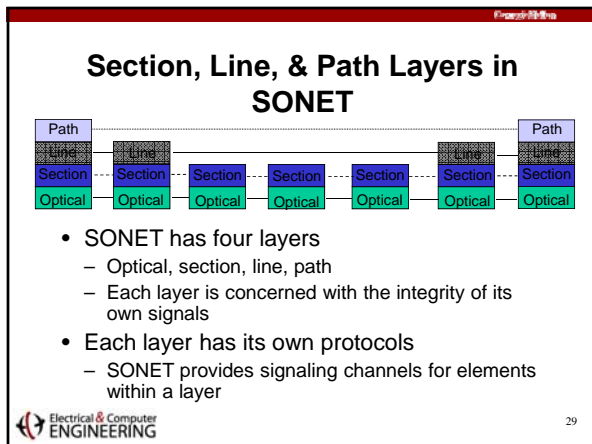
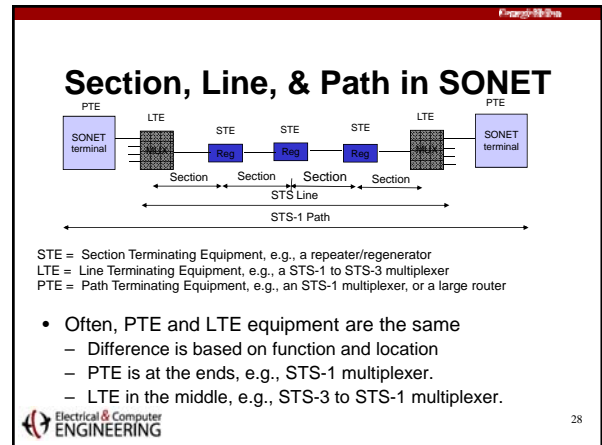
- ### SONET Specifications
- Defines electrical & optical signal interfaces
 - Electrical
 - Multiplexing, Regeneration performed in electrical domain
 - STS – Synchronous Transport Signals defined
 - Very short range (e.g., within a switch)
 - Optical
 - Transmission carried out in optical domain
 - Optical transmitter & receiver
 - OC – Optical Carrier
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SONET & SDH Hierarchy

SONET Electrical Signal	Optical Signal	Bit Rate (Mbps)	SDH Electrical Signal
STS-1	OC-1	51.84	N/A
STS-3	OC-3	155.52	STM-1
STS-9	OC-9	466.56	STM-3
STS-12	OC-12	622.08	STM-4
STS-18	OC-18	933.12	STM-6
STS-24	OC-24	1244.16	STM-8
STS-36	OC-36	1866.24	STM-12
STS-48	OC-48	2488.32	STM-16
STS-192	OC-192	9953.28	STM-64
STS: Synchronous Transport Signal	OC: Optical Channel		STM: Synchronous Transfer Module



- ## SONET Equipment
- By Functionality
 - ADMs: dropping & inserting tributaries
 - Regenerators: digital signal regeneration
 - Cross-Connects: interconnecting SONET streams
 - By Signaling between elements
 - Section Terminating Equipment (STE): span of fiber between adjacent devices, e.g. regenerators
 - Line Terminating Equipment (LTE): span between adjacent multiplexers, encompasses multiple sections
 - Path Terminating Equipment (PTE): span between SONET terminals at end of network, encompasses multiple lines



- ## SONET STS Frame
- SONET streams carry two types of overhead
 - Path Overhead (POH):**
 - inserted & removed at the ends of SONET
 - Synchronous Payload Envelope (SPE)* consisting of Data + POH traverses network as a single unit
 - Transport Overhead (TOH):**
 - processed at every SONET node
 - TOH occupies a portion of each SONET frame
 - TOH carries management & link integrity information

