

L03 - TDM Techniques

TDM Techniques

Time Division Multiplexing (synchronous, statistical)
Digital Voice Transmission, PDH, SDH

Agenda

- Introduction
- **Synchronous (Deterministic) TDM**
- **Asynchronous (Statistical) TDM**
- **Digital Voice Transmission**
- **PDH**
- **SDH**

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Introduction

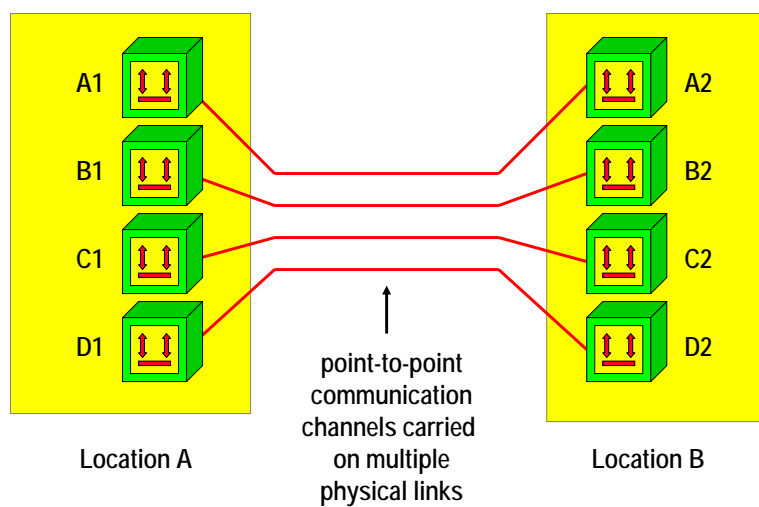
- **line protocol techniques (data link procedures)**
 - were developed for communication between two devices on one physical point-to-point link
 - bandwidth of physical link is used exclusively by the two stations
- **in case multiple communication channels are necessary between two locations**
 - multiple physical point-to-point are needed
 - expensive solution
- **in order to use one physical link for multiple channels**
 - multiplexing techniques were developed

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Point-To-Point Channels



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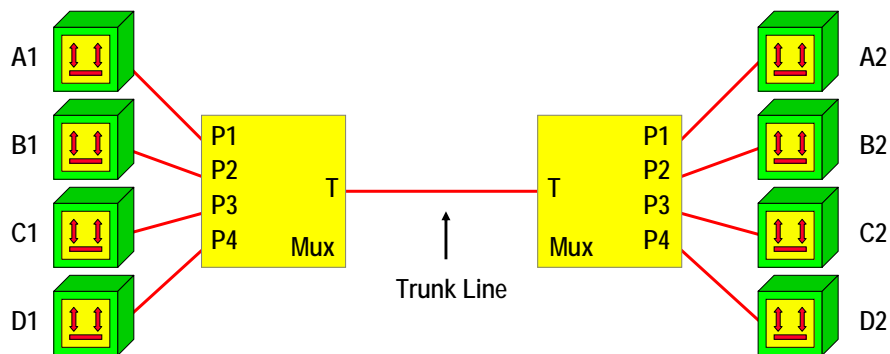
4

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Multiplexing / Demultiplexing

- **multiplexer is a device**

- which can take a number of input channels and, by interleaving them, output them as one data stream on one physical trunk line



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Time Division Multiplexing (TDM)

- **time division multiplexer**

- allocates each input channel a period of time or timeslot
- controls bandwidth of trunk line among input channels

- **individual time slots**

- are assembled into frames to form a single high-speed digital data stream

- **available transmission capacity of the trunk**

- is time shared between various channels

- **at the destination demultiplexer reconstructs**

- individual channel data streams

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Types of TDM

- **depending on timing behavior two methods**
 - synchronous TDM
 - timeslots have constant length (capacity) and can be used in a synchronous, periodical manner
 - asynchronous (statistical) TDM
 - timeslots have variable length and are used on demand (depending on the statistics of channel communication)

Synchronous TDM Standards

- **TDM framing on the trunk line**
 - can be vendor dependent
 - proprietary TDM products
 - can be standard based
- **two main architectures for standardizing synchronous TDM for trunk lines**
 - **PDH – Plesiochronous Digital Hierarchy**
 - e.g. E1 (2Mbit/s), E3 (34Mbit/s), E4, T1 (1,544Mbit/s), T3
 - **SDH - Synchronous Digital Hierarchy**
 - e.g. STM-1 (155Mbit/s), STM-4 (622Mbit/s), STM-16

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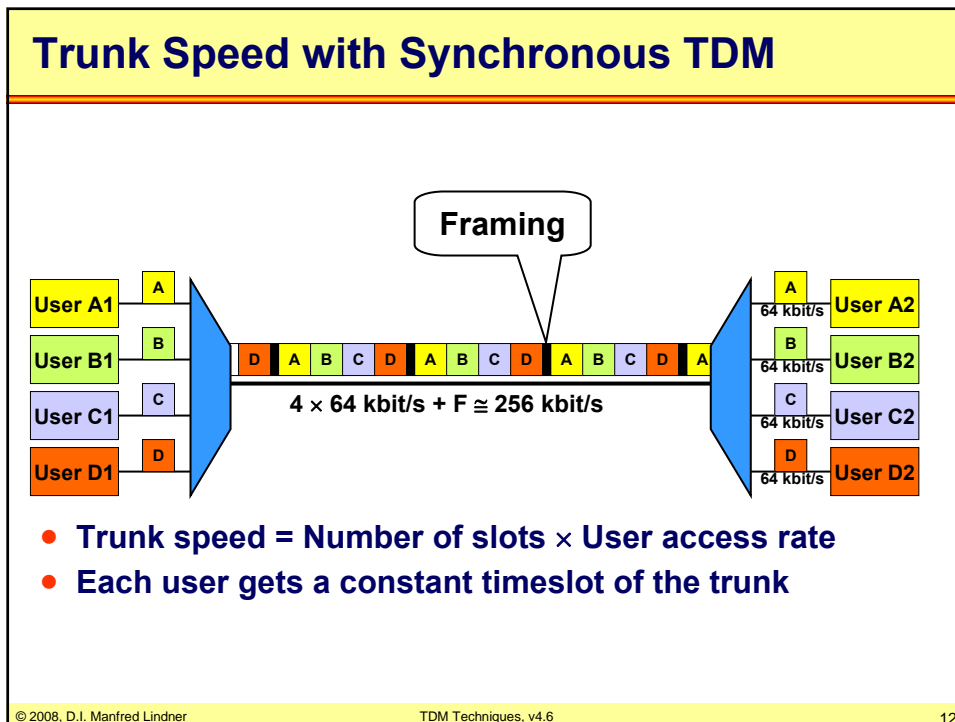
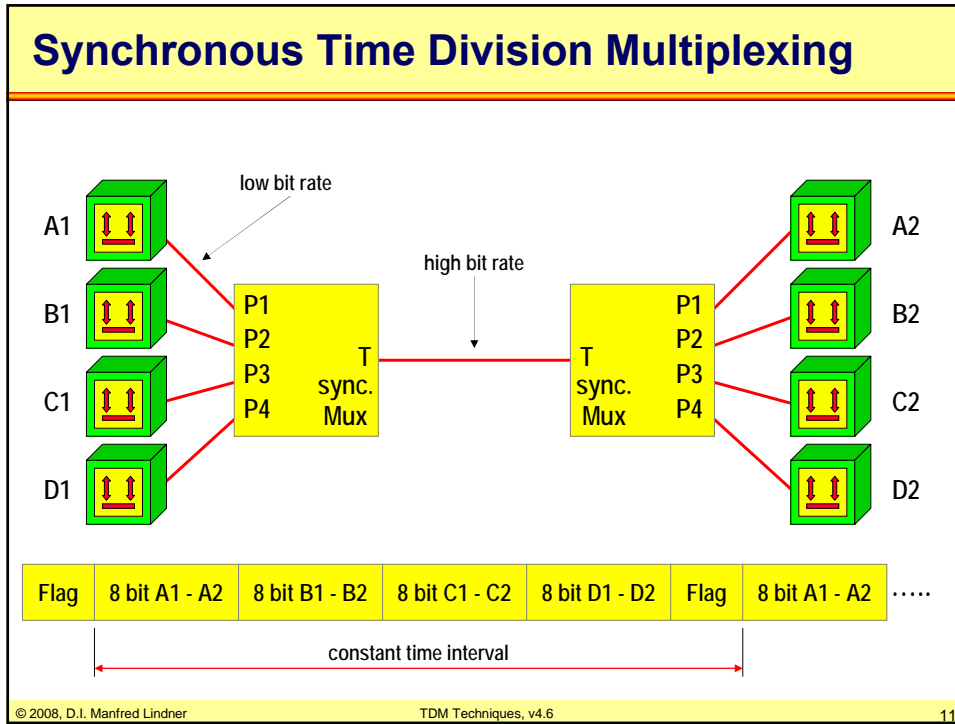
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Synchronous Time Division Multiplexing

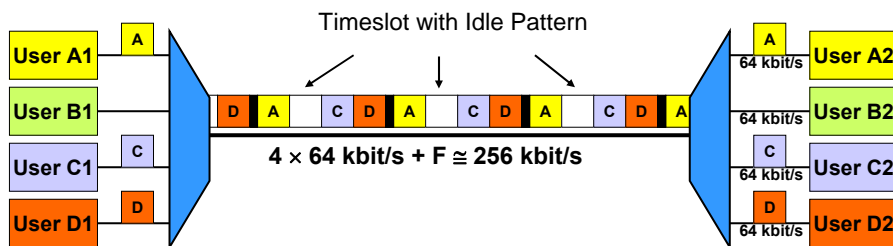
- **synchronous TDM**
 - periodically generates a frame consisting of a constant number of timeslots each timeslot of constant length
 - timeslots can be identified by position in the frame
 - timeslot 0, timeslot 1,
 - frame synchronization achieved by extra flag field
- **every input channel is assigned**
 - a reserved timeslot
 - e.g. timeslot numbers refer to port numbers of a multiplexer
 - traffic of port P1 in timeslot 1 for A1- A2 channel
 - traffic of port P2 in timeslot 2 for B1- B2 channel
 -

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Idle Timeslots with Synchronous TDM



- If a communication channel has nothing to transmit
- -> Idle timeslots -> Waste of bandwidth

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Advantages

- compared to pure point-to-point physical links
 - synchronous multiplexing adds only minimal delays
 - time necessary to packetize and depacketize a byte
 - transmission/propagation delay on trunk
- the delay for transporting a byte is constant
- the time between two bytes to be transported is constant
 - hence optimal for synchronous transmission requirements like traditional digital voice
- any line protocol could be used between devices
 - method is protocol-transparent
- to endsystems
 - channel looks like a single physical point-to-point line

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Disadvantages

- **bitrate on trunk line T**
 - sum of all port bitrates (P1-P4) plus frame synchronization (flag)
 - high bitrate is required
 - hence expensive
- **if no data is to be sent on a channel**
 - special idle pattern will be inserted by the multiplexer in that particular timeslot
 - waste of bandwidth of trunk line
- **asynchronous (statistic) time division multiplex avoids both disadvantages**
 - making use of communication statistics between devices

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15

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Asynchronous Time Division Multiplexing

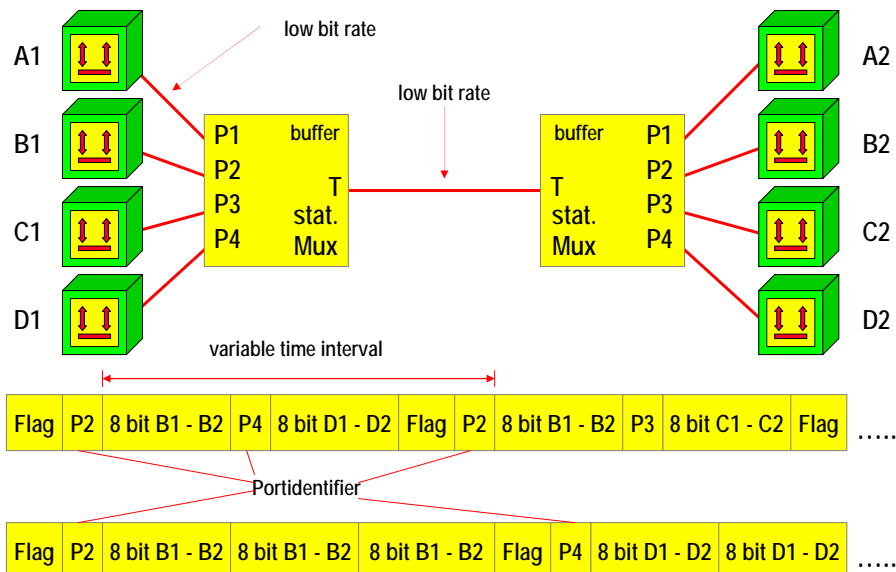
- **usually devices communicate in a statistical manner**
 - not all devices have data to transmit at the same time
- **therefore it is sufficient**
 - to calculate necessary bitrate of the multiplexer trunk line according to the average bitrates caused by device communication
- **if devices transmit simultaneously**
 - only one channel can occupy trunk line
 - data must be buffered inside multiplexer until trunk is available again
 - statistics must guarantee that trunk will not be monopolized by a single channel

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Asynchronous Time Division Multiplexing



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ATDM Operation

- **multiplexer only generates a transmission frame**
 - if data octets are present at input ports
- **source of data**
 - must be explicitly identified in transmission frames
 - addressing
- **reason for addressing**
 - there exists no constant relationship between timeslot and portnumber as with synchronous TDM
 - Note: addressing in synchronous TDM is implicit by recognizing the flag of the frame and hence the position of a certain timeslot
- **port identifier**
 - is used as address of source and sent across the trunk

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ATDM Operation / Facts

- **transmission frame can be assembled using**
 - either a single channel octet by frame
 - suitable for character oriented terminal sessions
 - or multiple channel octets per frame
 - suitable for block oriented computer sessions
- **in case of congestion**
 - buffering causes additional delays compared to synchronous TDM
- **delays are variable because of statistical behavior**
 - hence not optimal for synchronous transmission requirements like traditional digital voice
 - sufficient for transmission requirements of bursty data transfers

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Asynchronous / Statistical TDM

Average data rates ≈ 16 kbit/s

- Trunk speed dimensioned for **average** usage
- Each user can send packets whenever he wants
- Buffering necessary if trunk already occupied

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Asynchronous / Statistical TDM

- If other users are silent, one user can fully utilize his access rate

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ATDM Facts

- **ATDM can be used protocol transparent**
 - however in case of buffer overflow transmission errors will be seen by devices
 - FCS errors
- **to avoid FCS errors a kind of flow control between multiplexer and device (end system) should be used**
 - which is a new element in data communication methods
 - this is different from flow control between end systems learned so far in module about line protocols
 - examples for flow control
 - HW flow control based on handshake signals (e.g. RTS, CTS)
 - SW flow control (e.g. XON/XOFF)
 - Protocol based flow control such as known in connection oriented line protocols like HDLC (e.g. RR and RNR)
 - end system and ADTM have to speak the same protocol language

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23

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Voice Transmission

- **digital voice transmission**

- based on Nyquist's Theorem
- analogous voice can be digitized using pulse-code-modulation (PCM) technique requiring a 64kbit/s digital channel
 - voice is sampled every 125µsec (8000 times per second)
 - every sample is encoded in 8 bits
- used nowadays in the backbone of our telephone network
- today analogous transmission only between home and local office -> so called local loop

- **synchronous TDM**

- originated from digital voice transmission

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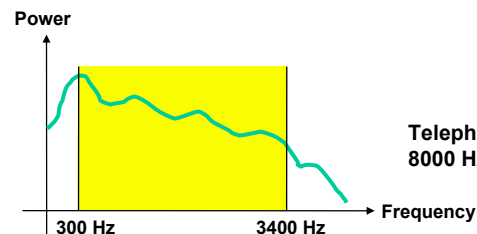
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Sampling of Voice

- **Nyquist's Theorem**

- any analogue signal with limited bandwidth f_B can be sampled and reconstructed properly when the sampling frequency is $2 \cdot f_B$
- transmission of sampling pulses allows reconstruction of original analogous signal
- sampling pulses are quantized resulting in binary code word which is actually transmitted



$$R = 2 \cdot B \cdot \log_2 V$$

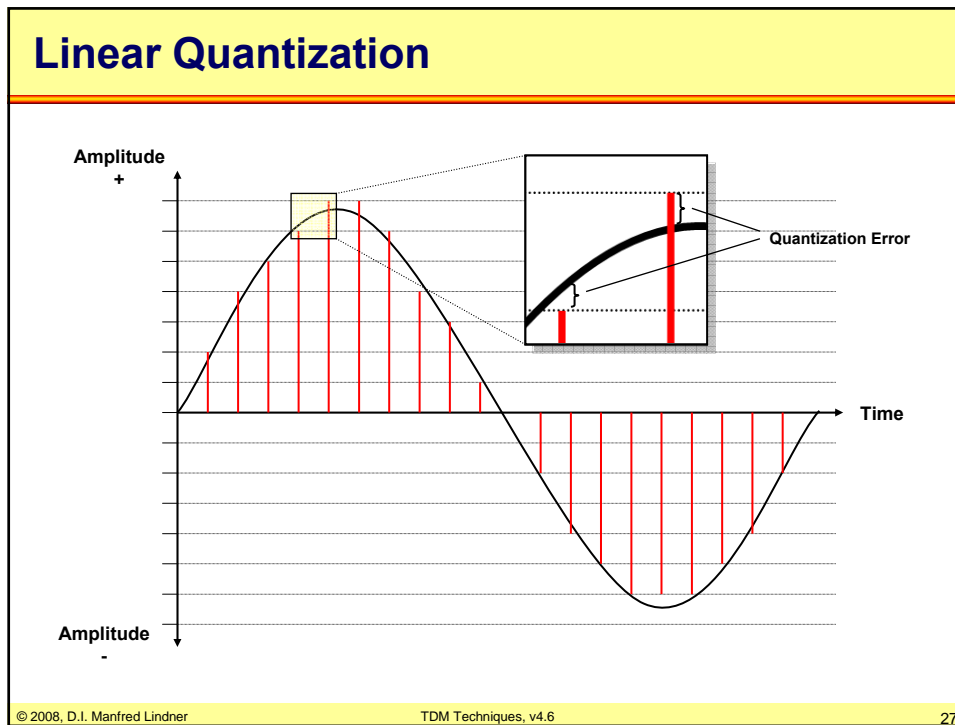
Telephone channel: 300-3400 Hz
8000 Hz x 8 bit resolution = 64 kbit/s

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26

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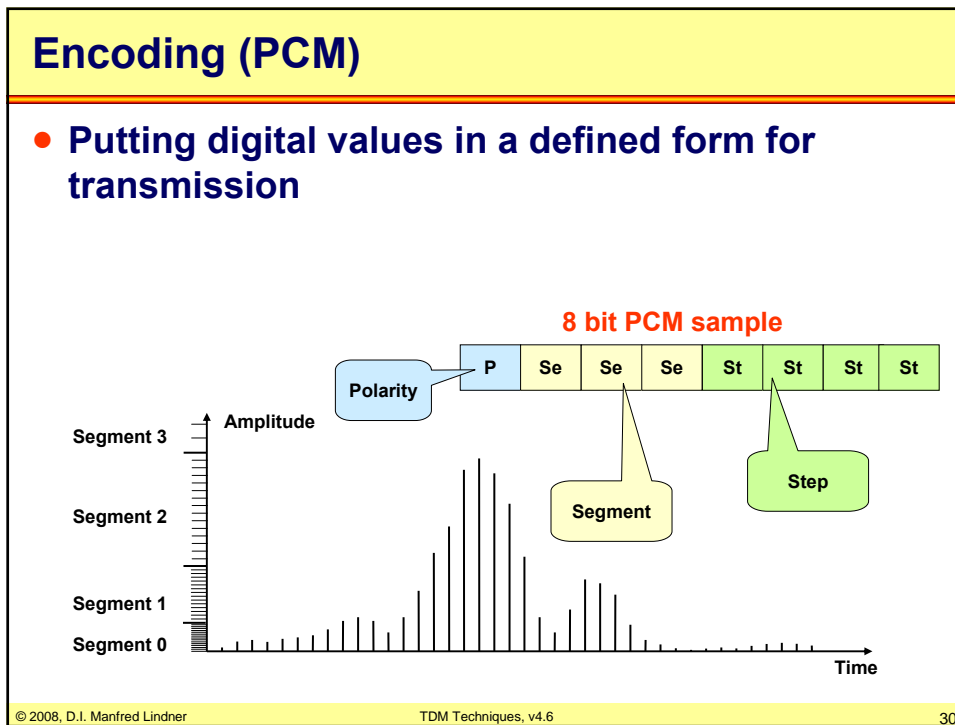
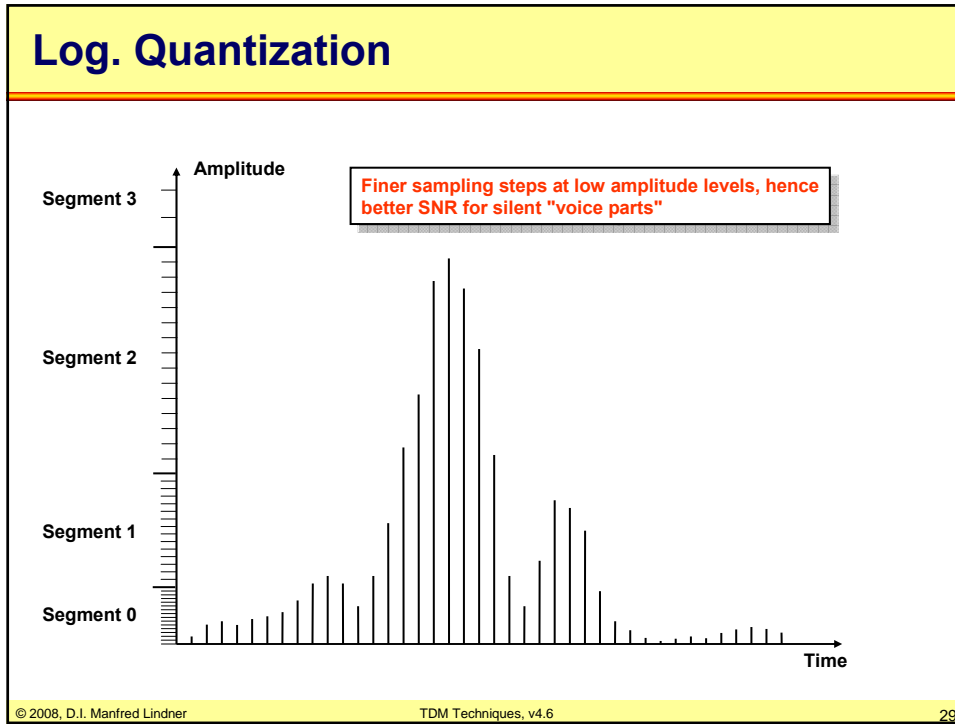


Improving SNR (Signal Noise Ratio)

- **to improve the SNR of speech signals**
 - lower amplitudes receive a finer resolution than greater amplitudes
- **a nonlinear function (logarithmic) is used for quantization**
 - USA: μ -law (Bell)
 - Europe: A-law (ITU)

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Voice Compression

- **Waveform Coders**

- Non-linear approximation of analog waveform
- PCM (no compression), ADPCM

- **Vocoders**

- speech is analyzed and compared to a codebook
- only codebook values are transmitted and speed synthesizer at the receiver

- **Hybrid coders**

- Combination of waveform coders and vocoders
- 4.8 kbps to 16 kbps
- Used for mobile phones
- CELP, GSM

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Standardized Codec's

- PCM
 - G.711 (64 kbps)
- Adaptive Differential Pulse Code Modulation (ADPCM)
 - only the difference from one sample pulse to the next will be transmitted
 - fewer bits used for encoding the difference value
 - G.726 (16, 24, 32, 40 kbps)
- Low Delay Code Excited Linear Predictor (LD-CELP)
 - G.728 (16 kbps)
- Conjugate Structure Algebraic Code Excited Linear Predictor (CS-ACELP)
 - G.729 (8 kbps)
- Dual Rate Speech Coding Standard G.723
 - is the basic standard for voice transmission in IP networks
 - basis is the CELP-Technique of GSM
 - uses minimal data rate of 5,3K at fair quality or 6,3K with good quality

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32

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Digital voice channel

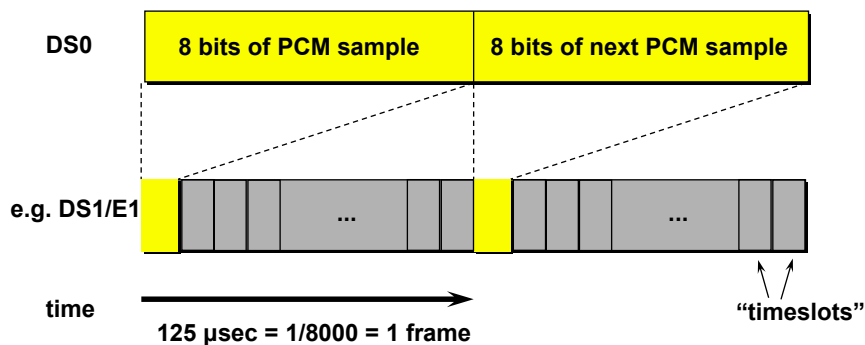
- **DS0 = Digital Signal, Level 0**
 - 1 timeslot in multiplexing frames
- **Base for hierarchical digital communication systems**
- **Equals one PCM coded voice channel**
 - 64 kbit/s
- **Each samples (byte) must arrive within 125 μ s**
 - To receive 8000 samples (bytes) per second
 - Higher order frames must ensure the same byte-rate **per user(!)**

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Multiplexing Basics



- **frame rate is always 8000 frame per second at all levels of the hierarchy**
- **byte interleaved multiplexing**

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34

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Multiplexing Basics

The diagram shows three levels of TDM multiplexing:

- DS0: 1 Byte**: 1 digital voice channel, 64 kbit/s.
- E1: 32 Byte**: 31 digital voice channels, 2.048 kbit/s. Includes a frame alignment byte (F).
- E2: 132 Byte**: 131 digital voice channels, 8.448 kbit/s.

Each frame has a duration of 125 μ s.

– note: DS0 and higher rates can be used for any transport digital information -> [data transmission](#)

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Multiplexing Hierarchies

- **why hierarchy and standardization?**

- only a hierarchical digital multiplexing infrastructure which is standardized
 - can connect millions of (low speed) customers across the city/country/world

- **two main architectures**

- PDH - plesiochronous digital hierarchy
 - plesio means nearly synchronous, clock differences are compensated by bit stuffing techniques / overhead bits
 - PDH is still used for low-speed lines
- SDH - synchronous digital hierarchy
 - overcomes deficits of PDH
 - in North America SONET is used
 - telecommunication backbones move very quickly to SONET/SDH

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37

PDH Hierarchy

North America / ANSI

Signal	Carrier	Channels	Mbit/s
DS0		1	0.064
DS1	T1	24	1.544
DS1C	T1C	48	3.152
DS2	T2	96	6.312
DS3	T3	672	44.736
DS4	T4	4032	274.176

Europe / ITU

Signal	Carrier	Channels	Mbit/s
DS0	"E0"	1	0.064
CEPT-1	E1	32	2.048
CEPT-2	E2	128	8.448
CEPT-3	E3	512	34.368
CEPT-4	E4	2048	139.264
CEPT-5	E5	8192	565.148

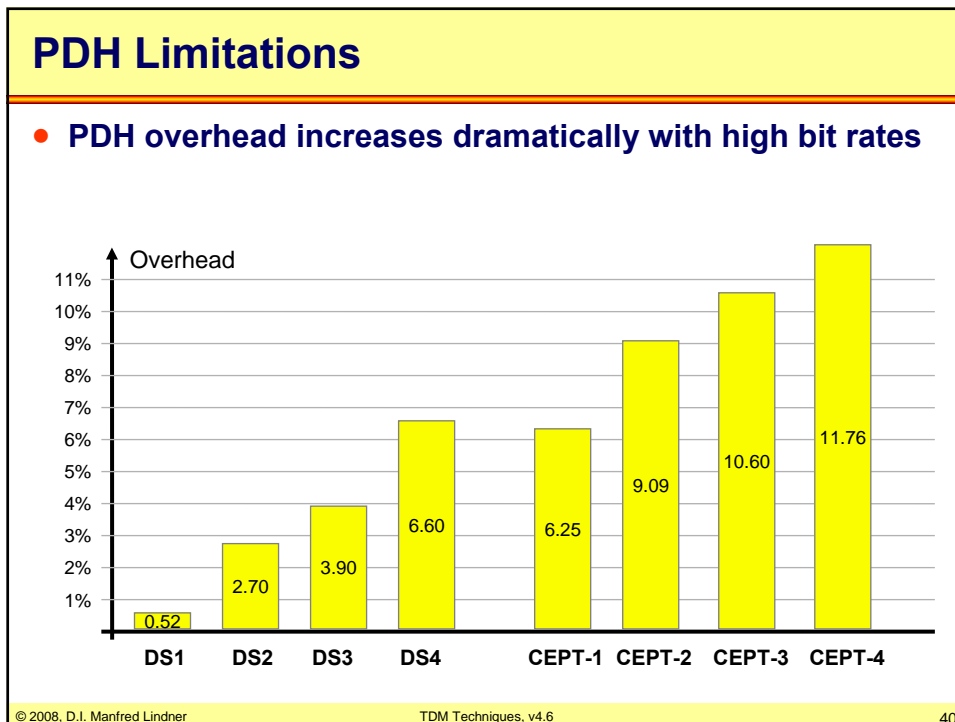
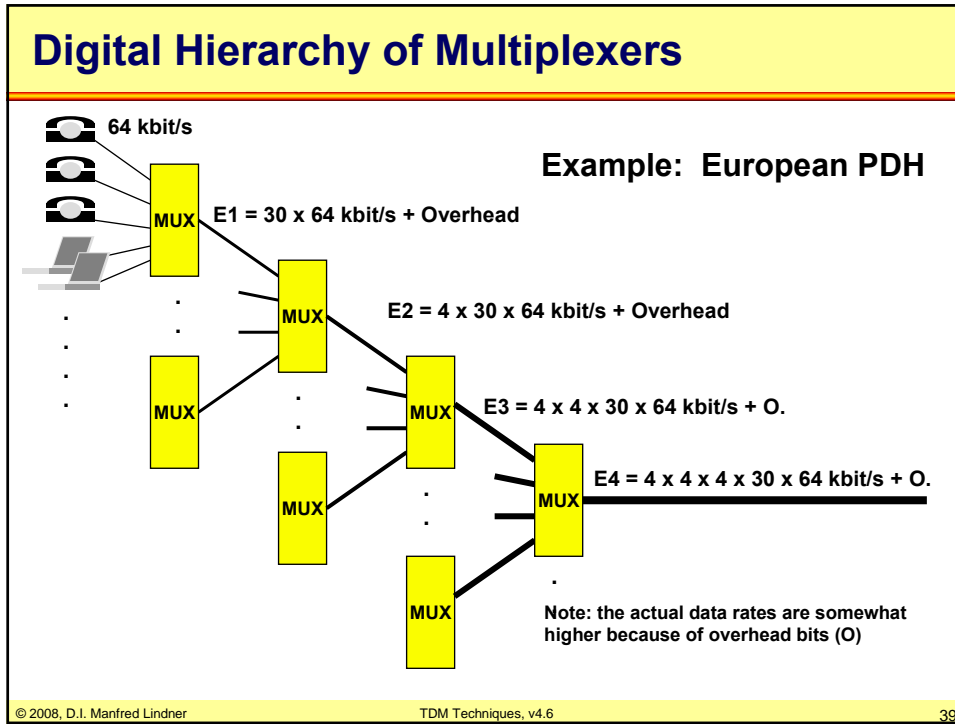
- Incompatible MUX rates
- Different signalling schemes
- Different overhead
- μ -law versus A-law

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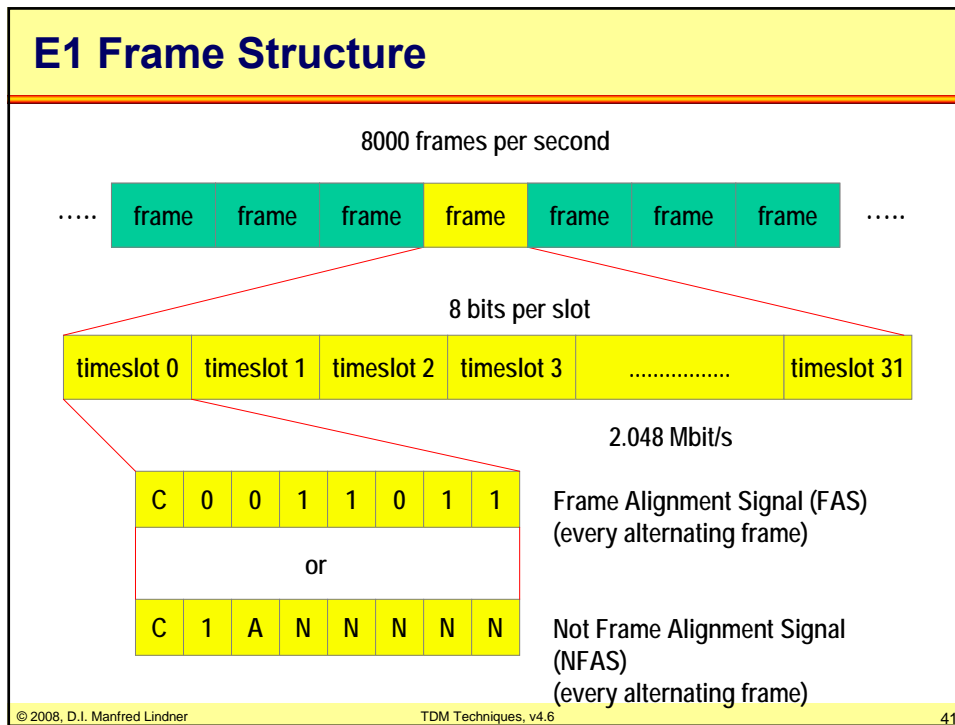
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38

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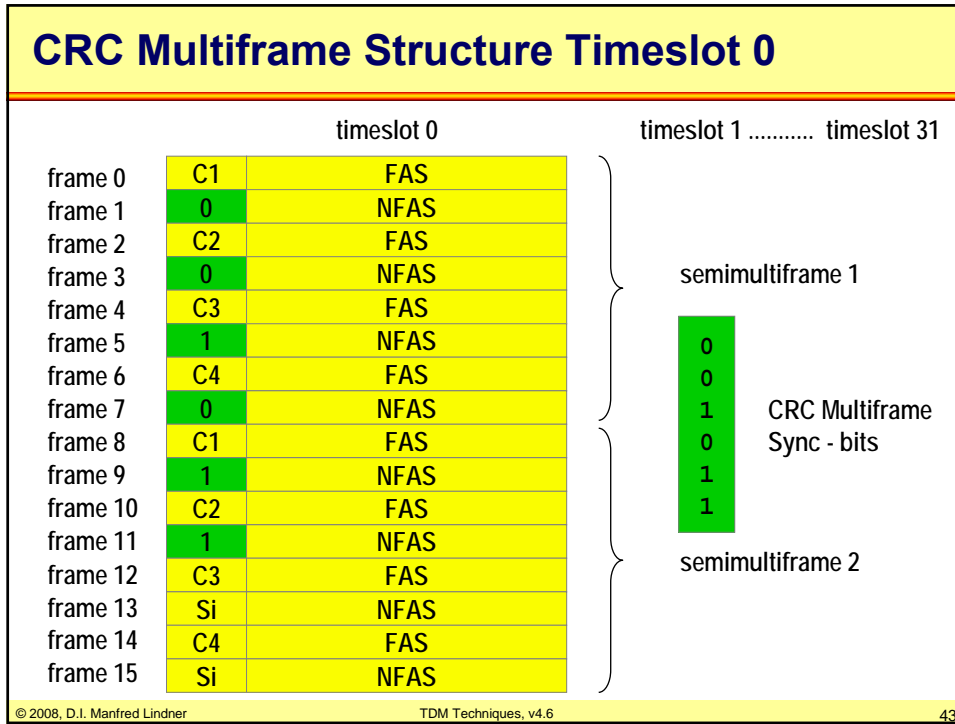


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- ### E1 Frame Structure
- **every second frame**
 - timeslot 0 contains FAS used for frame synchronization
 - **C (CRC) bit**
 - is part of an optional 4-bit CRC sequence
 - provides frame checking and multiframe synchronization
 - **A (Alarm Indication) bit**
 - so called Yellow (remote) alarm
 - used to signal loss of signal (LOS) or out of frame (OOF) condition to the far end
 - **N (National) bits**
 - reserved for future use
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Reasons for SONET/SDH Development

- **Incompatible PDH standards !!!**
- **PDH does not scale to very high bit rates**
 - Increasing overhead
 - Various multiplexing procedures
 - Switching of channels requires demultiplexing first
- **Demand for a true synchronous network**
 - No pulse stuffing between higher MUX levels
 - Phase shifts are compensated by floating payload and pointer technique
- **Demand for add-drop MUXes and ring topologies**

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45

SDH History

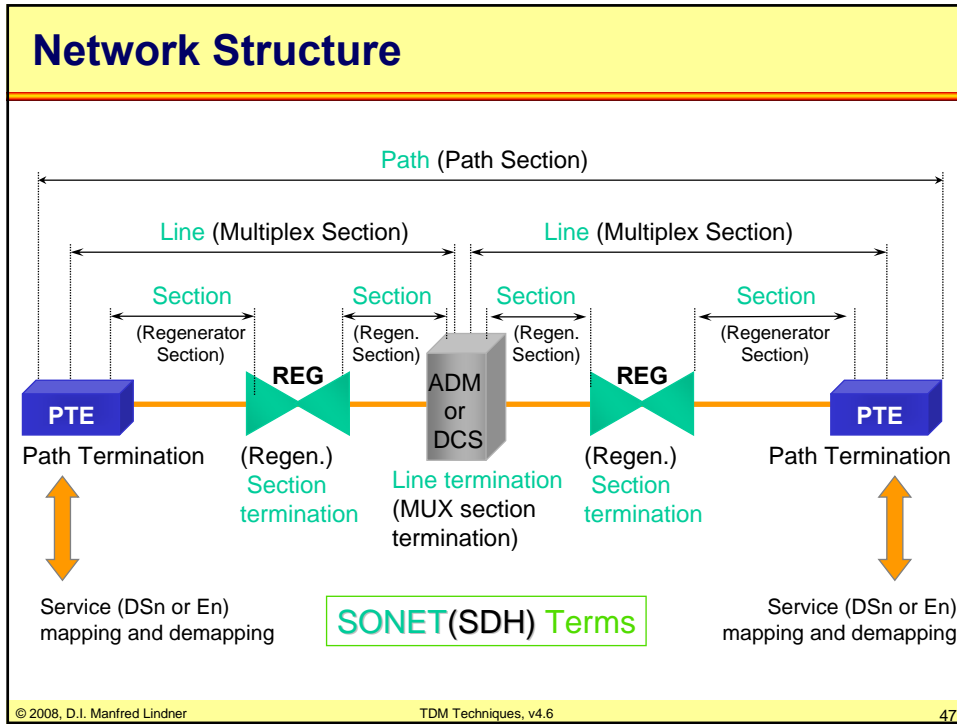
- After divestiture of AT&T
 - Many companies -> many proprietary solutions for PDH successor technology
- In 1984 ECSA (Exchange Carriers Standards Association) started on SONET
 - Goal: one common standard
 - Tuned to carry US PDH payloads
- In 1986 CCITT became interested in SONET
 - Created SDH as a superset
 - Tuned to carry European PDH payloads including E4 (140 Mbit/s)
- SDH is a world standard
 - SONET is subset of SDH
- Originally designed for fiber optics

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46

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SONET/SDH Line Rates

SONET Optical Levels	SONET Electrical Level	Line Rates Mbit/s	SDH Levels	
OC-1	STS-1	51.84	STM-0	
OC-3	STS-3	155.52	STM-1	
OC-9	STS-9	466.56	STM-3	
OC-12	STS-12	622.08	STM-4	
OC-18	STS-18	933.12	STM-6	Defined but later removed, and only the multiples by four were left!
OC-24	STS-24	1244.16	STM-8	
OC-36	STS-36	1866.24	STM-12	
OC-48	STS-48	2488.32	STM-16	
OC-96	STS-96	4976.64	STM-32	
OC-192	STS-192	9953.28	STM-64	
OC-768	STS-768	39813.12	STM-256	(Coming soon)

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