Telecommunication Backbones

PDH and SONET/SDH

Agenda

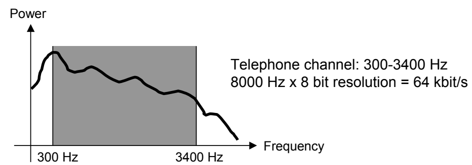
- PDH
  - Speech Transmission Basics
  - Plesiochrone Digital Hierarchy
  - Digital Signal Levels
  - Synchronization
  - E1 Framing
  - T1 Framing
- SONET/SDH
  - History
  - Network Structure
  - Frame Structure
  - Topology

Telco Backbones

- Telecommunication backbones are primarily designed to carry voice signals
  - Even today, although data traffic increases dramatically
  - Led to technological constraints and demands
- Origins in analogue networks
  - Same terms (circuit, cross-connect, ...)
  - Same signalling principles
- High demand for
  - Interoperability
  - Availability
  - Backward-compatibility

Sampling of Voice

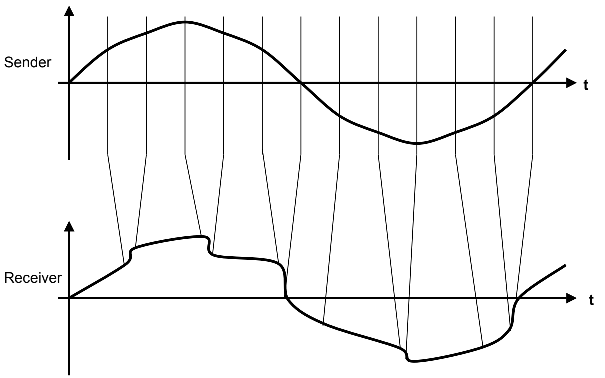
- Shannon's Theorem
  - Any analogue signal with limited bandwidth f_B can be sampled and reconstructed properly when the sampling frequency is $2 \cdot f_B$
  - Speech signal has most of its power between 0 and 4000 Hz



Isochronous Traffic

- ❑ Isochronous traffic
  - ◆ Is very sensitive on delay variations (jitter)
  - ◆ E.g. sampled analogue signals
- ❑ Some amount of delay is tolerable
  - ◆ Up to 500 ms
- ❑ Certain amount of jitter is not tolerable
  - ◆ Even if the delay is very small
  - ◆ Reconstruction of analogue signal too distorted
- ❑ Solutions
  - ◆ *Isochronous* network (common clock for all components)
  - ◆ *Plesiochronous* network with end-to-end synchronization
  - ◆ Totally asynchronous network using buffer and playback

Isochronous Traffic and Jitter

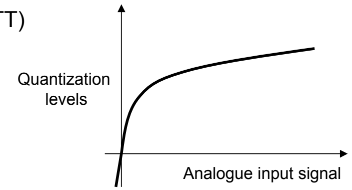


Institute of Computer Technology - Vienna University of Technology

L13 - PDH and SDH

Improving SNR

- ❑ To improve the SNR of speech signals
  - ◆ loud signals are quantized much coarser than quiet signals
- ❑ Expansion and compression can be expressed using a nonlinear function
  - ◆ USA: μ-law (Bell)
  - ◆ Europe: A-law (CCITT)



Agenda

- ❑ PDH
  - ◆ Speech Transmission Basics
  - ◆ <u>Plesiochrone Digital Hierarchy</u>
  - ◆ Digital Signal Levels
  - ◆ Synchronization
  - ◆ E1 Framing
  - ◆ T1 Framing
- ❑ SONET/SDH
  - ◆ History
  - ◆ Network Structure
  - ◆ Frame Structure
  - ◆ Topology

© 2005, D.I. Manfred Lindner

The Plesiochronous Digital Hierarchy

- Created in the 1960s to supersede the analogue telephony infrastructure
- Smooth migration
  - Adaption of analogue signaling methods
- Based on deterministic TDM
- Widely used even today
  - Telephony access level
  - ISDN PRI
  - Leased line

Why Plesiochronous?

- Limitations of 1960s technology
  - No buffering of frames at high speeds possible
- Goal
  - Fast delivery, very short delays (voice!)
- Solution
  - Immediate forwarding of bits
  - Bit stuffing instead of buffering
- Plesiochronous = "nearly synchronous"
  - Network itself is not synchronized but fast
  - Sufficient to synchronize sender and receiver

Institute of Computer Technology - Vienna University of Technology

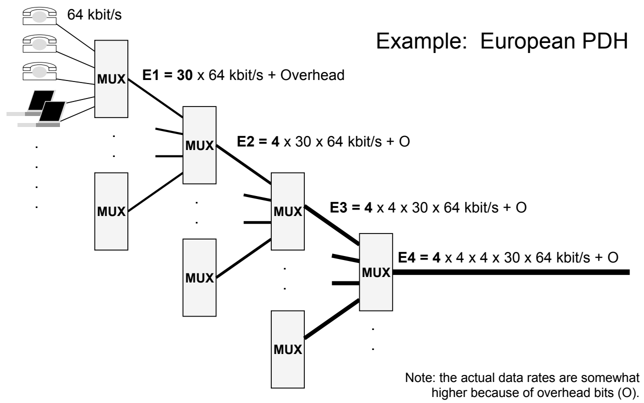
L13 - PDH and SDH

Why Hierarchy?

- A hierarchical digital multiplexing infrastructure is needed
  - To connect millions of low speed customers across the whole city/country/world
- Local infrastructure
  - Star topology
  - Big number of local loops between customers and central offices
- Wide area infrastructure
  - Point-to-point trunks or ring topologies
  - Grooming required

Digital Hierarchy of Multiplexers

Example: European PDH



Note: the actual data rates are somewhat higher because of overhead bits (O).

Agenda

- PDH
  - Speech Transmission Basics
  - Plesiochrone Digital Hierarchy
  - Digital Signal Levels
  - Synchronization
  - E1 Framing
  - T1 Framing
- SONET/SDH
  - History
  - Network Structure
  - Frame Structure
  - Topology

Terminology: Digital Signal Levels

- Note: Different terms for
  - Signal (Framing layer)
  - Carrier system (Physical Layer)
- North America
  - American National Standards Institute (ANSI)
  - DS-n = Digital Signal level n
  - Carrier system: T1, T2, ...
- Europe
  - Conference of European Post and Telecommunications (CEPT, now ETSI)
  - CEPT-n = ITU-T digital signal level n
  - Carrier system: E1, E2, ...

Institute of Computer Technology - Vienna University of Technology

L13 - PDH and SDH

Worldwide Digital Signal Levels

North America

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

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

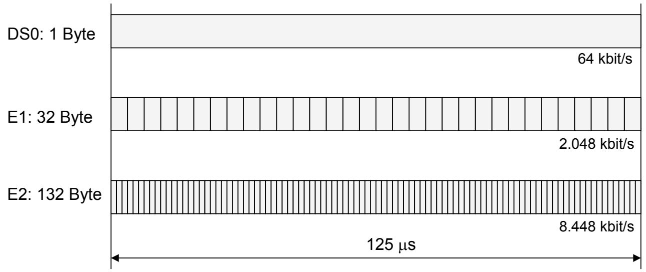
- Incompatible MUX rates
- Different signalling schemes
- Different overhead
- μ-law versus A-law

Digital Hierarchy Levels

- ANSI T1.107 Hierarchy
  - DS1C = 2 × DS1
  - DS2 = 4 × DS1
  - DS3 = 7 × DS2
  - DS4/NA = 3 × DS3 (for international connections only)
  - DS4 = 6 × DS3 (rare)
- ITU-T Hierarchy
  - $E_{n+1} = 4 \times E_n$
- Lately harmonization of ANSI and ITU-T hierarchy
  - ANSI international DS4/NA is 139264 Kbit/s = E4

Frame Duration

- Samples (bytes) must arrive in 125 μs intervals
  - So receiver gets 8000 samples (bytes) per second
  - Higher order frames must ensure the same frequency per channel



Agenda

- PDH
  - Speech Transmission Basics
  - Plesiochrone Digital Hierarchy
  - Digital Signal Levels
  - <u>Synchronization</u>
  - E1 Framing
  - T1 Framing
- SONET/SDH
  - History
  - Network Structure
  - Frame Structure
  - Topology

Institute of Computer Technology - Vienna University of Technology

L13 - PDH and SDH

Plesiochronous Multiplexing

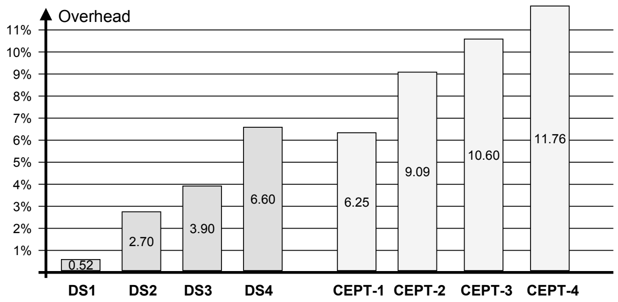
- Clocks are not synchronized centrally
  - Impractical at the time of the creation of this scheme
  - However, drift is inside specified limits
  - Asynchronous TDM (!) must be used at higher levels
- Buffering is avoided in multiplexers
  - Because of technology limitations at the time of design
  - *Stuffing bits* are added to compensate differences in clocks and resulting phase shift
    - So-called "pulse stuffing"
    - Total number of bits/frame might be increased or decreased
    - Placeholders within frame can carry removed data bits

Plesiochronous Multiplexing

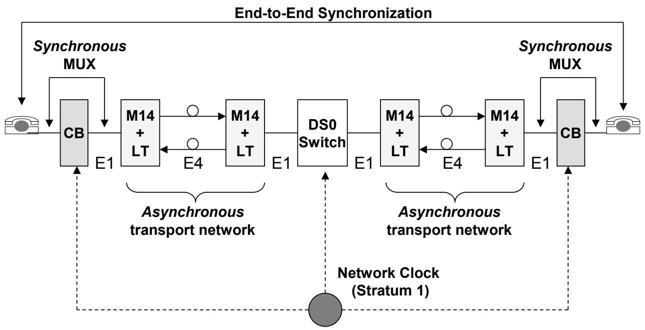
- *Bit interleaved multiplexing* at higher levels
  - Simpler at high line bit rates at that time
  - Complex frame structures (e.g. M12, M13, M14)
- Consequences
  - DS1/E1 signals can only be accessed by demultiplexing
    - Needed by Digital Cross Connects (DXCs)
    - Remove bit stuffing and do resynchronization
  - Add-drop multiplexing not possible
    - All channels must be demultiplexed and then recombined
    - High costs, so careful design is needed
    - No ring structures, only point-to-point

PDH Limitations

- PDH overhead increases dramatically with high bitrates



Synchronization



CB .... Channel Bank
M14+LT ... MUX and Line Termination

Synchronization

- Stratum 1 clock synchronizes E1 frames
  - Atomic clock with accuracy of 10^{-11} (0.000001 ppm)
  - Using independent Stratum 1 clocks would cause only one frame loss every 72.3 days
- Stratum 1 clocks are typically only available in Central Offices
  - Expensive
  - Timing signal can be embedded inside dedicated E1 channels to supply branch offices (timing distribution)
- Higher rate signals are asynchronous with respect to the transported E1 signals
  - Frequency shifts are compensated by pulse stuffing

Agenda

- PDH
  - Speech Transmission Basics
  - Plesiochrone Digital Hierarchy
  - Digital Signal Levels
  - Synchronization
  - E1 Framing
  - T1 Framing
- SONET/SDH
  - History
  - Network Structure
  - Frame Structure
  - Topology

E1 Basics

- CEPT standardized E1
  - As part of European channelized framing structure for PCM transmission (PDH)
    - E1 (2 Mbit/s)
    - E2 (8 Mbit/s)
    - E3 (34Mbit/s)
    - E4 (139Mbit/s)
- Relevant standards
  - G.703: Interfacing and encoding
  - G.704: Framing
  - G.732: Multiplex issues

E1 Physical Aspects: G.703

- G.703 specifies
  - Electrical and physical characteristics
    - 75 ohm coax, unbalanced
    - 120 ohm twisted pair, balanced
  - Encoding
    - HDB3

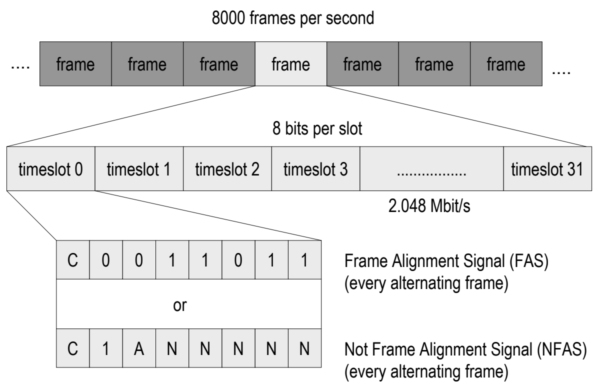
E1 Framing: G.704

- G.704 specifies framing structures for different interface rates
  - E1 is specified at interface rate of 2.048Mbit/s
  - 32 timeslots (8 bit each) per frame
  - Frame repetition rate is 8000 Hz
  - 32 x 8 x 8000 = 2.048 Mbit/s
- Reserved timeslots
  - Timeslot 0 for frame synchronization
    - Allows distinction of frames and timeslots within frames
  - Timeslot 16 *can* be used for signaling

E1 Operational Aspects: G.732

- G.732 specifies
  - Characteristics of PCM multiplex equipment operating at 2.048Mbit/s
    - Based on frame structure G.704
    - Encoding law when converting analogue to digital to be A-law
  - Procedures for
    - Loss and recovery of frame alignment
    - Fault conditions and consequent actions
    - Acceptable jitter levels

E1 Frame Structure



 PDH-SDH, v3.4 29

Timeslot 0

- 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

 PDH-SDH, v3.4 30

Institute of Computer Technology - Vienna University of Technology

L13 - PDH and SDH

CRC Multiframe Structure (Timeslot 0)

	timeslot 0		timeslot 1 .... timeslot 31
frame 0	C1	FAS	semimultiframe 1
frame 1	0	NFAS	
frame 2	C2	FAS	
frame 3	0	NFAS	
frame 4	C3	FAS	
frame 5	1	NFAS	
frame 6	C4	FAS	
frame 7	0	NFAS	
frame 8	C1	FAS	semimultiframe 2
frame 9	1	NFAS	
frame 10	C2	FAS	
frame 11	1	NFAS	
frame 12	C3	FAS	
frame 13	Si	NFAS	
frame 14	C4	FAS	
frame 15	Si	NFAS	

0
0
1
0
1
1

CRC Multiframe Sync - bits

 PDH-SDH, v3.4 31

CRC Multiframe Structure

- CRC check is an optional feature
  - 16 frames are combined to a multiframe
  - Start of multiframe can be detected by CRC Multiframe Sync bits
  - Semimultiframe 2 contains four CRC bits, which were calculated over semimultiframe 1
  - Si bits are used to report CRC errors to the far end

 PDH-SDH, v3.4 32

E1 Signalling: Timeslot 16

- E1 framing is often used to connect PBXs via leased line
  - PBX = Private Branch Exchange
  - Timeslot 16 can carry out-band signaling information between PBX´s
- Two signalling types
  - **Common Channel Signalling (CCS)**
    - Transparent channel (capacity 64kbit/s) for signalling protocols such as DPNSS, CorNet, QSIG, SS7
  - **Channel Associated Signalling (CAS)**
    - Additional CAS multiframe structure
    - Provides 4 bit signalling information per timeslot every 16th frame
    - 30 independent signalling channels (capacity 2kbit/s per channel)

CAS Multiframe Structure (Timeslot 16)

timeslots 0-15	timeslot 16		timeslots17-31
Frame 0	0 0 0 0	X Y X X	
Frame 1	A B (01) C D	A B (17) C D	
Frame 2	A B (02) C D	A B (18) C D	
Frame 3	A B (03) C D	A B (19) C D	
Frame 4	A B (04) C D	A B (20) C D	
Frame 5	A B (05) C D	A B (21) C D	
Frame 6	A B (06) C D	A B (22) C D	
Frame 7	A B (07) C D	A B (23) C D	
Frame 8	A B (08) C D	A B (24) C D	
Frame 9	A B (09) C D	A B (25) C D	
Frame 10	A B (10) C D	A B (26) C D	
Frame 11	A B (11) C D	A B (27) C D	
Frame 12	A B (12) C D	A B (28) C D	
Frame 13	A B (13) C D	A B (29) C D	
Frame 14	A B (14) C D	A B (30) C D	
Frame 15	A B (15) C D	A B (31) C D	

0000 CAS Multiframe Alignment signal

A B C D are signaling bits for the timeslot indicated in ( )

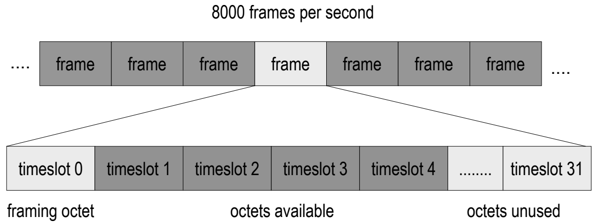
Y is Multiframe Yellow alarm bit to signal a Loss of Multiframe (LOM)

X bits not used (set to 1)

Institute of Computer Technology - Vienna University of Technology

L13 - PDH and SDH

Fractional E1



Only a portion or a fraction in every frame is available for data octets (example above is called E1/4). This is typically done for financial reasons since service provide charges a lower price than for the full capacity. However the fractional E1 line still has 8000 frames per second, the total bit rate of the line (2.048 Mbit/s) is absolutely unchanged.

Agenda

- PDH
  - Speech Transmission Basics
  - Plesiochrone Digital Hierarchy
  - Digital Signal Levels
  - Synchronization
  - E1 Framing
  - T1 Framing
- SONET/SDH
  - History
  - Network Structure
  - Frame Structure
  - Topology

T1 Basics

- T1 is North American channelized framing structure for PCM transmission
  - Plesiochronous TDM originated from digital voice transmission
  - DS0 is basic element
  - Encoding and physics:
    - AMI or B8ZS (Bipolar 8 Zero bit Suppression)
    - 100 ohm, twisted pair

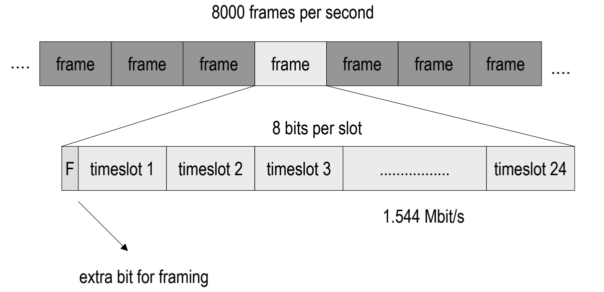
T1 Framing

- T1 frame
  - 24 timeslots per frame, numbered 1-24
    - One timeslot can carry 8 bits
  - One extra bit for framing
  - Frame length 193 bits
  - Frame repetition rate: 8000 Hz
  - (24 x 8 +1) x 8000 = 1.544 Mbit/s

Institute of Computer Technology - Vienna University of Technology

L13 - PDH and SDH

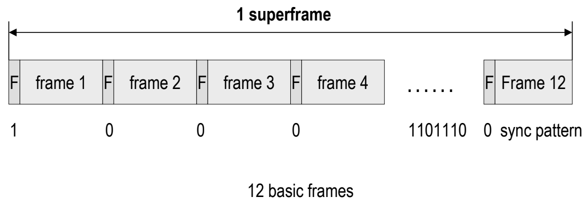
T1 Basic Frame Structure



Superframe

- One framing bit is not sufficient for frame synchronization
  - Framing bits of consecutive frames are combined to form a multiframe synchronization pattern
  - Multiframe structure is called superframe
- D4 format
  - 12 frames are combined to one superframe (SF)
  - 12 consecutive framing bits are 100011011100

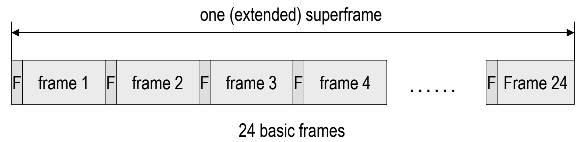
D4 Format



Extended Superframe

- ESF format
  - 24 frames are combined to one extended superframe (ESF)
  - 6 framing bits (2000 bit/s) are used for synchronization in frames 4, 8, 12, 16, 20, 24 (pattern 001011)
  - 6 framing bits (2000 bit/s) may be used for CRC error checking in frames 2, 6, 10, 14, 18, 22
  - 12 framing bits (4000 bit/s) may be used for a diagnostic channel in all odd numbered frames

ESF Format

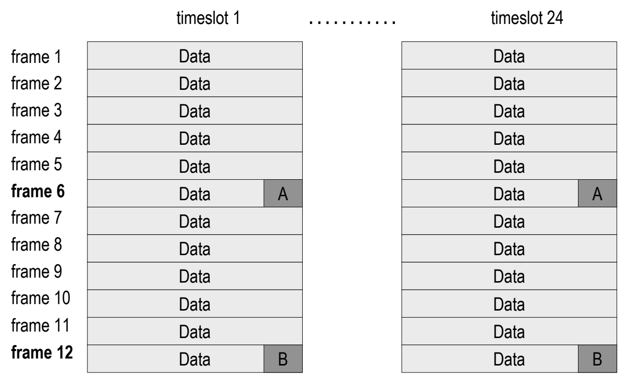


Sync pattern 001011 in frames 4, 8, 12, 16, 20, 24
Six CRC bits in frames 2, 6, 10, 14, 18, 22
Diagnostic bits in frame 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23

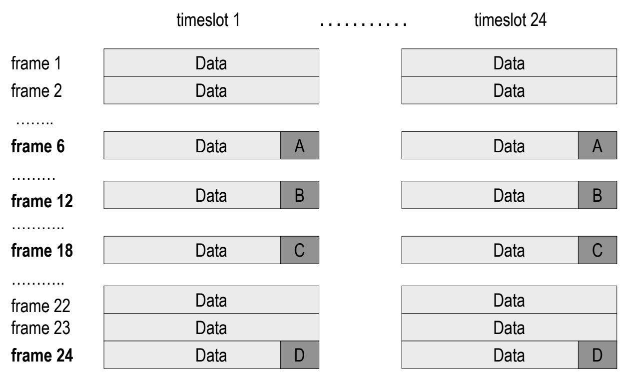
T1 Signalling

- T1 framing is often used to connect PBX (Private Branch Exchanges) via leased line
  - Hence signaling information between PBX´s must be exchanged
- *T1 defines no reserved timeslot for signalling*
- For Channel Associated Signalling (CAS)
  - Robbed bit signalling is used
    - Signalling information is transmitted by robbing certain bits, which are normally used for data
    - Signalling is placed in the LSB of every time slot in the 6th and 12th frame of every D4 superframe (A, B)
    - Signalling is placed in the LSB of every time slot in the 6th, 12th 18th and 24th frame of every ESF superframe (A, B, C, D)

Robbed Bit Signalling D4



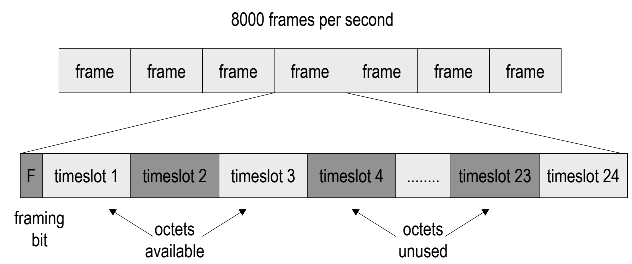
Robbed Bit Signalling ESF



Robbed Bit Signalling

- Robbed Bit Signalling
  - Does not affect PCM signals (analogue sources)
  - Damages data channels totally !!
- T1 system which uses this technique
  - Cannot carry 24 transparent data channels of 64 kbit/s each
  - Only n x 56 kbit/s data channels are possible
- Common Channel Signalling (CCS)
  - Can be used in the same way like E1
  - E.g. timeslot 24 is used as transparent signalling channel

Fractional T1



Only a portion or a fraction in every frame is available for data octets (example above is called T1/12).
However the fractional T1 line still has 8000 frames per second, the total bit rate of the line (1.544 Mbit/s) is absolutely unchanged.

T1 and ISDN

- In the USA, ISDN is typically carried over CAS systems
  - Bit robbing!
  - So only 56 kbit/s per B channel usable
- 64 kbit/s B channels would require CCS
  - Also called Clear Channel Capability (CCC)

Agenda

- PDH
  - Speech Transmission Basics
  - Plesiochrone Digital Hierarchy
  - Digital Signal Levels
  - Synchronization
  - E1 Framing
  - T1 Framing
- SONET/SDH
  - History
  - Network Structure
  - Frame Structure
  - Topology

Reasons for SONET/SDH Development

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

History (1)

- 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
  - A standard that almost wasn't: over 400 proposals !
- SONET became an ANSI standard
  - Tuned to carry US PDH payloads

History (2)

- 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
  - First published in the CCITT Blue Book in 1989
    - G.707, G.708, G.709
- Originally designed for fiber optics
  - But radio systems are also implemented
    - Might have partially filled payload
    - ETSI defined 34 Mbit/s SDH

Agenda

- PDH
  - Speech Transmission Basics
  - Plesiochrone Digital Hierarchy
  - Digital Signal Levels
  - Synchronization
  - E1 Framing
  - T1 Framing
- SONET/SDH
  - History
  - <u>Network Structure</u>
  - Frame Structure
  - Topology

Institute of Computer Technology - Vienna University of Technology

L13 - PDH and SDH

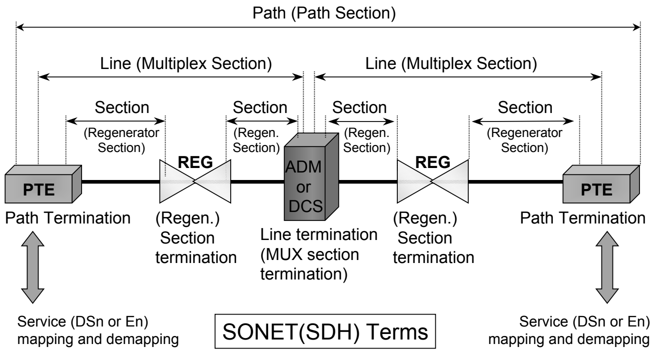
Network Elements

- Terminal Multiplexer
  - At the edge of the SONET/SDH network
  - Provides connectivity to the PDH network devices
- Regenerator
  - Extending the possible distance and quality of a line
  - Decomposes a line into multiple sections
- Add/drop multiplexer – ADM
  - Main element for configuring paths on top of line topologies (point-to-point or ring)
  - Multiplexed channels might be dropped and added

Network Elements

- Digital Cross Connect – DCS or DXC
  - Named after historical patch panels
  - Connects equal level channels with each other

Network Structure



Layers and Overhead

- SONET (SDH) consists of 4 layers
  - Physical Layer
  - Section (Regenerator Section) Layer
  - Line (Multiplex Section) Layer
  - Path Layer
- All layers (except the physical) insert information into the so-called <u>overhead</u> of each frame
- *Note:*
  - *SONET and SDH are technically consistent, only the terms might be different*
  - *In this chapter, each SONET term is named first, followed by the associated SDH term written in brackets*

1. Physical Layer

- Optical-Electrical and Electrical-Optical conversions
- Recovering of the transmit clock for proper sampling of the incoming signal
- No frame overhead is associated with the physical layer
- Line coding depends on kind of interfaces
  - For electrical: compatible with PDH
  - For optical: very simple binary encoding (NRZ)

2. Section (Regenerator Section)

- Deals with the transport of an STS-N frame across the physical medium
  - Framing, scrambling
  - Section error monitoring
  - Section level communications overhead
- Together with physical layers can be used in some equipment without involving higher layers
  - Regenerator Equipment
- Section is terminated by (Regenerator-) Section Terminating Equipment
  - STE (RSTE)

3. Line (Multiplex Section)

- Transport of path layer payloads across the physical medium
  - Supports the synchronization and multiplexing functions of the path layer
- Overhead associated functions
  - Includes maintenance and protection
- Overhead is interpreted and modified by
  - SONET: Line Terminating Equipment (LTE)
  - SDH: Multiplex Section Terminating Equipment (MSTE)
- Overhead can be accessed only after the (regen.-) section overhead has been first terminated
  - By definition, any LTE (MSTE) contains a STE (RSTE)

4. Path

- Transport of various payloads between SONET/SDH terminal multiplexing equipment
  - Path layer maps payloads into the format required by the Line Layer
  - Communicates end-to-end via the Path Overhead – POH
- POH is terminated and modified by Path Terminating Equipment (PTE)
  - Lower layer overhead must be terminated to access the Path overhead
  - PTE also contains STE (RSTE) and LTE (MSTE)

Institute of Computer Technology - Vienna University of Technology

L13 - PDH and SDH

Agenda

- PDH
  - Speech Transmission Basics
  - Plesiochrone Digital Hierarchy
  - Digital Signal Levels
  - Synchronization
  - E1 Framing
  - T1 Framing
- SONET/SDH
  - History
  - Network Structure
  - Frame Structure
  - Topology

SONET Signals

- Electrical signal: **STS-n**
  - Synchronous Transport Signal level n
- Optical signal: **OC-n**
  - Optical Carrier level n
  - OC-nc means concatenated
    - Not multiplexed signal
    - Originates at that speed (e.g. ATM)
    - Administrative overhead optimized compared to real multiplexed signal
- Frame format is independent from electrical or optical signals
    - Typically only the term OC-n is used

SDH Signals

- Electrical signal: **STM-n**
  - Synchronous Transport Module level n
  - STM-nc means concatenated
    - Not multiplexed signal
    - Originates at that speed
    - Administrative overhead optimized compared to real multiplexed signal
- Optical signal: **STM-nO**
- Frame format is independent from electrical or optical signals
    - Typically only the term STM-n is used

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	Defined but later removed, and only the multiples by four were left!
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	Defined but later removed, and only the multiples by four were left!
OC-36	STS-36	1866.24	STM-12	Defined but later removed, and only the multiples by four were left!
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)

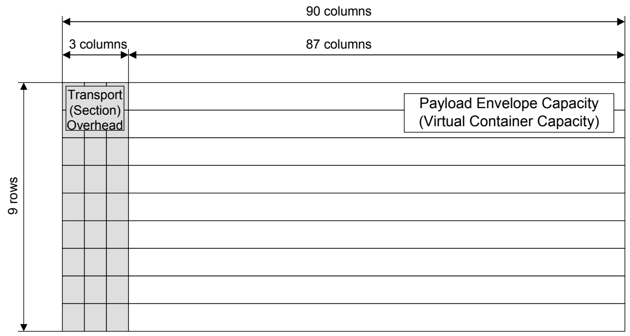
Two-dimensional Frame Model

- Similar to PDH every frame has 125 μs time length
  - To support 8 kHz sampled voice applications
- Bytes organized into rows and columns
  - Administrative channels are rate decoupled for easier processing
- Basic SONET frame is STS-1
  - 9 rows and 90 columns = 810 bytes total
  - 810 bytes $\times$ 8 bits $\times$ 8000/s = 51.8 Mbit/s
- Basic SDH frame is STM-1
  - 9 rows and 270 (3$\times$90) columns = 2430 bytes total
  - 2430 bytes $\times$ 8 bits $\times$ 8000/s = 155.52 Mbit/s

SONET/SDH Frame Model Basics

- STM-0 frame was defined to be compatible with STS-1 of SONET
  - Same frame size
  - Originally only thought for comparisons
  - Recently become real-life frame format for microwave links
- Higher level frames can be defined
  - by multiplying STS-1 and STM-1 frame sizes by a certain factor
  - Only a few of them are available in real world
- Frames are strictly byte oriented and byte multiplexed

STS-1 (STM-0) Frame Structure



Frame Structure

- Frame consists of
  - Transport Overhead (Section Overhead)
  - Payload Envelope Capacity (Virtual Container Capacity)
- Higher level signals have *same percentage of overhead*
  - Number of columns are simply multiplied by rate factor
  - Other than PDH frames !
- Overhead consists of
  - Section Overhead – SOH (Regen. Section Overhead – RSOH)
  - Line Overhead (Multiplex Section Overhead – MSOH)

Institute of Computer Technology - Vienna University of Technology

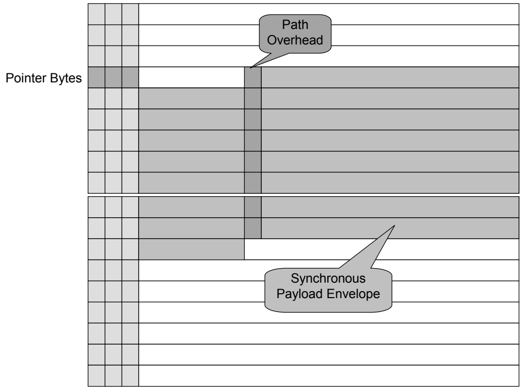
L13 - PDH and SDH

Transport Overhead (Section Overhead)

Payload

- The payload is transported inside the Synchronous Payload Envelope or SPE
  - The SPE may *float* inside the Payload Envelope Capacity (Virtual Container Capacity)
  - To compensate phase and frequency shifts
- Path Overhead – POH
  - The first column of the SPE
- Various additional "envelopes" were defined
  - For each type of payload
    - e. g. DS1, DS3, E1, E3, E4, ..., ATM
  - Virtual Tributaries (Virtual Containers)

Floating Payload



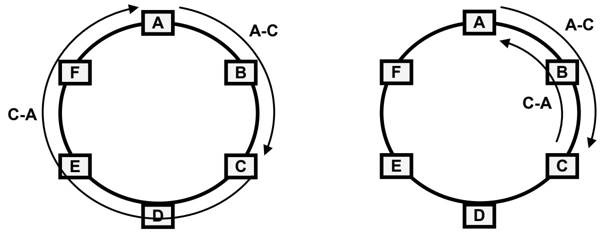
Agenda

- PDH
  - Speech Transmission Basics
  - Plesiochrone Digital Hierarchy
  - Digital Signal Levels
  - Synchronization
  - E1 Framing
  - T1 Framing
- SONET/SDH
  - History
  - Network Structure
  - Frame Structure
  - <u>Topology</u>

Institute of Computer Technology - Vienna University of Technology

L13 - PDH and SDH

Uni- and Bi-directional Routing



Uni-directional Ring
(1 fiber)

Bi-directional Ring
(2 fibers)

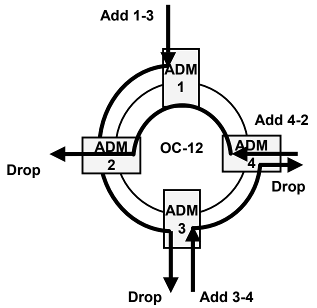
- Only working traffic is shown
- Path or line switching for protection

Add-drop Provisioning

- Transport connections over a SONET infrastructure are created by *add-drop provisioning*
  - A path is built up hop-by-hop by specifying which channels should be added to a ring and which channels should be dropped from the ring
- Add-drop provisioning is typically done by the network management system
  - There is no signalling protocol !!!

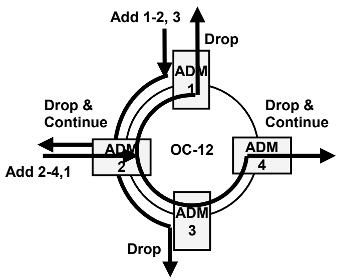
Add and Drop Example

- Example: OC-12 ring
  - Consists of 4 x OC-3c channels
  - Uni-directional routing
- Provisioning:
  - Add 1-3 (drop 3-1)
  - Add 3-4 (drop 4-3)
  - Add 4-2 (drop 2-4)
- 2 channels occupied



Drop and Continue Example

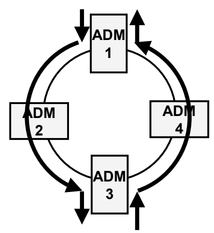
- Provisioning:
  - add 1-2,3
  - add 2-4,1
- 2 channels occupied



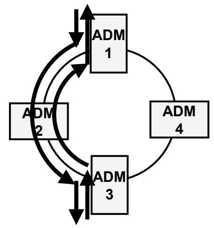
Uni- and Bi-directional Example

- Provisioning:
  - add 1-3
  - add 3-1

Uni-directional routing



Bi-directional routing



Topology Concepts

- SONET/SDH topologies are designed for providing a flexible and reliable transport for required paths
  - Capacity planning and bandwidth provisioning
  - Redundancy and automatic fail-over
  - Delay and jitter control
- Typical topology concepts:
  - Point-to-point links (with protection) and DCS/MUX
    - Arbitrary complex topology might be built
  - Interconnected protected rings with ADM/DCS
    - Minimum resource usage (physical media) for avoiding single point of failures

Operations

- Protection
  - Circuit recovery in milliseconds
- Restoration
  - Circuit recovery in seconds or minutes
- Provisioning
  - Allocation of capacity to preferred routes
- Consolidation
  - Moving traffic from unfilled bearers onto fewer bearers to reduce waste trunk capacity
- Grooming
  - Sorting of different traffic types from mixed payloads into separate destinations for each type of traffic

SONET/SDH and the OSI Model

- SONET/SDH covers
  - Physical, Data Link, and Network layers
- However, in data networking it is used mostly as a transparent bit stream pipe
- Therefore SONET/SDH is regarded as a Physical layer, although it is more
- Functions might be repeated many times in the overall protocol stack
  - Worst case: IP over LANE over ATM over SONET

Summary

- Telecommunication backbones must be very much reliable and backward compatible
  - Changes are slow
  - Smooth path for reusing existing knowledge and skill sets
- PDH is still an important backbone technology
- Recently moving to optical backbones using SONET/SDH
  - First US nation-wide SONET ring backbone finished in 1997
- Traffic volume of voice services will decrease relative to general IP traffic