SONET/SDH

SONET/SDH

- SONET (Synchronous Optical Network) is the current standard for high speed carrier infrastructure in North America.
- SDH (Synchronous Digital Hierarchy) is the European counterpart (closely related).
- Before SONET/SDH , the infrastructure was based on PDH (Plesiochronous (or asynchronous) Digital Hierarchy – 1960s).

PDH

PDH

- A 4kHz band limited signal (voice) can be sampled with 8kHz and quantized at 8 bits/sample resulting in 64kbps.
- Higher bit rates are multiples of this bit rate and are offered as leased line speeds:

	North America		Europe		Japan	
Level	Name	Bit Rate	Name	Bit Rate	Name	Bit Rate
0	DS0	64k	E0	64k	J0	64k
1	DS1	1.544M	E1	2.048M	J1	1.544M
2	DS2	6.312M	E2	8.448M	J2	6.312M
3	DS3	44.736M	E3	34.368M	J3	32.064M
4	DS4	139.264M	E4	139.264M	J4	97.728M

Problems with PDH

1. Each terminal (switch) in the network runs its own clock, thus actual rates and offsets can be huge (bit rate differences up to 1.8kbps).
   - This means that when slower speed signals are multiplexed by interleaving their bits, extra bits need to be "stuffed" into the new stream.
   - In PDH, bit rates are not exact multiples of lower bit rates (e.g. $24*64k=1.536M \neq 1.544M$)

Problems with PDH

2. It is difficult to “pick out” (drop) a low bit rate stream out of a high bit rate stream w/o completely demultiplexing the stream.
   - Multiplexer “mountains” (stacked up).
   - Expensive and compromises network reliability (large amount of electronics).

SONET/SDH

Solution: SONET

- All the clocks in the network are synchronized to a single master.
- => rates are integral multiples of the basic rate.
- => no bit stuffing is needed
- => lower-speed signals can be extracted from a multiplexed SONET stream easily.

Solution: SONET

- Management: extensive management information for managing the network:
  - Performance monitoring
  - Identification of traffic type
  - Identification of connectivity
  - Identification and reporting of failures
  - Data channels between nodes for management info

Solution: SONET

- Interoperability: (PDH did not define standard formats, thus different vendors used different coding, interfaces, etc.)
  - Standard optical interfaces
  - But some issues were standardized too late, thus even today it is not trivial to interconnect SONET equipment of different vendors.

Solution: SONET

- Network availability:
  - Specific network topologies are supported (point-to-point, ring, linear add-drop)
  - => service restoration time is less than 60ms (while with PDH it was up to several minutes)

SONET Multiplexing

- Easily implemented in VLSI.
- SONET and SDH terms are unfortunately very different.
- SONET basic rate is 51.48Mbps (STS-1 ; synchronous transport signal).
- Higher rate signals are obtained by interleaving the bytes of N (aligned) frames (STS-N) (scrambling is used to prevent long runs of 0s or 1s)

SONET/SDH/OC Rates

SONET Signal	SDH Signal	Optical Carrier	Bit Rate [Mbps]
STS-1			51.84
STS-3	STM-1	OC-3	155.52
STS-12	STM-4	OC-12	622.08
STS-24			1244.16
STS-48	STM-16	OC-48	2488.32
STS-192	STM-24	OC-192	9953.28
STS-768	STM-256	OC-768	39,814.32

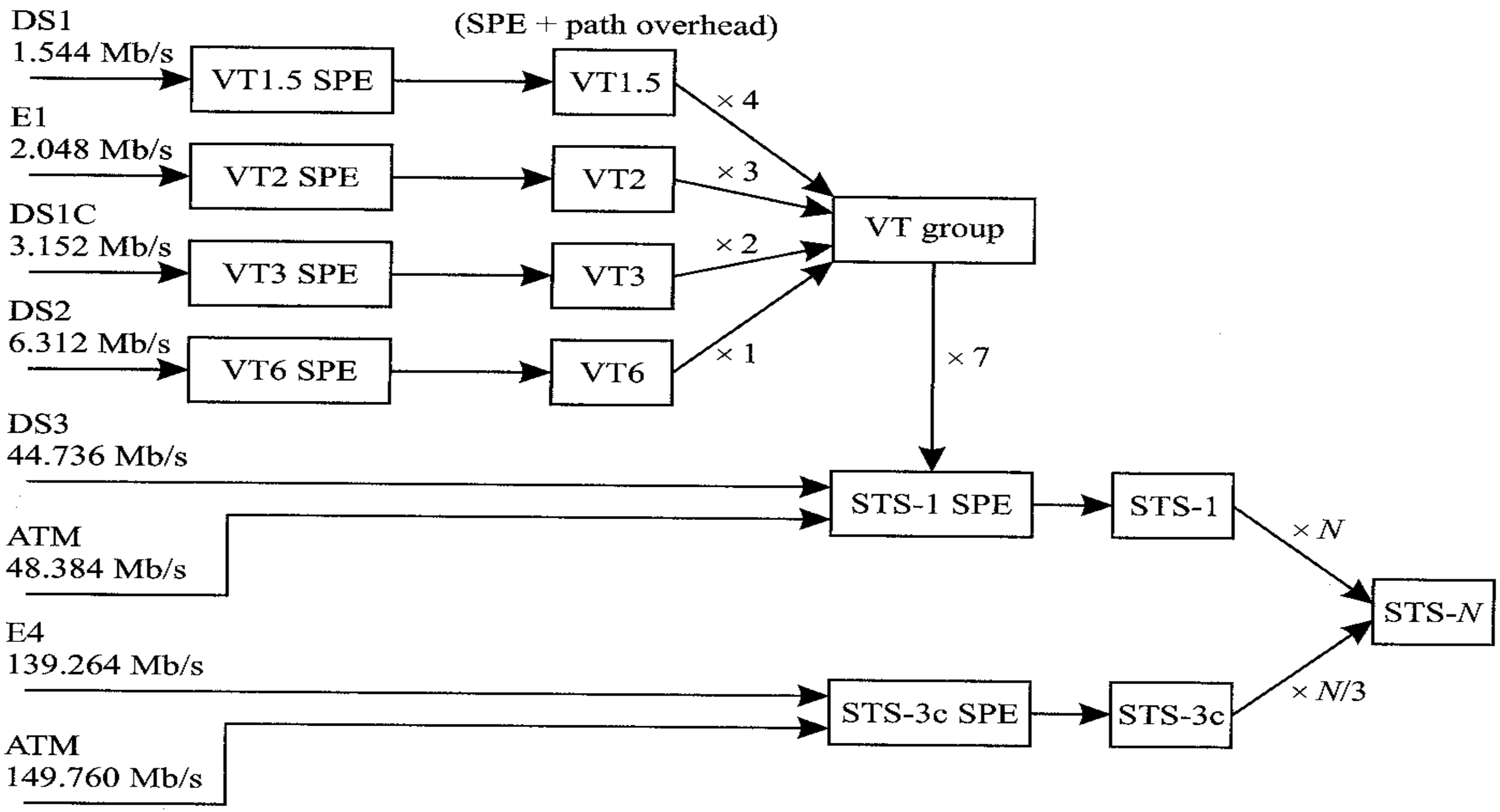
SONET/SDH Rates

- SONET's basic rate is to easily accommodate DS1 and DS3 signals, while SDH's objective was to accommodate E1,E3 and E4 signals.
- The frame structure makes extensive use of pointers to indicate the location of payload in the frame (payload is not fixed in the frame). This is required because off clock offsets and transients.

SONET Multiplexing

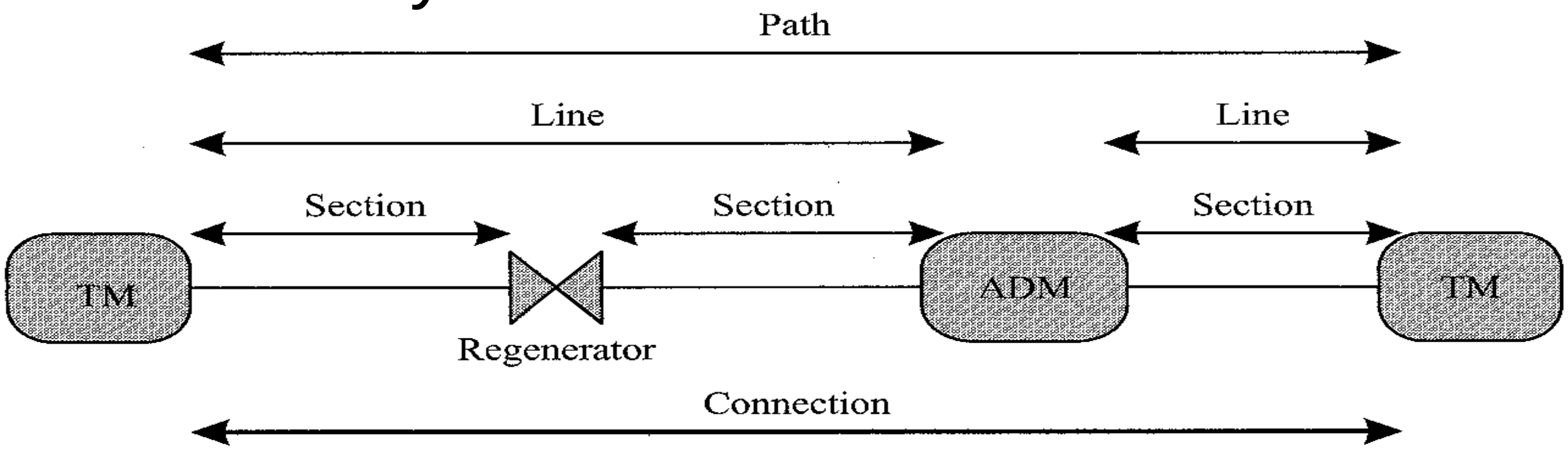
- Non-SONET streams below the STS-1 rate are mapped into Virtual Tributaries (VTs) (or VC – virtual containers in SDH). There are 4 different VTs as shown in the next picture.
- VTs can also float in an STS-1
- STS-Nc signals have “locked” payload that cannot be further demultiplexed via SONET (e.g., for ATM over SONET).

SONET Multiplexing



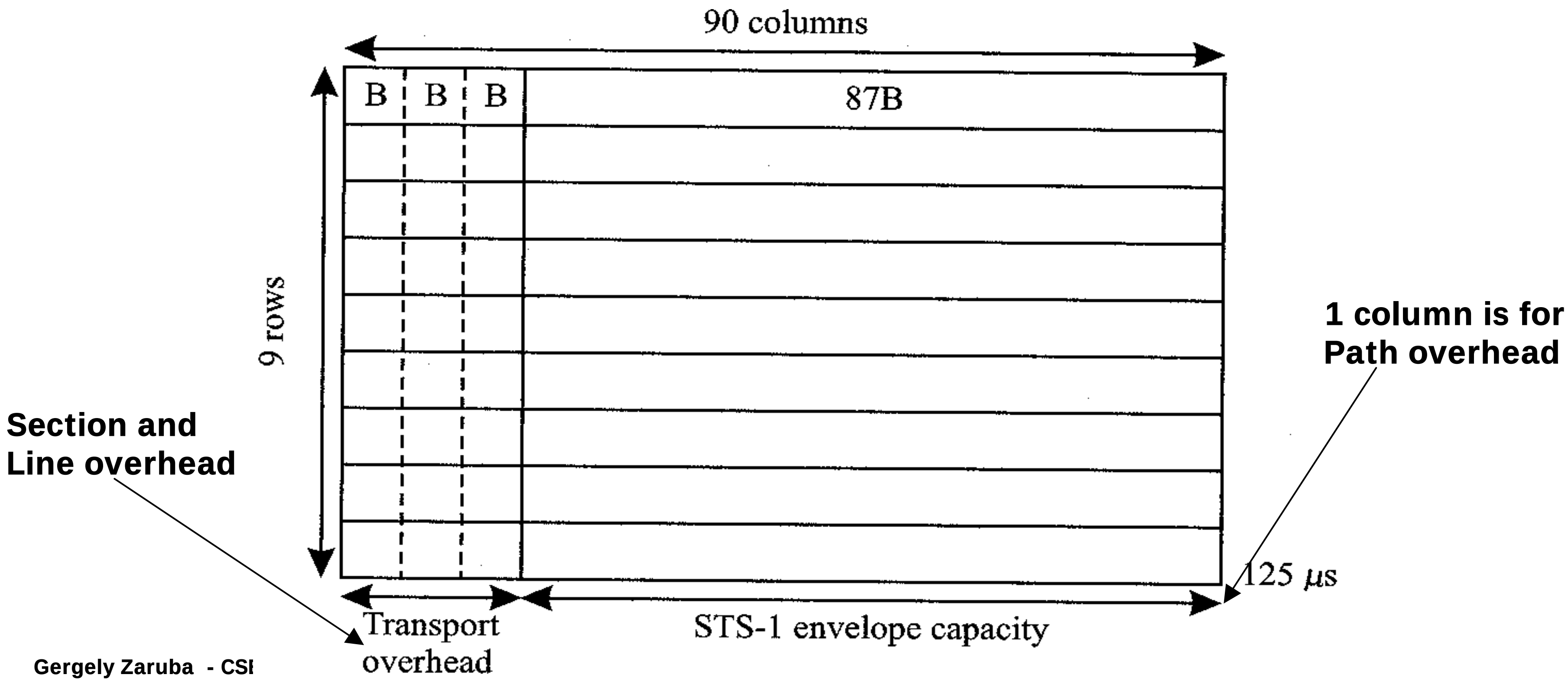
SONET Layers

- SONET layer consists of four sub-layers:
  - Path (end-to-end connections)
  - Line (protection)
  - Section
  - Physical



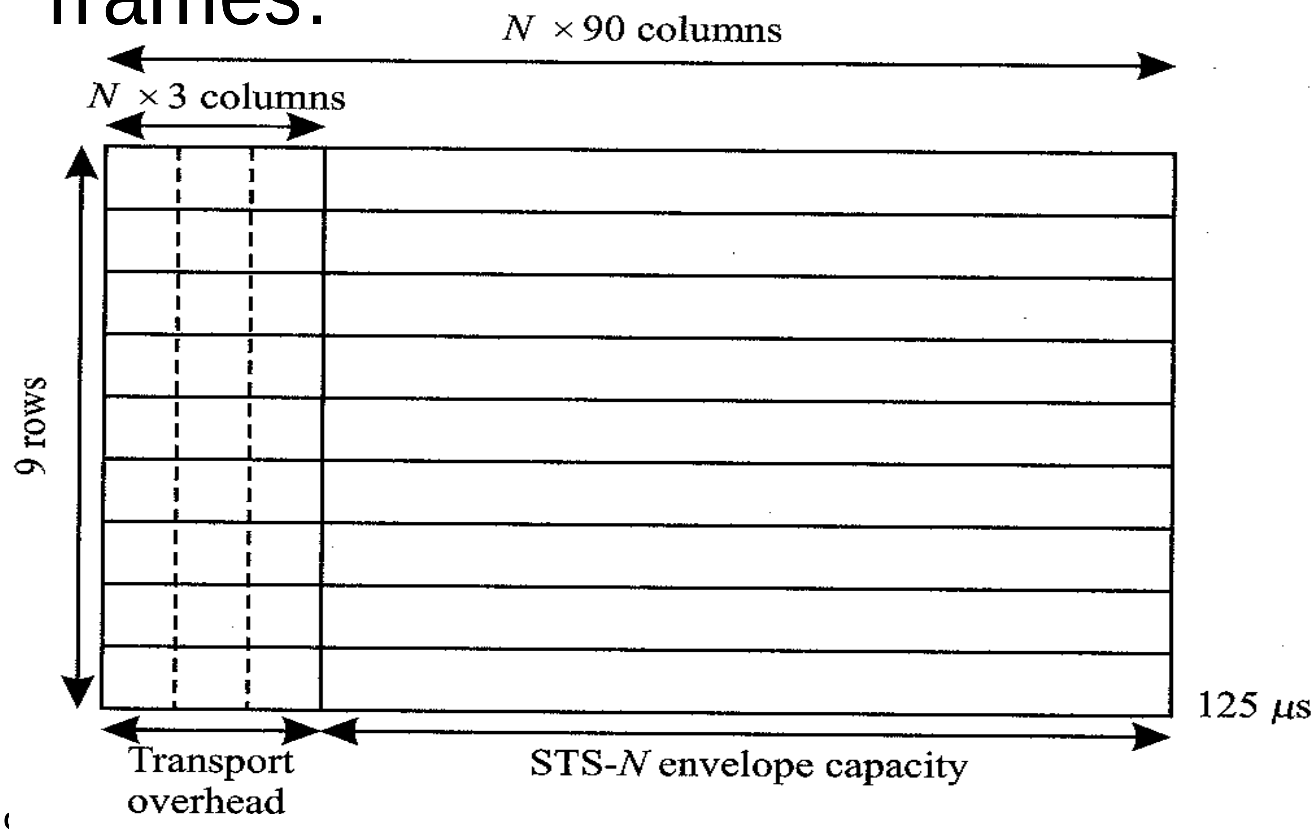
SONET Frame Structure

- Payload is carried in a synchronous payload envelope (SPE).



SONET Frame Structure

- STS-N frames are N interleaved STS-1 frames:



SONET Overhead Bytes

- To scare students ☺

Section overhead	Framing A1	Framing A2	Trace/Growth J0/Z0
	BIP-8 B1/undefined	Orderwire E1/undefined	User F1/undefined
	Datacom D1/undefined	Datacom D2/undefined	Datacom D3/undefined
Line overhead	Pointer H1	Pointer H2	Pointer H3
	BIP-8 B2	Datacom D5/undefined	Datacom D6/undefined
	Datacom D4/undefined	APS K1/undefined	APS K2/undefined
	Datacom D7/undefined	Datacom D8/undefined	Datacom D9/undefined
	Datacom D10/undefined	Datacom D11/undefined	Datacom D12/undefined
	Sync status/Growth S1/Z1	REI-L/Growth M0 or M1/Z2	Orderwire E2/undefined

Path overhead
Trace J1
BIP-8 B3
Signal label C2
Path status G1
User channel F2
Indicator H4
Growth Z3
Growth Z4
Tandem connection Z5

SONET Physical Specs

- Short-reach (I) connections (<2km)
- Short-haul (S) (15km or 40km)
- Long-haul (L) (40km or 80km)
- Very-long-haul (V) (60km or 120km)
- Ultra-long-haul (U) (160km)
- No optical line amplifiers are considered, but with the given parameters and EDFAs regenerators can be placed as far as 600km to a few thousand km. This is vendor dependent as has not been standardized yet.

SONET Physical Specs

Bit Rate	Code	Wavelength (nm)	Fiber	Loss (dB)	Transmitter	Dispersion (ps/nm)
STM-1	I-1	1310	G.652	0-7	LED/MLM	18/25
	S-1.1	1310	G.652	0-12	MLM	96
	S-1.2	1550	G.652	0-12	MLM/SLM	296/NA
	L-1.1	1310	G.652	10-28	MLM/SLM	246/NA
	L-1.2	1550	G.652	10-28	SLM	NA
	L-1.3	1550	G.653	10-28	MLM/SLM	296/NA
STM-4	I-4	1310	G.652	0-7	LED/MLM	14/13
	S-4.1	1310	G.652	0-12	MLM	74
	S-4.2	1310	G.652	0-12	SLM	NA
	L-4.1	1310	G.652	10-24	MLM/SLM	109/NA
	L-4.2	1550	G.652	10-24	SLM	ffs
	L-4.3	1550	G.653	10-24	SLM	NA
	V-4.1	1310	G.652	22-33	SLM	200
	V-4.2	1550	G.652	22-33	SLM	2400
	V-4.3	1550	G.653	22-33	SLM	400
	U-4.2	1550	G.652	33-44	SLM	3200
	U-4.3	1550	G.653	33-44	SLM	530

SONET Physical Specs

Bit Rate	Code	Wavelength (nm)	Fiber	Loss (dB)	Transmitter	Dispersion (ps/nm)
STM-16	I-16	1310	G.652	0-7	MLM	12
	S-16.1	1310	G.652	0-12	SLM	NA
	S-16.2	1550	G.652	0-12	SLM	ffs
	L-16.1	1310	G.652	10-24	SLM	NA
	L-16.2	1550	G.652	10-24	SLM	1600
	L-16.3	1550	G.653	10-24	SLM	ffs
	V-16.2	1550	G.652	22-33	SLM	2400
	V-16.3	1550	G.653	22-33	SLM	400
	U-4.2	1550	G.652	33-44	SLM	3200
	U-4.3	1550	G.653	33-44	SLM	530

SONET Physical Specs

Bit Rate	Code	Wavelength (nm)	Fiber	Loss (dB)	Transmitter	Dispersion (ps/nm)
STM-64	I-64.1r	1310	G.652	0-4	MLM	3.8
	I-64.1	1310	G.652	0-4	SLM	6.6
	I-64.2r	1550	G.652	0-7	SLM	40
	I-64.2	1550	G.652	0-7	SLM	500
	I-64.3	1550	G.653	0-7	SLM	80
	I-64.5	1550	G.655	0-7	SLM	ffs
	S-64.1	1550	G.652	6-11	SLM	70
	S-64.2	1550	G.652	3/7-11	SLM	800
	S-64.3	1550	G.653	3/7-11	SLM	130
	S-64.5	1550	G.655	3/7-11	SLM	130
	L-64.1	1310	G.652	17-22	SLM	130
	L-64.2	1550	G.652	11/16-22	SLM	1600
	L-64.3	1550	G.653	16-22	SLM	260
	L-64.3	1550	G.653	0-7	SLM	ffs
	V-64.2	1550	G.652	22-33	SLM	2400
	V-64.3	1550	G.653	22-33	SLM	400

SONET Infrastructure

- SONET can be deployed as:
  - Ring
  - Linear configurations
  - Point-to-point links
- End nodes for point-to-point links are called: Terminal Multiplexers (TMs – or line terminating equipment – LTE).
- ADMs are used to add/drop low speed streams to/from higher speed streams.
- ADMs can be inserted between TMs in point-to-point configurations to yield linear configurations.

SONET Infrastructure

- Maintaining service availability in presence of failures (protection) has become a key driver for SONET deployment => rings are the most common topologies.
- Rings consist of ADMs with protection mechanisms.
- Usually SONET equipment can be configured to work in any of these configurations

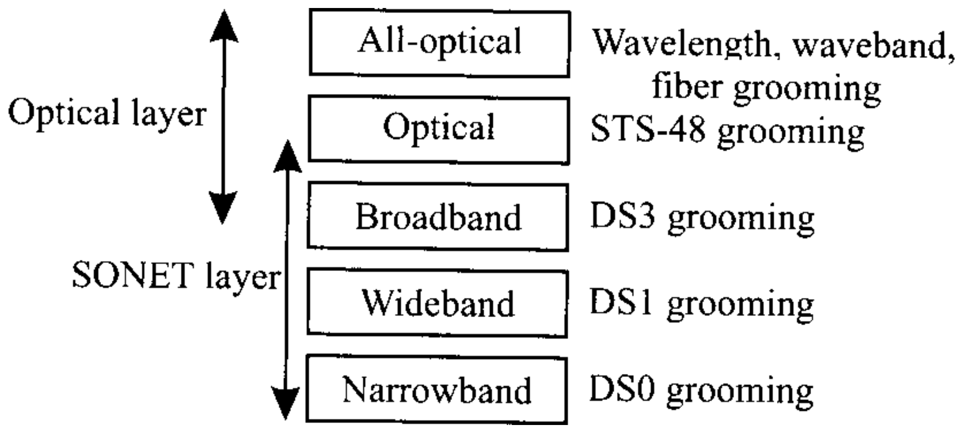
SONET Infrastructure

- Today most access rings run with OC3/OC-12 and most interoffice rings run at OC-12/OC-48/OC-192 (and increasing).
- It is common to use multiple overlaid rings (easy with an optical layer).
- Two types of ring architectures (protection):
  - Unidirectional Path Switched Rings (UPSR)
  - Bi-directional Path Switched Rings (BPSR) with two (BPSR/2) or four fibers (BPSR/4).

SONET Infrastructure

- Another major component: Digital Crossconnect (DCS)
  - Can switch PDH signals with software control
  - Can also switch SONET signals with software control (evolved)
  - It incorporates multiplexing as well (evolved even more)

- DCSs can be narrowband, wideband or broadband, but not all of them at once.
- Broad-band DCSs are also called: Optical Crossconnects



SONET Infrastructure