North American Digital Hierarchy

DIGITAL SIGNAL NUMBER	**NUMBER O F 64 kb/s CHANNELS**	**BIT RATE IN Mb/s**	**T CARRIER IMPLEMENTATION**
DS0	1	.064	n/a
DS1	24	1.544	T-1
DS1C	48	3.152	T-1C
DS2	96	6.312	T-2
DS3	672	44.736	T-3
DS4	4032	274.176	T-4

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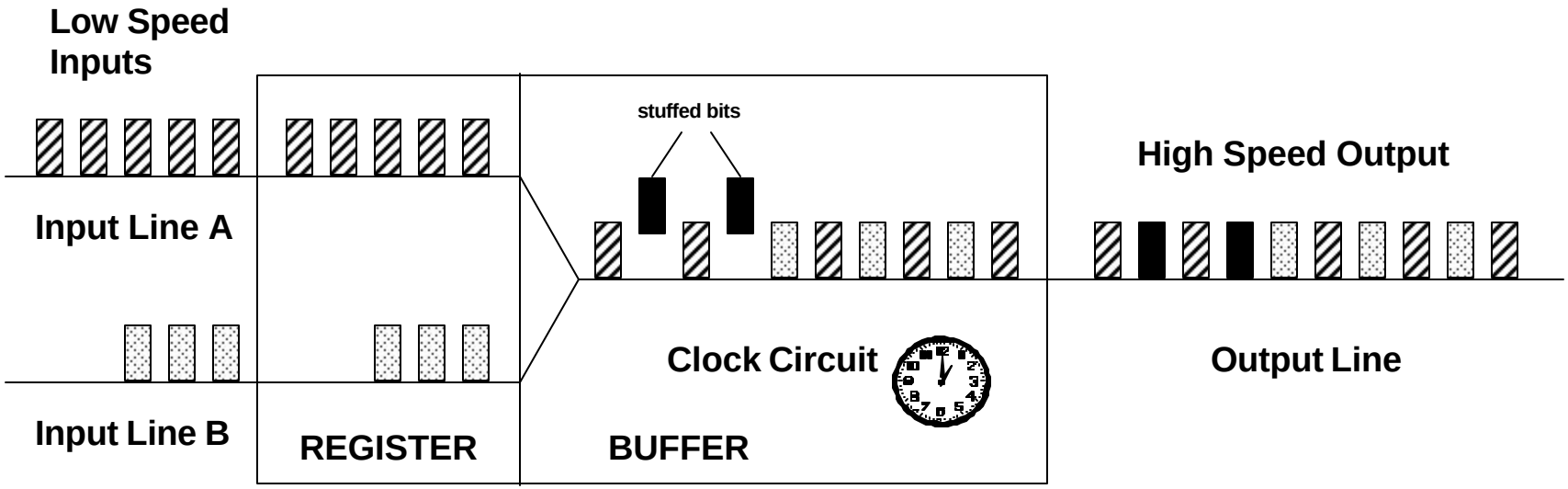
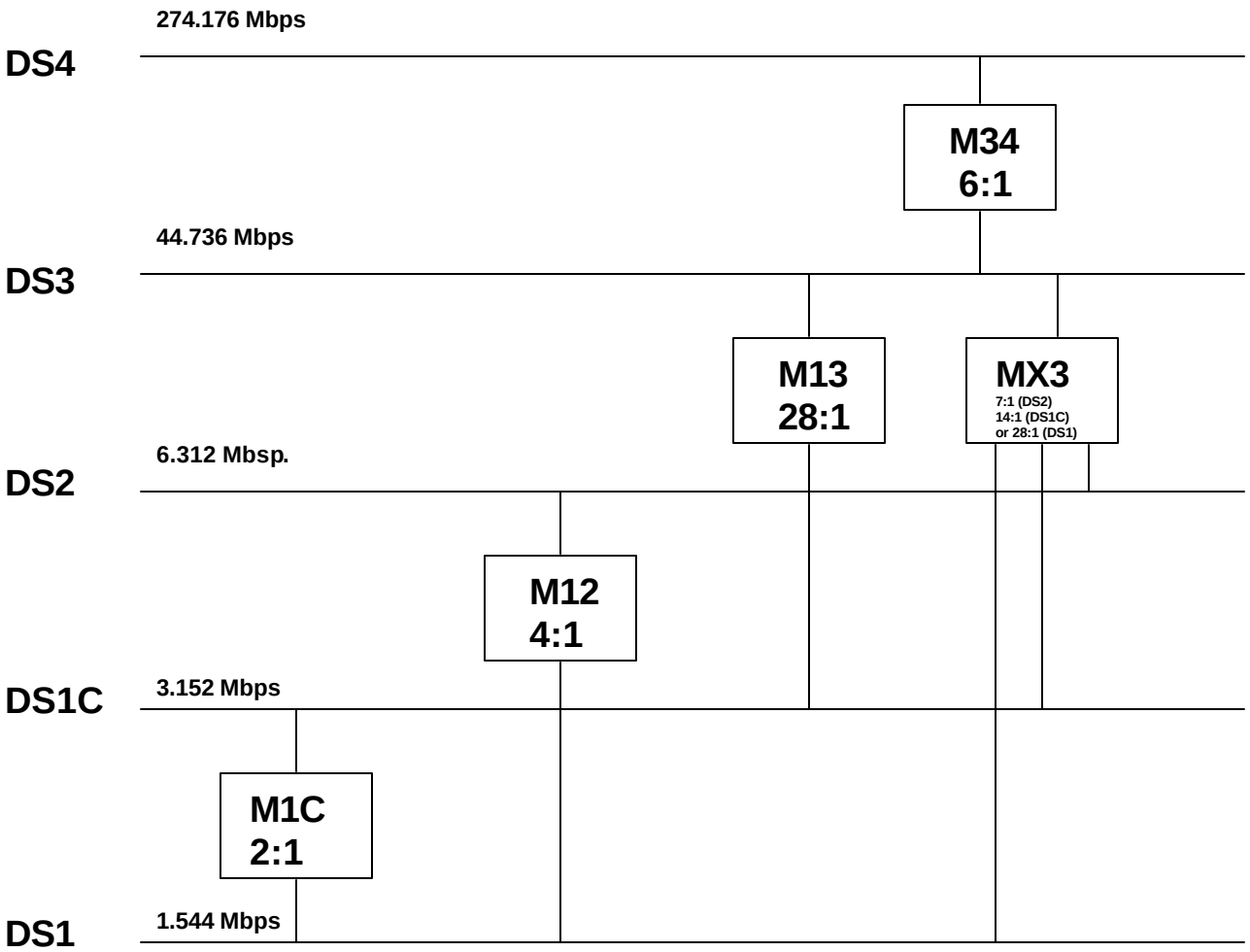
Bit Stuffing



Digital Multiplexer Designations With Multiplexing Ratios



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European Digital Hierarchy

LEVEL NUMBER	NUMBER OF VOICE CIRCUITS	MULTIPLEXER DESIGNATION	BIT RATE (Mb/s)
CEPT1	30		2.048
CEPT2	120	M12	8.448
CEPT3	480	M23	34.368
CEPT4	1920	M34	139.264
CEPT5	7680	M45	565.148

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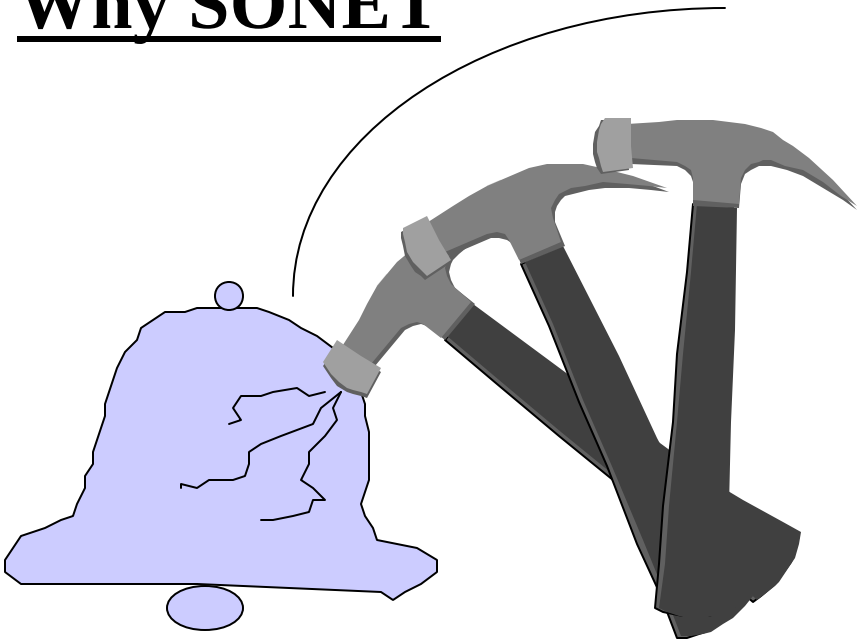
Why SONET



- **Break up of Bell System**
- **Open Standards**
- **Bellcore**
- **Telecommunications Act of 1996**

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Open Standards

- 1985, ANSI T1X1 Committee
- Fiber Optic Equipment
- Multi-vendor Environment
- Open Systems and Standards

» **DO NOT GET LOCKED INTO "A" VENDORS TECHNOLOGY**

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Phase 1 & 2 SONET

Phase 1

- Rates and formats
- Mapping hierarchical signals
- Performance monitoring
- Automatic protection switching
- Synchronization requirements
- Optical parameter specifications.

Phase 2

- Short reach (INTRA-office) specifications for OC-1 to OC-12 rates.
- Electrical intra-office specifications from EC-1 to EC-12
- Intra-office LAN topology
- Data communications channel protocol using a seven layer stack
- Asynchronous Transfer Mode (ATM) and Fiber Distributed Data Interface (FDDI) signal mapping
- Core OAM&P
- Synchronization specifications
- Payload and interface jitter and wander specifications.

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SONET Line Rates

OPTICAL CARRIER LEVEL	ELECTRICAL CONNECTION	LINE RATE Mb/s
OC-1	EC-1	51.840
OC-3	EC-3	155.520
OC-9	EC-9	466.560
OC-12	EC-12	622.080
OC-18	EC-18	933.120
OC-24	EC-24	1244.160
OC-36	EC-36	1866.240
OC-48	EC-48	2488.320
OC-192	EC-192	9953.280
OC-N	**EC-N**	**= N * 51.840**

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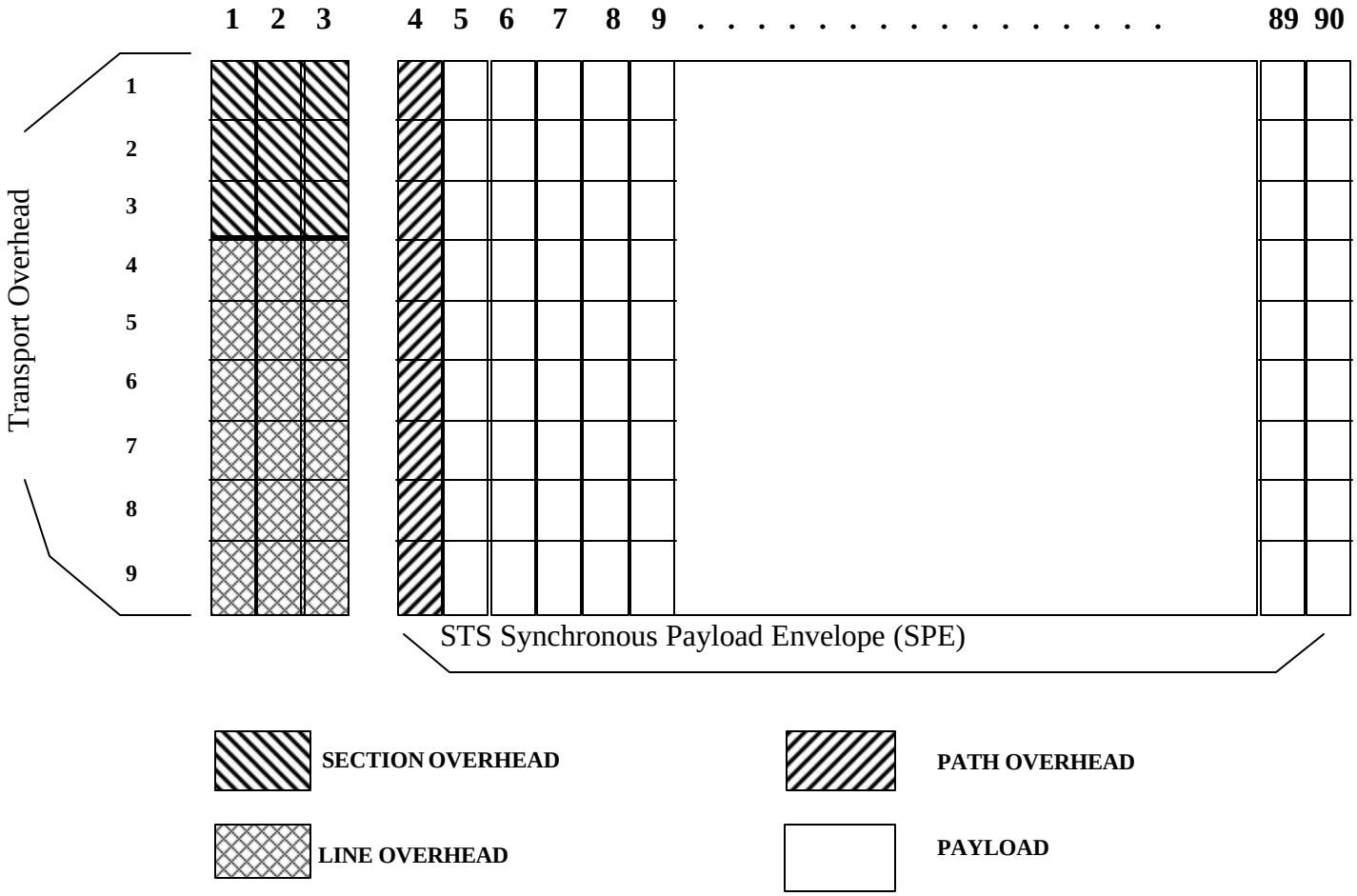
SONET Frame

9 X 90 Bytes
51,840,000 bits per second



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Types of SONET Overhead

Section **Line**	9 Bytes 18 Bytes	72 bits 144 bits	Section and Line Overhead are called the *Transport Overhead (TOH)*
Path	9 Bytes	72 bits	
Overhead Total	36 Bytes	288 bits	
Payload	774 bytes	6,192 bits	
Frame Total	810 bytes	6,480 bits	There are 8000 of these frames each second to give a total bit rate of 51,840,000 b/s
Thus, the fixed overhead for the SONET frame is 36 bytes or 4.4% of the total bits transmitted.			

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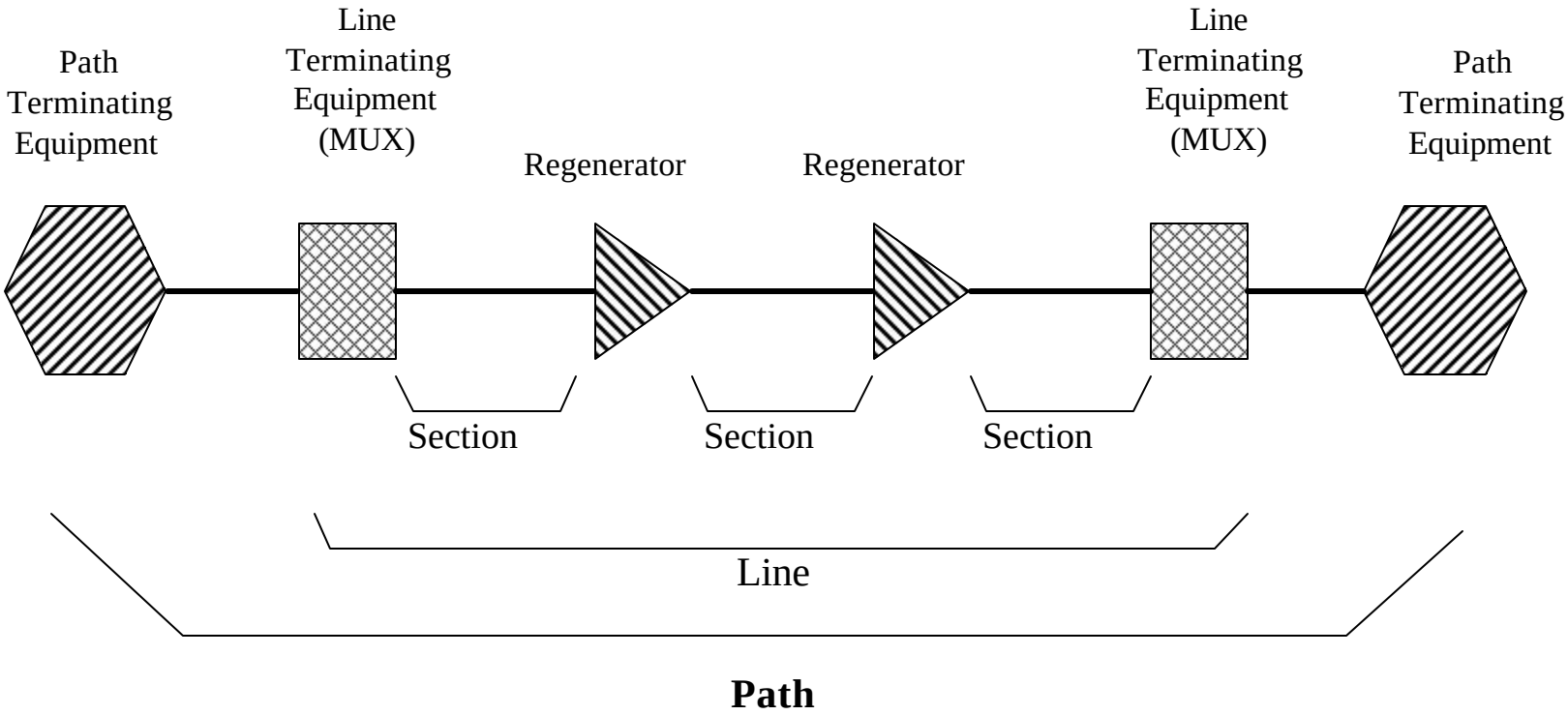
End to End SONET Transmission



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SONET Overhead Content

SECTION OVERHEAD					PATH Overhead
Framing A1	**Framing A2**	**STS-1 ID C1**			Trace J1
BIP-8 B1	**Orderwire E1**	**User F1**			BIP-8 B3
Data COM D1	**Data COM D2**	**Data COM D3**			Signal Label C2
Pointer H1	*Pointer H2*	*Pointer Action H3*			Path Status G1
BIP-8 B2	*APS K1*	*APS K2*			User Channel F2
Data COM D4	*Data COM D5*	*Data COM D6*			Multiframe H4
Data COM D7	*Data COM D8*	*Data COM D9*			Growth Z3
Data COM D10	*Data COM D11*	*Data COM D12*			Growth Z4
Growth Z1	*Growth Z2*	*Orderwire E2*			Growth Z5
LINE OVERHEAD					

Line Overhead and Section Overhead together are referred to as Transport Overhead (TOH).

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Virtual Tributary (VT) Data Rates

VT Type	VT Rate Mb/s	Example Payload Mb/s	STS-1 Columns Needed	Total Payloads Carried in a STS-1
VT1.5	1.728	DS-1 @ 1.544	3	28
VT2	2.304	CEPT-1 @ 2.048	4	21
VT3	3.456	DS-1C @ 3.152	6	14
VT6	6.912	DS-2 @ 6.312	12	7

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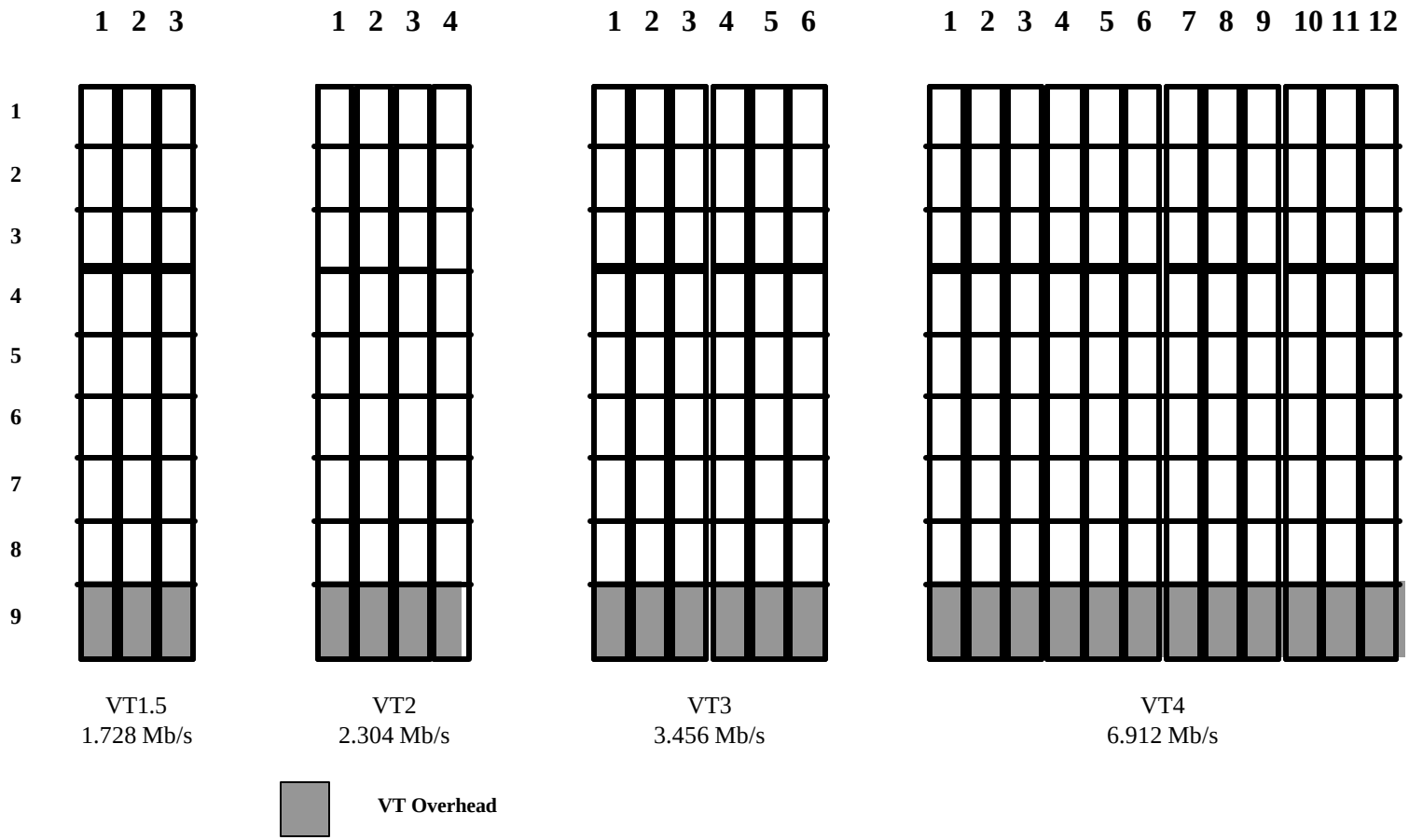
Size Comparison of VT Frames Carried in the SPE



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VT Combinations Examples

Asynchronous Signal	Quantity	VT Frames Required	VT Groups Used for this Signal Level	Total VT Groups	Spare Space in VT Group at this Rate
EXAMPLE 1					
DS-1	3	3 - VT1.5	1	1	1 - DS-1
DS-1C	1	1 - VT3	1	2	1 - DS-1C
DS-2	4	4 - VT4	4	6	-
CEPT-1	1	1 - VT2	1	7	2 - CEPT-1
EXAMPLE 2					
DS-1	5	5 - VT1.5	2	2	3 - DS-1
DS-1C	0	0	0	2	-
DS-2	4	4 - VT4	4	6	-
CEPT-1	3	3 - VT2	1	7	-
EXAMPLE 3					
DS-1	0	0	0	0	-
DS-1C	0	0	0	0	-
DS-2	6	6 - VT4	6	6	-
CEPT-1	2	2 - VT2	1	7	1 - CEPT-1

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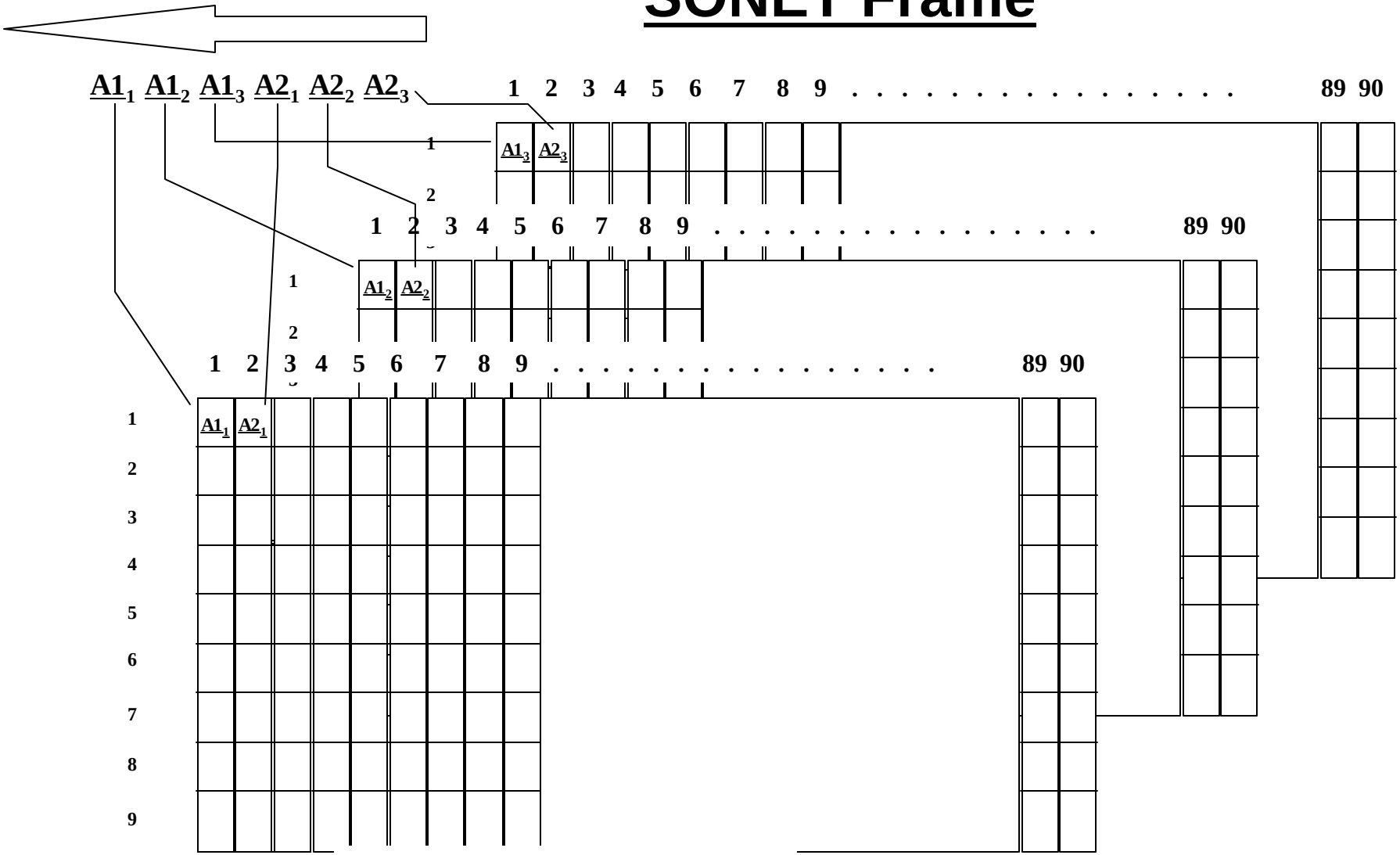
SONET Frame



STS Synchronous Payload Envelope (SPE)

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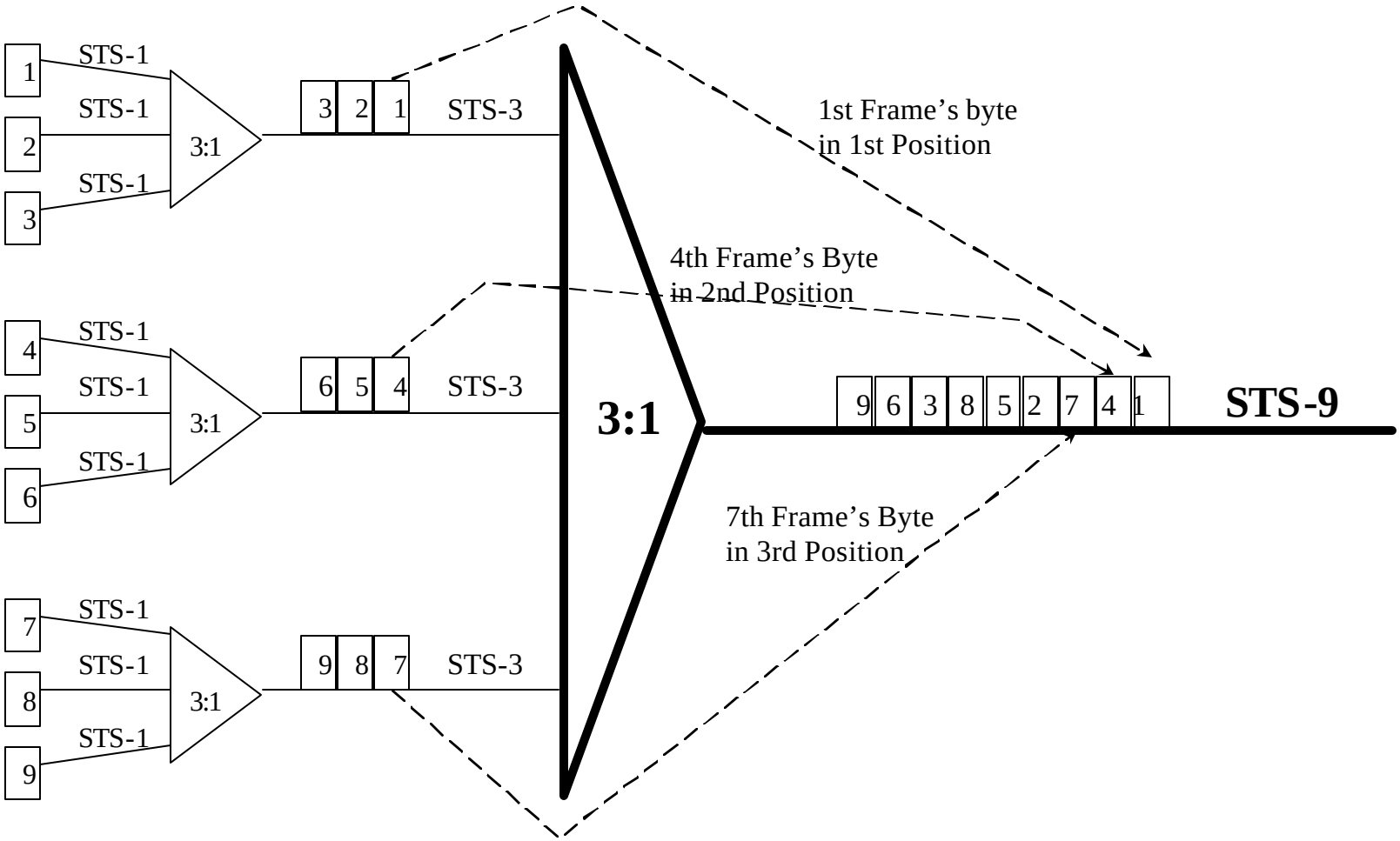
SONET STS-9 Multiplexing



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SONET Standards

US	ITU-T (formerly CCITT)	Bellcore Generic Requirements
ANSI T1.106	G.707 ~ G.709	TR NWT 253
ANSI T1.105	G.957	TA NWT 253
ANSI T1.117	G.958	TA NWT 1042
ANSI T1.119	G.803	TA NWT 1042 issue 3
ANSI T1-101	G.774	TA NWT 1250
ANSI T1-204	G.831	TA TSY 000378
ANSI T1-208	Blue Books	TR TSY 000064
ANSI T1-210		TR TSY 000482
		TR TSY 000499

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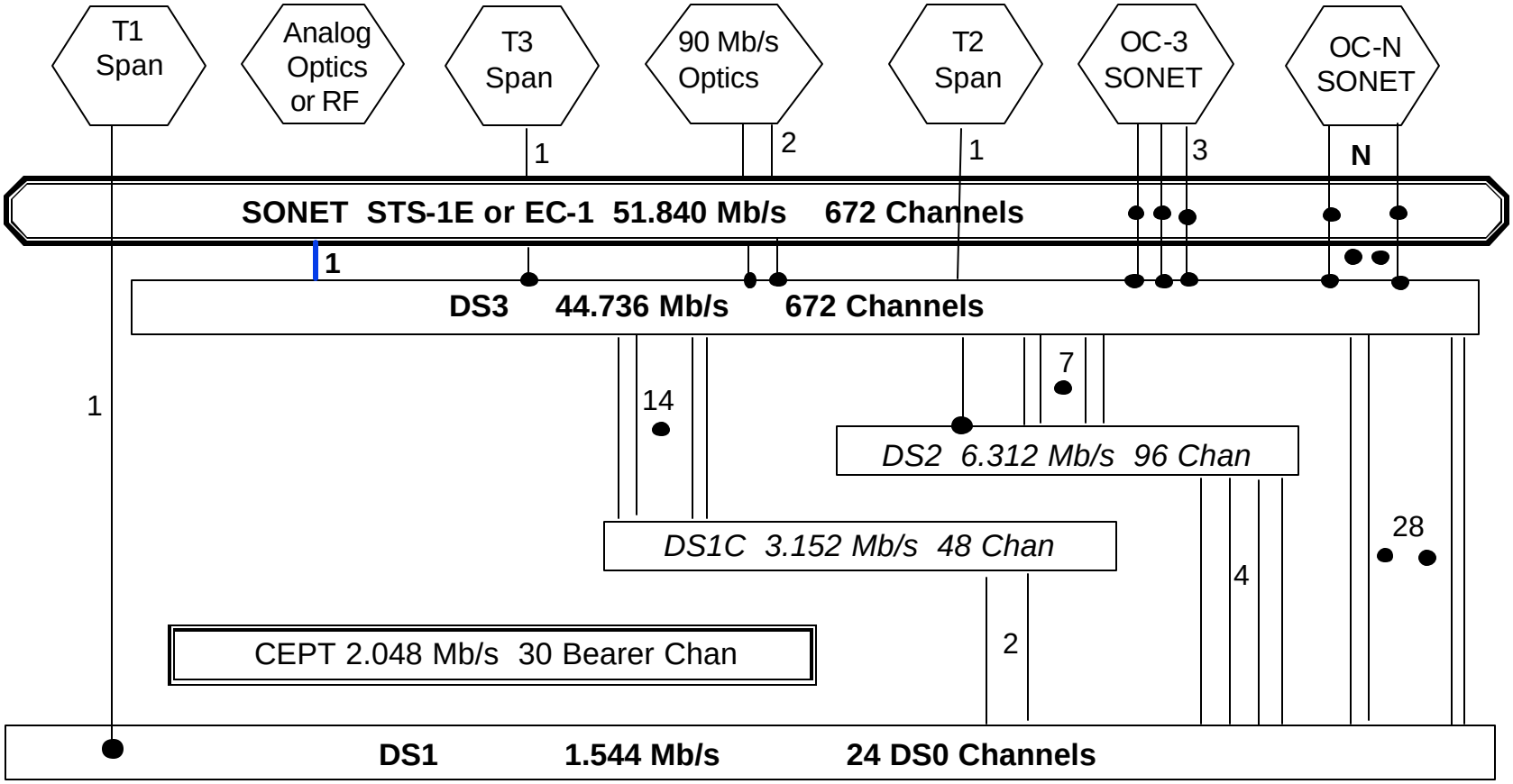
NORTH AMERICAN, CEPT, AND SONET HIERARCHY



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