SONET/SDH Essentials

WHITE PAPER

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XRWP00003

TABLE OF CONTENTS

1.0 THE BIRTH OF SONET AND SDH

The American telecommunications industry that developed and emerged in the 20th Century had been largely dominated by the national monopoly of a company that became known as AT&T (American Telephone and Telegraph 1885-2005) Corporation. In 1982, following anti-trust litigations, the Justice Department ordered AT&T's divestiture of it's local exchange services and mandated equal access to vendors in the long distance telecommunications market.

Prior to divestiture, telecom traffic was comprimise of T1 point-to-point circuits and DS3 link facilities and trunk lines. Optical long-haul transmission were emerging and propriety. Following the aftermath of the AT&T's divestiture in 1984 and the resulting open market competition in the long distance telephony market, it soon became quickly evident that interoperability between the network infrastructure of competing long distance carriers such as MCI, AT&T, and US Sprint and the newly formed incumbent local exchange carriers like the Regional Bell Operating Companies such as Pacific Bell/Telesis, Southwestern Bell, Bell Atlantic, Bell South, was a daunting challenge that had to be resolved.

AT&T's competitors took the case of the interoperability predicament to governing standard bodies that included the Interexchange Carrier Compatibility Forum, Telcordia (formerly Bellcore), ANSI (American National Standards Institute), and ITU-T (International Telecommunications Union). Together over the following eight years, they forged a new standard that would address the interoperability issue and provide equal access to all vendors in the telecommunications market. This developement effort eventually led to the birth and arrival of the SONET (Synchronous Optical Network) standard in North America and Japan and it's European counterpart, the SDH (Synchronous Digital Hierarchy) standard in Europe and throughout the rest of the world.

The SONET and SDH ideal hierarchical transport network topology where quickly adapted and deployed by the telecommunications industry. Telcordia/Bellcore GR-253-CORE SONET and ITU-T G.707/G.708 SDH standards govern and define the optical transmission of digital data today and will continue to do so for many years to come. This transport layer network has a linear and typical ring topology that allow for efficient integration of different regional network systems and services such as voice telephony over PSTN (Public Switched Telephone Networks), FDDI (Fiber Distributed Data Interface), Fibre Channel, ATM (Asynchronous Transfer Mode), PPP (Point-to-Point Protocol), Ethernet, and Gigabit Ethernet to create a seamless global telecommunication network.

2.0 THE SONET STS FRAMING FORMATS

SONET defines its structure in Synchronous Transport Signal Levels. The Synchronous Transport Signal - Level 1 (STS-1) is the lowest level fundamental framing structure in SONET. The STS-1 frame structure is byte oriented and consist of a matrix of 810 bytes per frame. The STS-1 nomenclature in SONET specifically refers to the digital or electrically framed signal. Synonymously, the optical counterpart is the Optical Carrier - Level 1 (OC-1) which is the result of direct optical conversion of the electrical STS-1 signal. The industry typically deploy STS-1 access ports on an electrical level using BNC cables and begin to deploy with STS-3 and higher rate STS-N signals access port on an optical level using fiber optics.

SONET is a hierarchial network transport layer protocol. Higher level signals are denoted by STS-N and OC-N. The higher-level STS-N signals are obtained by synchronously byte multiplexing lower-level STS framing formats such as STS-1. There is an integer multiple relationship between the rates of the basic STS-1 frame and STS-N signals or OC-N. Currently, the standardized most common values of N are: 1, 3, 12, 48, 192, and 768 providing multiplexing rate at 51.84 Mbit/s, 155.52 Mbit/s, 622.08 Mbit/s, 2.48832 Gbit/s, 9.95328 Gbit/s, and 39.813 Gbit/s respectively.

TABLE 1: SONET/SDH STANDARD DATA RATES

ELECTRICAL LEVEL	OPTICAL LEVEL	DATA RATE (MBPS)	PAYLOAD RATE (MBPS)	SDH EQUIVALENT
STS-1	OC-1	51.84	48.38	STM-0
STS-3	OC-3	155.52	149.76	STM-1
STS-12	OC-12	622.08	599.04	STM-4
STS-48	OC-48	2488.32	2396.16	STM-16
STS-192	OC-192	9953.28	9584.64	STM-64
STS-768	OC-768	39813.12	38486.02	STM-256

Currently, the fastest well-defined communication channel used in optical transmission of digital data is the SONET standard OC-768, which sends about 40 gigabits per second.

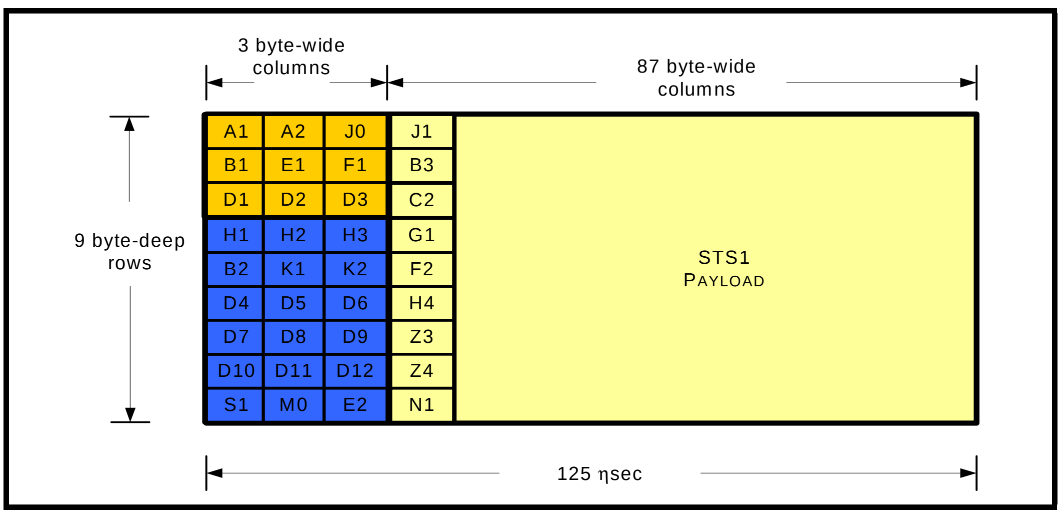
The theoretical maximum capacity of an optic fiber is more than 1012 gigabits (one terabit or one trillion bits) per second. However, current encoding system cannot approach this theoretical limit, even with wavelength division multiplexing.

2.1 The STS-1 Framing Format

The STS-1 frame forms the fundamental building block of the STS-N signals. The STS-1 frame structure is a matrix of 9 byte rows by 90 byte columns as illustrated below in Figure 1. The STS-1 specific sequence of 810 bytes includes various overhead bytes and an envelope capacity for transporting payloads. There are two main sections and three distinct overhead layer defined in the STS-1 frame. The Transport Overhead (TOH) section consists of the Section Overhead (SOH) layer and the Line Overhead (LOH) layer. The Synchronous Payload Envelope (SPE) consists of the Path Overhead (POH) layer and the STS Payload Envelope. The first 9 byte rows by 3 byte columns compromise the Transport Overhead Section (TOH) of the STS-1 frame. Of the 27 TOH bytes, 9 bytes (shown in orange) are overhead for the Section layer, and 18 bytes (shown in blue) are overhead for the Line layer. The SPE (shown in yellow) compromise the rest of the 9 byte rows by 87 byte columns wide section. In summary, a single STS-1 frame consist of 810 total bytes of which 27 are Transport Overhead Bytes and 9 are Path Overhead Bytes. The STS-1 frame has a period of 125µsec for each frame, thereby resulting in a repetition rate of 8000 frames per second. An STS-1 Frame therefore yields a nominal bit rate of 51.84 Mbps.

Transmission of the STS-1 frame begins with the first row, first column A1 byte and then the A2 byte followed by the J0 byte and going accross the first 87 byte-row of the SPE before sending the second row begining then with the B1 byte.

FIGURE 1. THE STS-1 FRAME STRUCTURE



The STS-1 Frame Summary

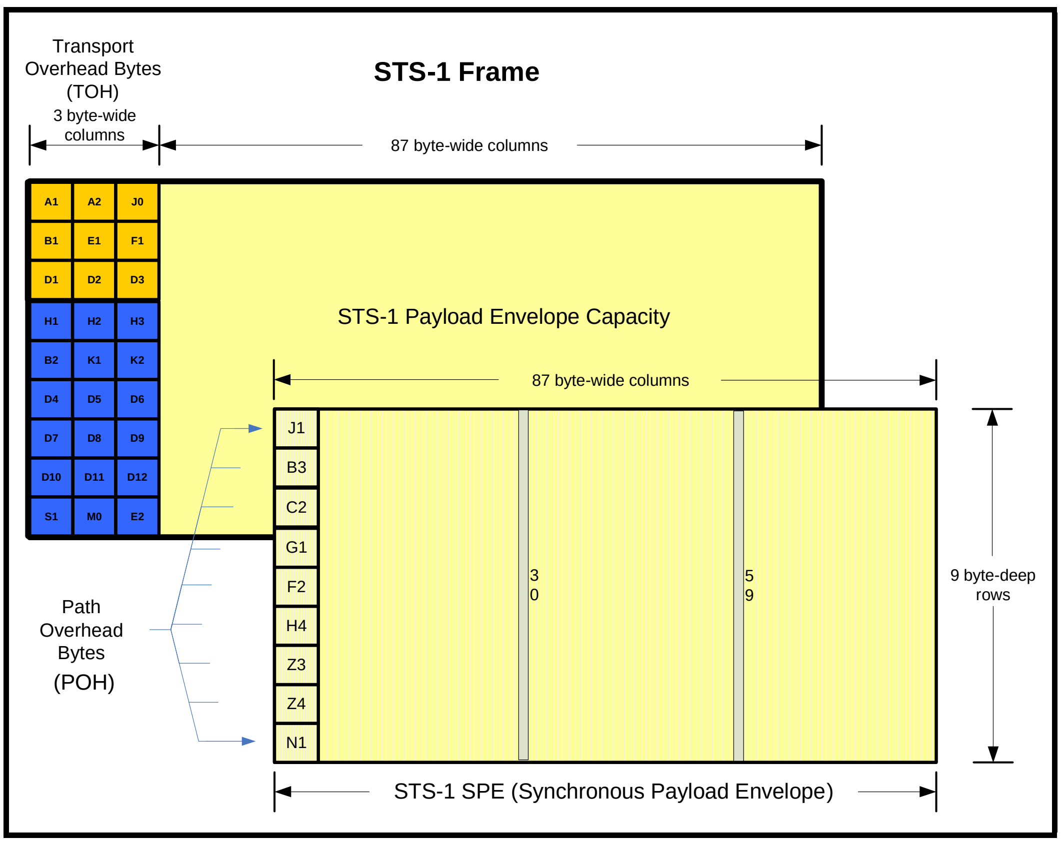
- **Frame Size: 810 bytes**
- **Number of Overhead Functions: 2**
- **Number of Transport Overhead Bytes: 27 bytes (9 byte rows x 3 byte columns)**
- **Number of Path Overhead Bytes: 9 bytes (9 byte rows x 1 byte column)**
- **Frame Repetition Rate: 8000 Hertz**
- **Nominal Bit Rate: 51.84 Mbps**

2.2 The Synchronous Payload Envelope

The STS-1 SPE consists of 783 bytes which occupies the STS-1 Payload Envelope Capacity and can be depicted as a matrix of 9 byte-deep rows by 87 byte-wide columns structure. The first column byte contains the nine bytes of the STS-1 Path Overhead (POH) layer. The STS-1 POH is associated with each payload and is used to communicate various information from the point where a payload is mapped into the STS-1 SPE to where it is delivered. Two columns (30 and 59) are not used for payload, but are used as the fixed stuff columns. The remaining 756 bytes from the 84 byte-wide columns are designated for payload.

One of the most amazing aspects of the SONET is that the STS-1 SPE portion of a SONET signal is allowed to dynamically "float" within the STS-1 Payload Envelope Capacity. The STS-1 SPE may begin anywhere in the STS-1 Payload Envelope Capacity. Within the TOH is a pointer word that identifies the starting position of the SPE with respect to the TOH Bytes in the frame.

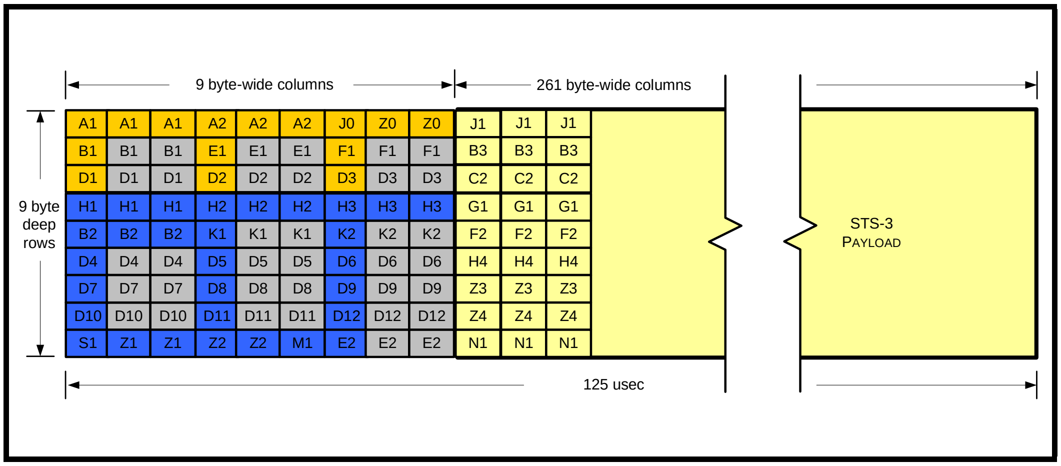
FIGURE 2. THE STS-1 SPE (SYNCHRONOUS PAYLOAD ENVELOPE)



2.3 STS-3 Framing Format and Higher Rate STS-N

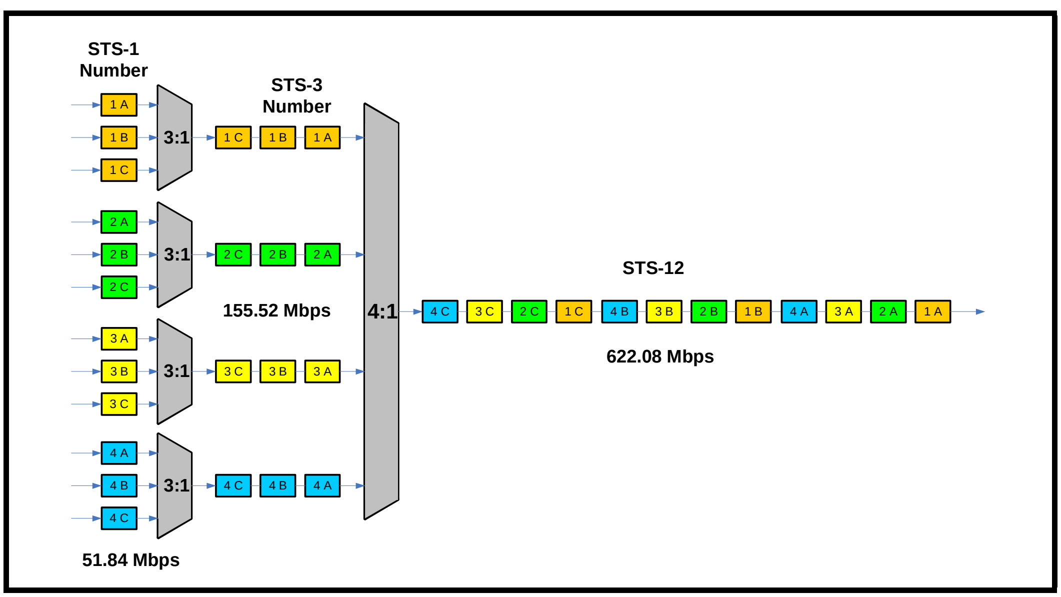
The SONET framing standard is a hierarchal structure in which successive levels or layers of the STS-1 rate is built upon. The STS-1 frame forms the fundamental unit in which higher rate STS-N are constructed. STS-N formats are higher order multiplex structures which allow the transportation of N number of STS-1 payloads. An STS-N contains a specific sequence of N x 810 bytes, as shown for STS-3 in **Figure 3**.

FIGURE 3. THE STS-3 FRAME



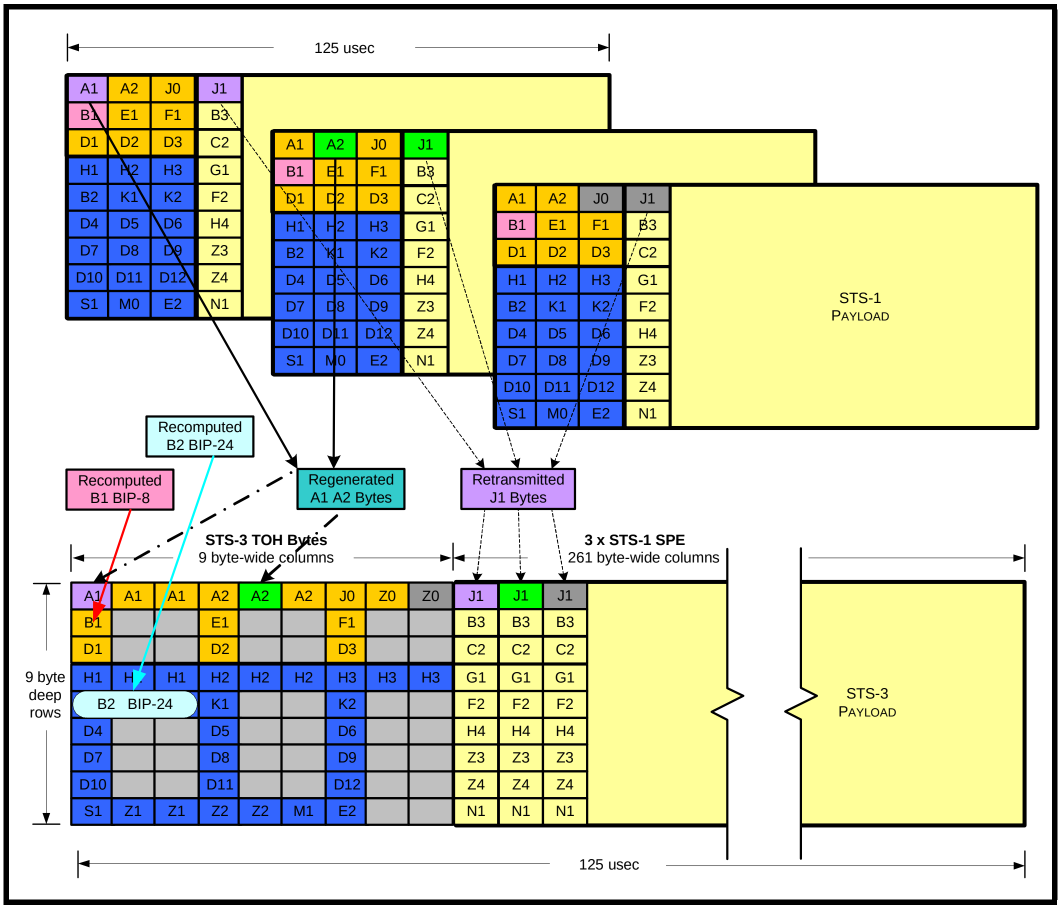
The STS-N is formed by byte-interleaving STS-1 or STS-M (M<N) modules, as shown in both **Figure 4** and **Figure 5**. The TOH of each STS-1 and STS-M are frame aligned before interleaving, but the SPE's are not required to be aligned because each one has its own payload pointer to indicate the location of the SPE. The STS-N Frame matrix consists of nine rows and N × 90 columns. The TOH is N × 3 columns wide. There are N number of nine rows by 87 byte-wide column SPEs, each of which contains one column of POH. The TOH contains N number of pointers: one for each of the SPE's.

FIGURE 4. THE STS-3 FRAME AND STS-12 BYTE INTERLEAVING



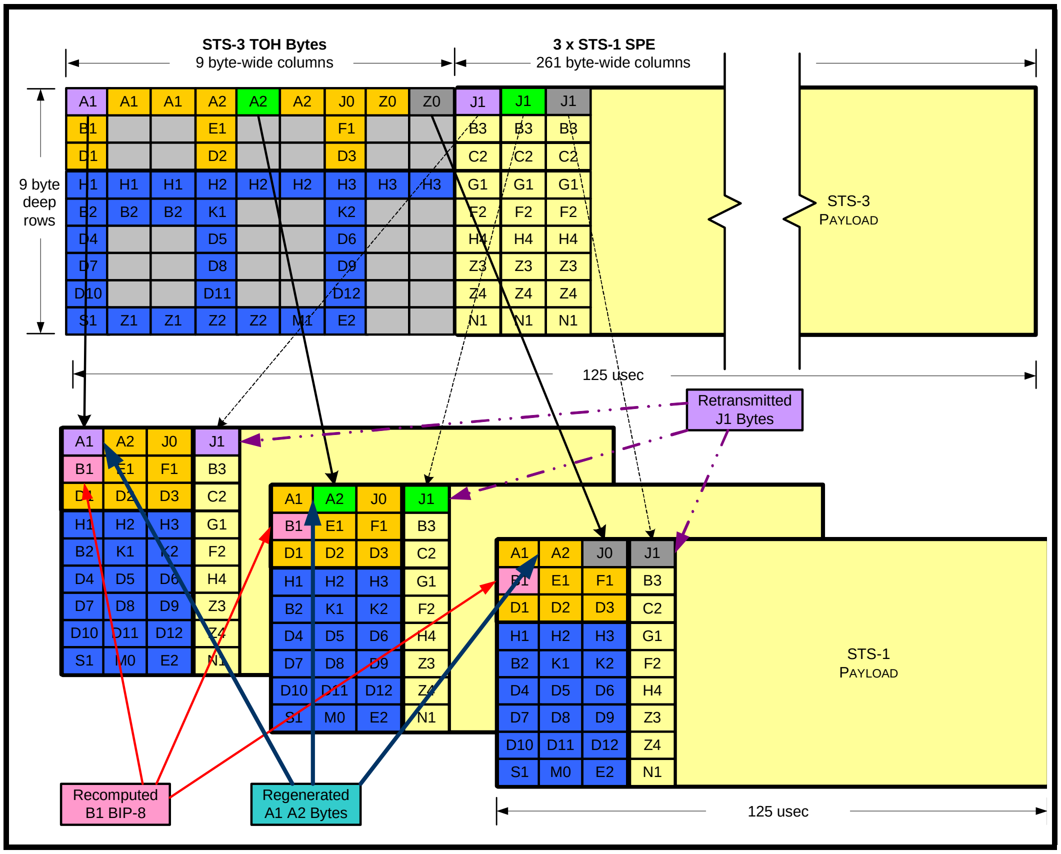
There are slight to moderate variations in some but not all the overhead frame definitions for higher rate STS-N's. For example, since the B1 BIP-8 byte is calculated over the entire STS-N Frame, where N is greater than or equal to 3, only the first B1 byte is valid at higher rate STS-N signals. The B1 byte location for the second and third STS1 signal thru N STS1 is no longer valid since the first B1 byte location is a BIP-8 calculation over the entire previous STS-N, where N is greater than or equal to 3, and the second and third B1 byte thru N B1 Byte no longer serve its former purpose in the STS-1 Frame. The B2 BIP-8 from the former STS-1 are also recalculated over the entire new STS-N TOH and SPE section and sent as BIP-(Nx8) parity bytes in the B2 Byte locations of the new STS-N Frame.

FIGURE 5. THE STS-3 FRAME MUX



When a channelized STS-N is demultiplexed into their respective STS-1 such as in the case with a Demultiplexer, the STS-N TOH Bytes are terminated (stripped) and the B1 and B2 byte of each individual STS-1's are then recomputed for a new STS-1 Mapping before re-transmission of the demultiplexed channelized STS-1 SPE.

FIGURE 6. THE STS-3 FRAME DEMUX



The following table shows the SONET supported rates. A channelized STS-N signal is a byte interleaved, time divisioned, multiplexed N channel STS-1 signals.

TABLE 2: SONET/SDH STANDARD DATA RATES

ELECTRICAL LEVEL	OPTICAL LEVEL	DATA RATE (MBPS)	PAYLOAD RATE (MBPS)	SDH EQUIVALENT
STS-1	OC-1	51.84	48.38	STM-0
STS-3	OC-3	155.52	149.76	STM-1
STS-12	OC-12	622.08	599.04	STM-4
STS-48	OC-48	2488.32	2396.16	STM-16
STS-192	OC-192	9953.28	9584.64	STM-64
STS-768	OC-768	39813.12	38486.02	STM-256

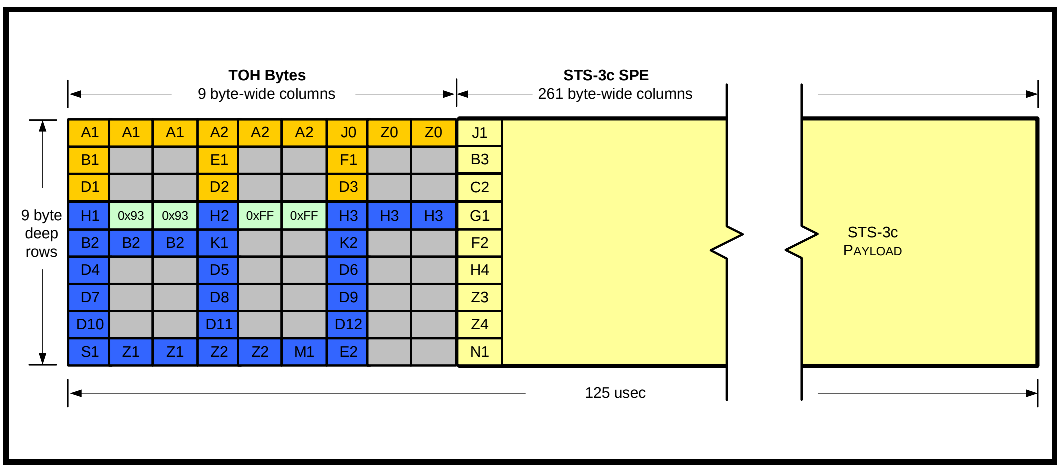
2.4 STS-3c Framing Format and Higher Rate STS-Nc

While multiple STS-1 SPE's are needed to transport Super Rate payloads in STS-N signals, SONET contains another mechanism by which payloads at that scale can be carried. This mechanism is called Concatenation (literally meaning "stringed together") and is indicated by the designation Nc. To accommodate Super Rate payloads, the STS-Nc superframe is formed by linking N constituent of STS-1's together in fixed phase alignment. These STS-Nc superframes has the same datarate as the STS-N frames but unlike an STS-N frame containing N channels of STS-1 SPE's, STS-Nc contains only a single SPE in which the extent of their SPE allowable size and bandwidth is equal to approximately the sum of N channels of SPE's of an equivalent STS-N signal. The Super Rate payload is then mapped into the resulting STS-Nc SPE for transport. The STS-3c format illustrating the concatenate pointers and single SPE is shown in **Figure 7**. Notice that rather than contain channelized STS-1 SPE, the STS-3c contain only a single SPE with a payload size and bandwidth approximately equal to 3 channels of STS-1 SPE of an equivalent STS-3 signal.

As with the STS-N format, the Frame consists of nine rows and N × 90 columns. The TOH is N × 3 columns wide. There is a single SPE which is nine rows by N × 87 columns. The first SPE column is used for POH. The TOH contains only one pointer which identifies the start of the SPE in the Frame. Concatenation indicators contained in the second through Nth STS Payload pointers are used to show that the STS-1s are linked together. During the payload mapping, the first (N/3)-1 columns of the STS-Nc SPE following the STS POH are designated as fixed stuff columns (columns of undefined bytes).

Super Rate payload structures exceeding the payload bandwidth of STS-1 payload rate such as 100Mbps Ethernet or 100Mbps ATM are mapped into a 155Mbps STS-3c superframes. GigE or Giga Ethernet payloads are mapped into larger STS-Nc superframe entities.

FIGURE 7. THE STS-3C FRAME



The following table shows the SONET/SDH supported concatenate rates.

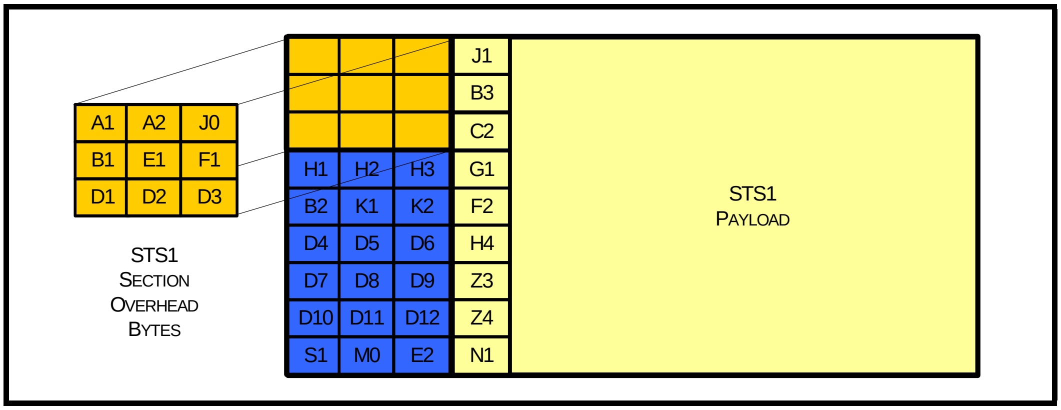
TABLE 3: SONET/SDH STANDARD DATA RATES

ELECTRICAL LEVEL	OPTICAL LEVEL	DATA RATE (MBPS)	PAYLOAD RATE (MBPS)	SDH EQUIVALENT
STS-3c	OC-3c	155.52	139.264	STM-1 (TUG-3 mapping)
STS-12c	OC-12c	622.08	599.04	STM-4
STS-48c	OC-48c	2488.32	2396.16	STM-16
STS-192c	OC-192c	9953.28	9584.64	STM-64

3.0 THE SONET SECTION OVERHEAD BYTES

The Section Overhead Bytes compromise a 3 byte-deep rows by 3 byte-wide columns in the STS-1 Frame structure. These Section Overhead Bytes known as the A1, A2, J0, B1, E1, F1, D1, D2 and D3 bytes are regenerated at every node in the network. A fault condition in these overhead bytes indicate an error condition in the immediate adjacent node. With the exception of the A1, A2, and J0 Byte, these overhead bytes are scrambled using the polynomial $1 + X^6 + X^7$ to guarantee sufficient timing content in the signal structure.

FIGURE 8. THE SECTION OVERHEAD BYTES



The A1 and A2 Bytes

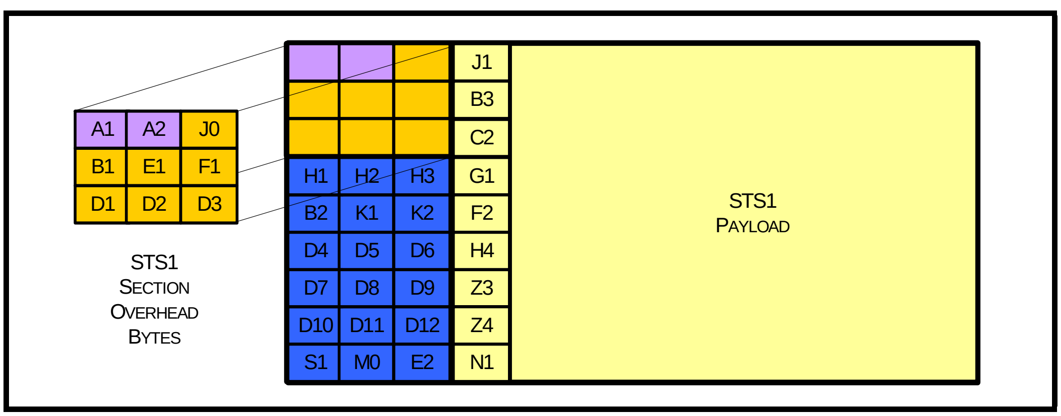
The Framing Alignment A1 Byte

This is the "Framing Alignment" byte that have a fixed value of "0xF6". The Receive STS-1 Framer will use this byte to acquire and maintain SONET frame synchronization. The A1 Byte is not included in the scrambling process. This byte is defined for all STS-1s of an STS-N/Nc signal.

The Framing Alignment A2 Byte

This is the "Framing Alignment" byte that have a fixed value of "0x28". The Receive STS-1 Framer will use this byte to acquire and maintain SONET frame synchronization. The A2 Byte is not included in the scrambling process. This byte is defined for all STS-1s of an STS-N/Nc signal.

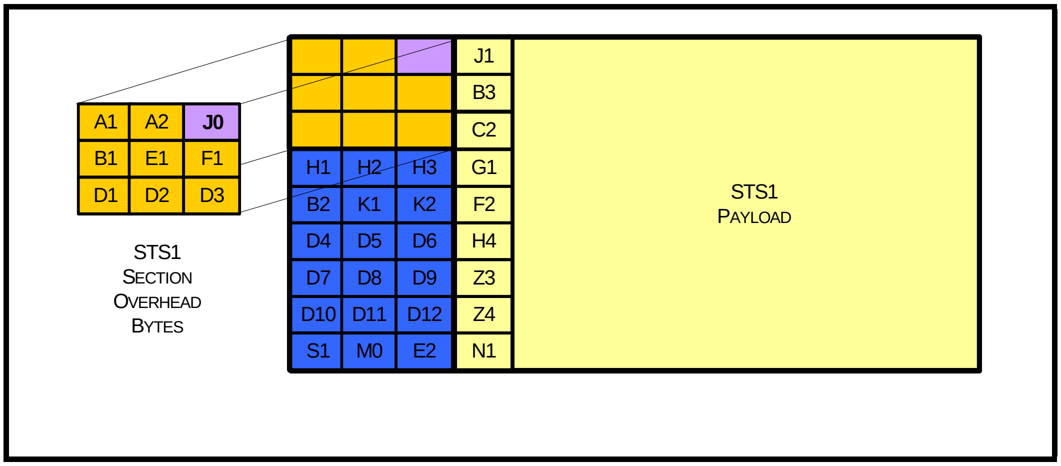
FIGURE 9. THE A1 AND A2 SECTION OVERHEAD BYTES



The J0 Section Trace Identifier Byte

This byte is allocated to be used for a Section Trace Identifier function. This byte is defined only for STS-1 or STS-1 number one in an STS-N/Nc signal. J0 (formerly C1 of STS-1 number N) is used to repetitively transmit a single-byte or a 16-byte fixed length message string so that a receiving terminal can verify its continued connection to the intended transmitter. Any value in the range of 0x00 through 0xFF may be placed in this byte. When the Section Trace function is not supported or if no value has been assigned then 01[H] shall be transmitted. When transmitting a 16 byte message, the termination byte must have the value 0x0A. The J0 Byte is not included in the scrambling process therefore, care must be taken when selecting their content to guarantee no long strings of zero's are present.

FIGURE 10. THE J0 SECTION OVERHEAD BYTE



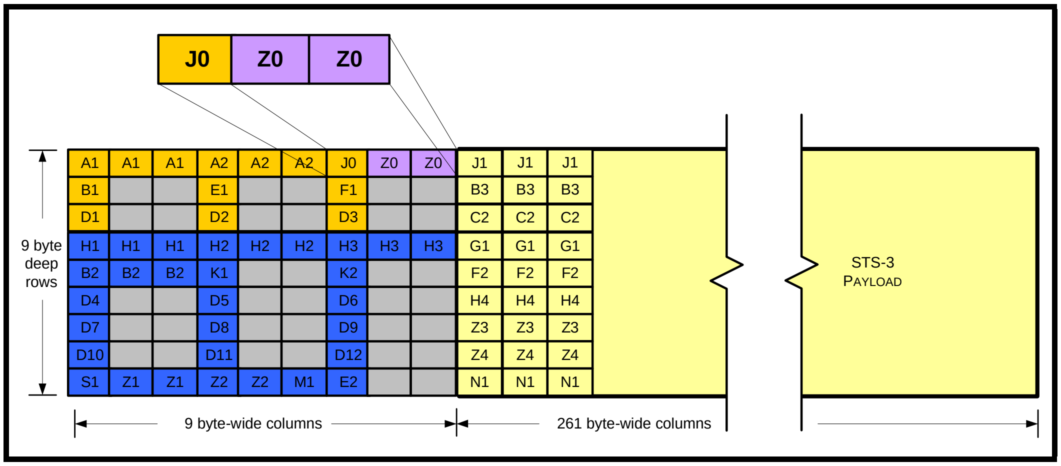
The J0 Byte as the C1 STS Identifier Byte

In earlier SONET standards, the J0 Byte was defined as the C1 Byte allocated for an STS-1 identification function in an STS-N frame. The C1 Byte is no longer used in modern SONET equipment but is included for backward compatibility. The C1 Byte value is set according to the order of appearance of the byte interleaved STS-1 frame. The first C1 Byte is given the value of [01]H in the STS-N frame and the second C1 Byte is given the value of [02]H and so on. The C1 Byte is not included in the scrambling process.

The Z0 STS-N/Nc Section Growth Byte

The Z0 Byte is reserved for future growth. The Z0 Byte does not exist in an STS-1 frame since the byte location is defined as the J0 Byte. In multiplexed STS-N frames, the first STS-1 will carry the J0 Byte and the subsequent STS-1s in the STS-N frame will carry and define the J0 Byte location as the Z0 Bytes. The Z0 Byte is not included in the scrambling process therefore, care must be taken when selecting their content to guarantee no long strings of zero's are present.

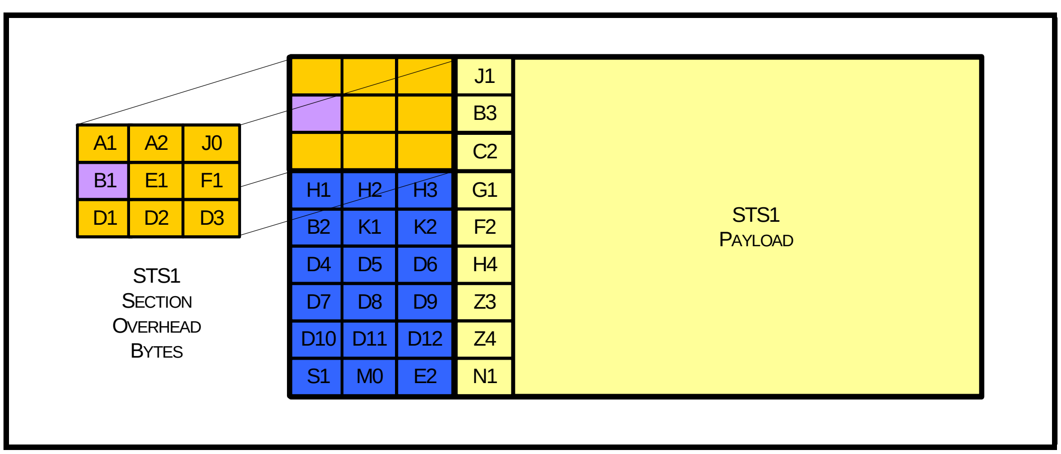
FIGURE 11. THE Z0 SECTION OVERHEAD BYTES IN AN STS-3 FRAME



The B1 (BIP-8) Section Bit Interleaved Parity Byte

This byte is allocated for Section Error Monitoring function on the Line path signal. This function is a bit-interleaved parity 8 code using even parity. The Section BIP-8 is calculated over all bits of the previous STS-N/Nc frame after scrambling. The computed BIP-8 is placed in the B1 Byte before scrambling. This byte is defined only for STS-1 number one of an STS-N/Nc signal. Subsequent B1 Bytes of the following STS-1s in an STS-N frames have no standard use and are therefore undefined. Although this byte is not defined for a drop-side STS-1 or both Line-Side and drop-side signals, a Network Equipment may transmit either all-zeros or the Section BIP-8 code in this byte.

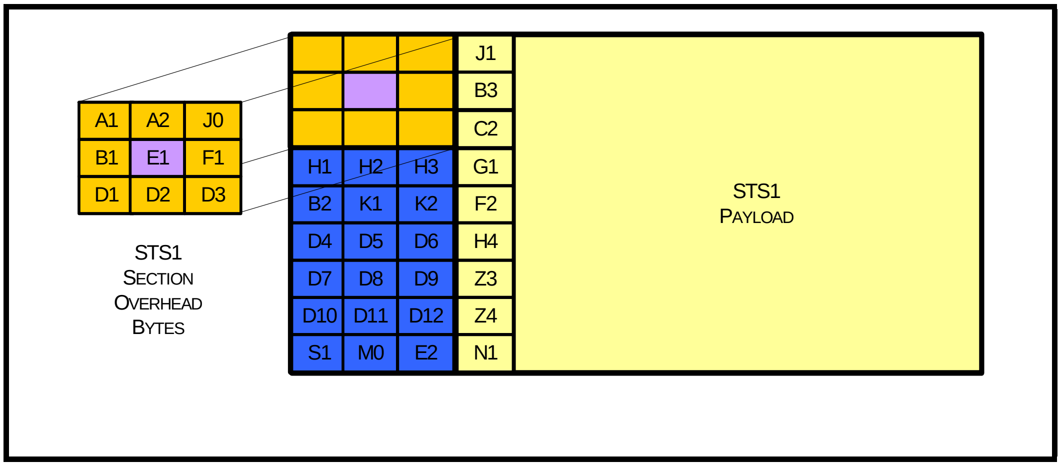
FIGURE 12. THE B1 SECTION OVERHEAD BYTE



The E1 Section Orderwire Byte

The E1 Byte is allocated to be used as a Section Orderwire. This is a local order-wire channel reserved for voice communications between STE's (Section Termination Equipment), hub's, and remote NE's (Network Equipment). It is only defined for STS-1 number one. SONET's 8000 frame repetition rate result in a 64 kilobits per second bit rate for the E1 Byte voice channel.

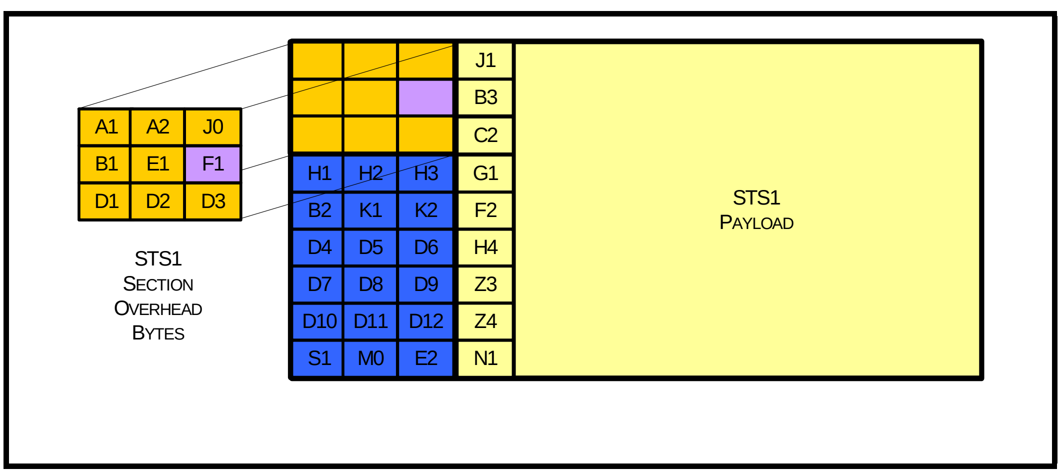
FIGURE 13. THE E1 SECTION OVERHEAD BYTE



The F1 Section User Channel Byte

The F1 Byte is set aside for the user's purposes. This Byte is passed from Section to Section within a transmission system and is readable, writable, or both at each STE (Section Terminating Equipment) in that system. The use of this function is optional. The F1 Byte can be optionally used for temporary data/voice channel connections for special maintennance purposes. The F1 Byte is defined only for STS-1 number one in an STS-N/Nc signal.

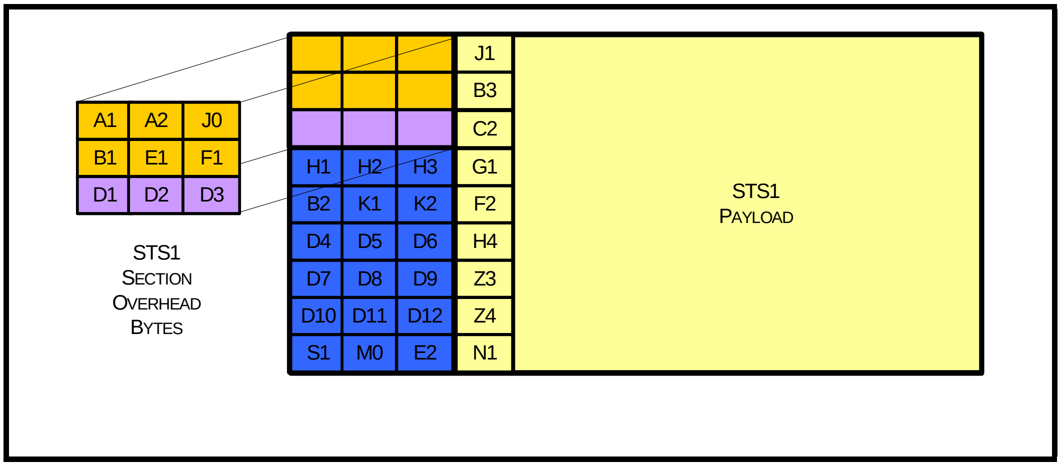
FIGURE 14. THE F1 SECTION OVERHEAD BYTE



The D1, D2, D3 Section Datacom Channel Byte

These three bytes are allocated for a Section Data Communications Channel and are considered as a single 192 kbit/s message-based channel between STEs. The messaging protocols used are defined in ANSI T1.105.04 for alarms, maintenance, control, monitoring, administration and other communication requirements. These bytes are defined only for STS-1 number one in an STS-N/Nc signal.

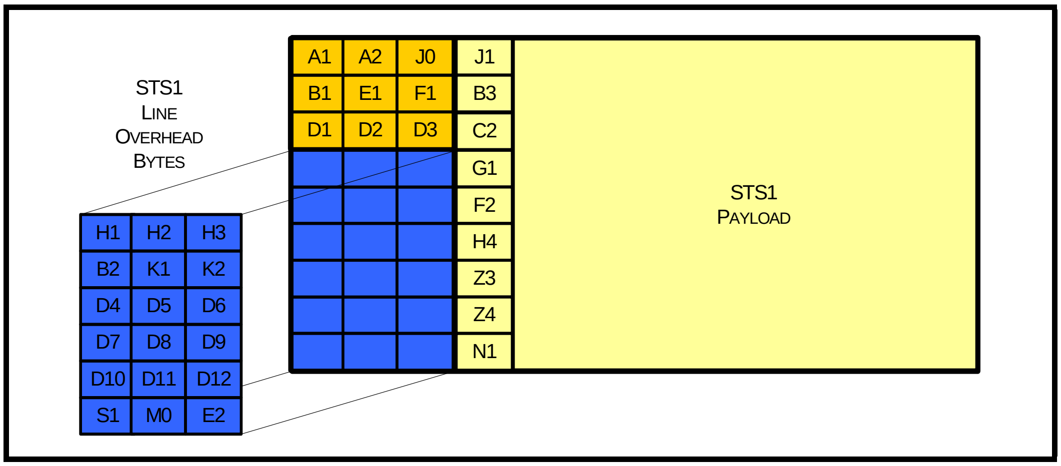
FIGURE 15. THE D1, D2, AND D3 SECTION OVERHEAD BYTES



4.0 THE SONET LINE OVERHEAD BYTES

The Line Layer deals with the transport of Path Layer payload and its overhead across the Section and Physical Medium Layers. All lower layers exist to provide transport for this layer. The functions of this layer are to provide synchronization and multiplexing for the Path Layer, as well as error monitoring, data communications, orderwire, and protection signaling for Line protection switching. An example of equipment that communicates at this level is an OC-M to OC-N multiplexer where: M < N. The Line overhead is interpreted and modified or created by LTE (Line Terminating Equipment). To access the Line Overhead, the Section Overhead must first be terminated.

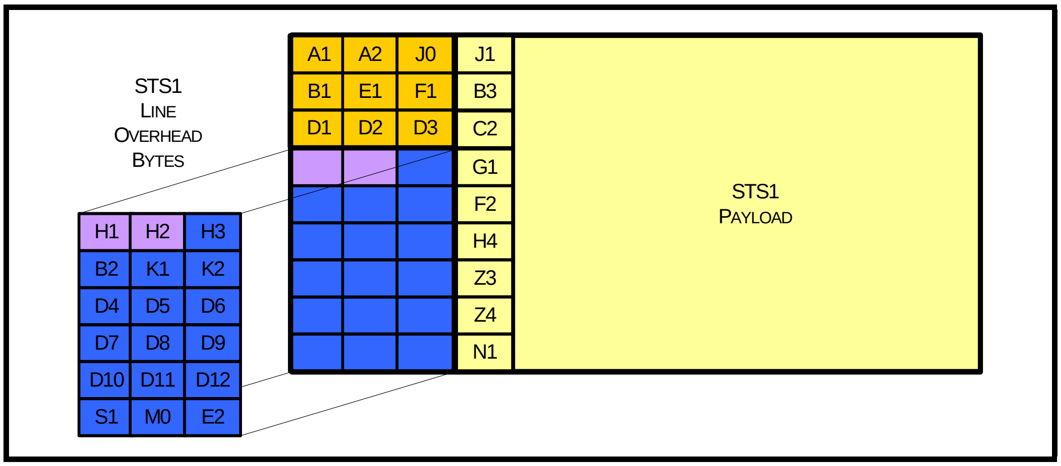
FIGURE 16. THE LINE OVERHEAD BYTES



The H1 and H2 Pointer Bytes

Two bytes are allocated to a pointer word that indicates the offset in bytes between the pointer and the first byte of the STS-1 SPE. It allows alignment of the STS-1 TOHs in an STS-N/Nc signal and performance of frequency justification. In an STS-Nc signal where only one SPE exists, the actual pointer is in the first set of H1 and H2 Bytes. H1 and H2 Bytes occupying STS-1 positions two through N carry a Concatenation Indicator, where: H1c = 93[H] and H2c = FF[H]. These bytes are required in all STS-1 portions of an STS-N/Nc signal. Section 6.0 define in details the H1 and H2 pointer bits and their functionalities in pointer operations.

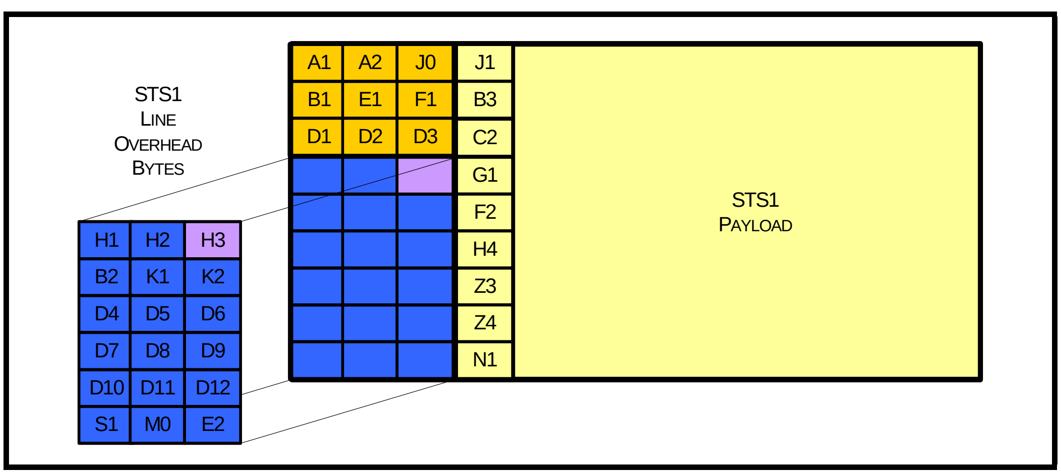
FIGURE 17. THE H1 AND H2 LINE OVERHEAD BYTES



The H3 Pointer Action Byte

The H3 Pointer Action Byte is allocated for the purpose of frequency justification. Depending on the pointer value, this byte is used to adjust the fill of input buffers. In the event of a negative justification, it carries valid information. This Byte is required in each STS-1 portion of an STS-N/Nc signal.

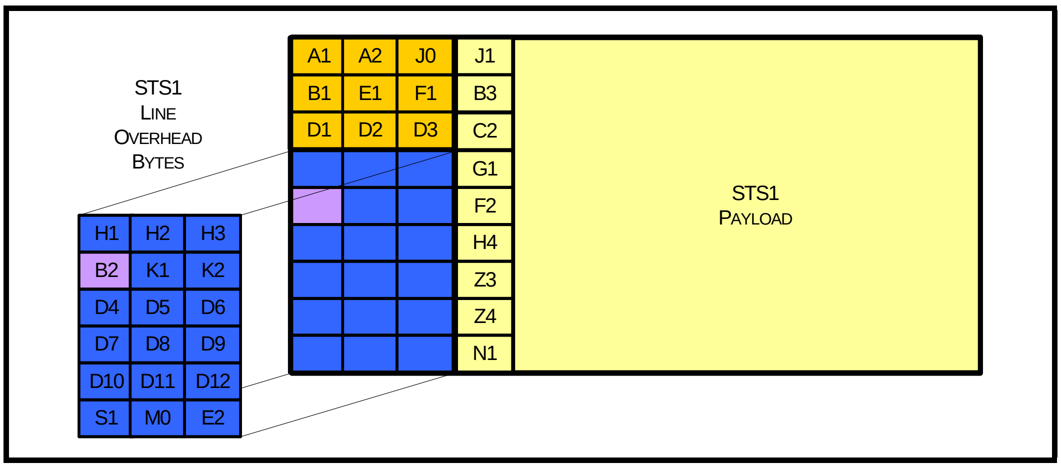
FIGURE 18. THE H3 LINE OVERHEAD BYTE



The B2 (BIP-8) Line Bit Interleaved Parity Byte

One byte is allocated in each STS-1 for a Line Error Monitoring function. This function is a Bit-Interleaved Parity 8 code using Even Parity. The Line BIP-8 is calculated over all bits of the Line Overhead and STS-1 SPE of the previous frame before scrambling. The computed BIP-8 is placed in the B2 Byte before scrambling. This byte is defined for all STS-1s of an STS-N/Nc signal. The N number of B2 Bytes in an STS-N/Nc are intended to form a single error monitoring function capable of measuring error rate up to 10^{-3} independent of the value of N. It can be thought of as either: (1) N BIP-8 functions each processing 1 / N of the signal or (2) a single BIP-(N×8) processing all of the information. The errors accumulated are to be accumulated into a single error count.

FIGURE 19. THE B2 LINE OVERHEAD BYTE



The K1, K2 APS Channel Bytes

Two bytes are allocated for Automatic Protection Switching (APS) signaling between LTE's. The signaling protocols used are defined in ANSI T1.105.01. **Figure 20** below illustrate the K1 and K2 Byte position and their associated values are defined by specific APS messages in **Table 4** and **Table 5**. These Bytes are defined only for STS-1 number one in an STS-N/Nc signal.

FIGURE 20. THE K1 AND K2 LINE OVERHEAD BYTES

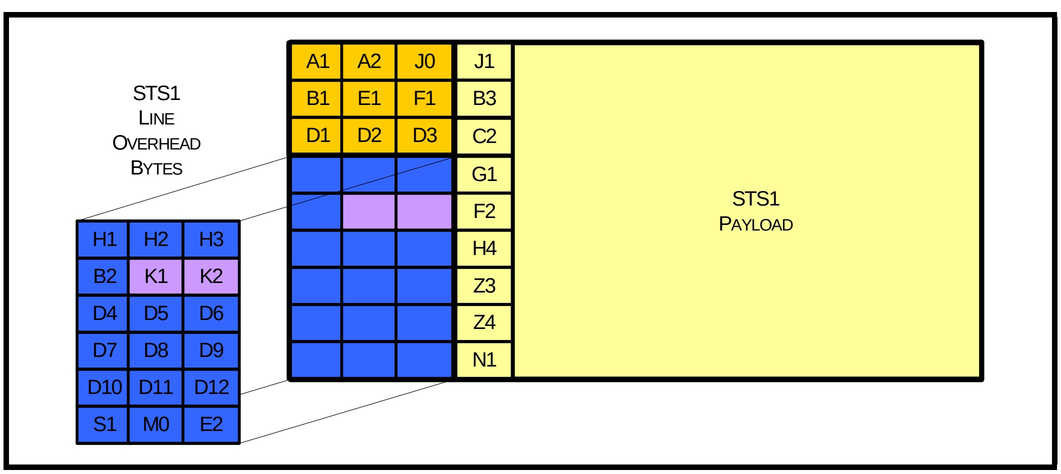


TABLE 4: K1/K2 BYTE ANSI T1.105.01 LINEAR APS MESSAGE PROTOCOL

K1 BYTE			K2 BYTE			
BIT 7 - BIT 4	BIT 3 - BIT 0	CONDITION	BIT 7 - BIT 4	BIT 3	BIT 3 - BIT 0	CONDITION
1111	Channel used by APS message	Lockout of protection	Selects bridge channel used	APS switch architecture	000	Reserved
1110		Forced Switch			001	Reserved
1101		Signal Fail - high priority			010	Reserved
1100		Signal Fail - low priority			011	Reserved
1011		Signal Degrade - high priority			100	Reserved
1010		Signal Degrade - low priority			101	Reserved
1001		Unused			110	Multiplex Section-RDI
1000		Manual Switch			111	Multiplex Section-AIS
0111		Unused				
0110		Wait-to-Restore				
0101		Unused				
0100		Excercise				
0011		Unsused				
0010		Reserve Request				
0001		Do not Revert				
0000		No Request				

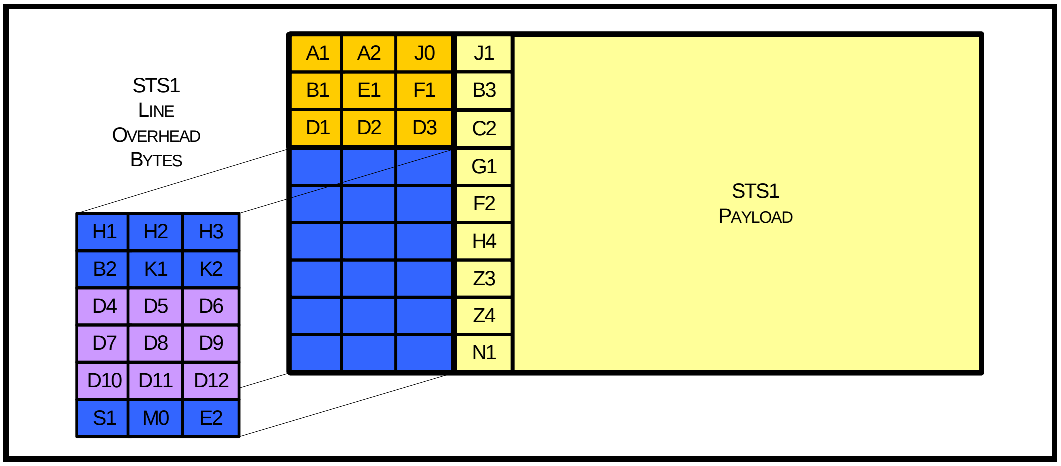
TABLE 5: K1/K2 BYTE ANSI T1.105.01 RING APS MESSAGE PROTOCOL

K1 BYTE			K2 BYTE			
BIT 7 - BIT 4	BIT 3 - BIT 0	CONDITION	BIT 7 - BIT 4	BIT 3	BIT 3 - BIT 0	CONDITION
1111	Destination Node ID	Lockout of protection (span) or Signal Fail protection	Source Node ID	Path Code: 0 = short path; 1 = long path;	000	Idle
1110		Forced Switch (Span)			001	Bridged
1101		Forced Switch (Ring)			010	Bridged and Switched
1100		Signal Fail (Span)			011	Reserved
1011		Signal Fail (Ring)			100	Reserved
1010		Signal Degrade (protection)			101	Reserved
1001		Signal Degrade (span)			110	Multiplex Section-RDI
1000		Signal Degrade (ring)				
0111		Manual Switch (Span)				
0110		Manual Switch (Ring)				
0101		Wait-to-Restore				
0100		Excerciser (Span)				
0011		Excerciser (Ring)				
0010		Reserve Request (Span)				
0001		Reserve Request (Ring)				
0000		No Request				

The D4, D5, D6, D7, D8, D9, D10, D11, and D12 Line Datacom Channel Bytes

Nine bytes are allocated for a Line Data Communications Channel and are considered as a single 576 kbit/s message-based channel between LTEs. The messaging protocols used are defined in ANSI T1.105.04 for alarms, maintenance, control, monitoring, administration and other communication requirements. These Bytes are defined only for STS-1 number one in an STS-N/Nc signal. All other subsequent D4, D5, D6, D7, D8, D9, D10, D11, and D12 Bytes on the second and following STS-1 in an STS-N/Nc frame are not defined.

FIGURE 21. THE D4, D5, D6, D7, D8, D9, D10, D11 AND D12 LINE OVERHEAD BYTES



The S1 Sychronization Status Byte

One byte is allocated for transporting synchronization status messages. Currently, only Bits 3 through 0 are defined. Bits 7 through 4 are reserved for future use. Table 6 define the Synchronizatin Status Messages. This Byte is defined only in STS-1 number one in an STS-N/Nc signal.

FIGURE 22. THE S1 LINE OVERHEAD BYTE

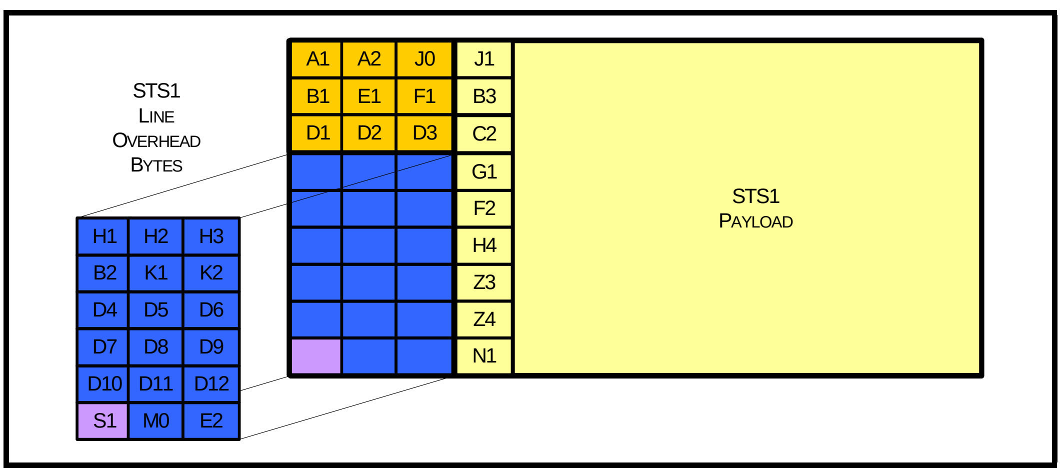


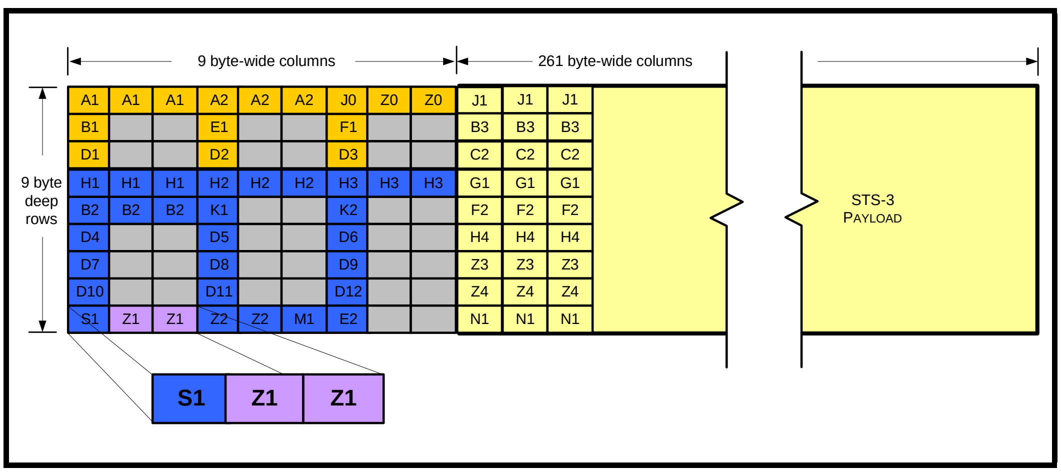
TABLE 6: SONET S1 BYTE SYNCHRONIZATION STATUS MESSAGES

S1 BYTE		SONET SYNCHRONIZATION QUALITY LEVEL DESCRIPTION
BIT 7 - BIT 4	BIT 3 - BIT 0	
Reserved	0000	Synchronized-tracebility unknown
Reserved	0001	Stratum 1 traceable
Reserved	0100	Transit node clock traceable
Reserved	0111	Stratum 2 traceable
Reserved	1010	Stratum 3 traceable
Reserved	1100	SONET minimum traceable
Reserved	1101	Stratum 3E traceable
Reserved	1110	Reserved for network synchronization
Reserved	1111	Do not use for synchronization

The Z1 STS-N/Nc Growth Byte

In a signal at or above the STS-3/3c level and less than the STS-192/192c rate, the Z1 Byte is reserved in STS-1 numbers two through N of the STS-N/Nc signal for future growth. At rates greater than or equal to STS-192/192c, Z1 is only defined for STS-1 numbers two through 48.

FIGURE 23. THE Z1 LINE OVERHEAD BYTES IN AN STS-3 FRAME



The M0 STS-1 Line FEBE Byte

In a STS-1 signal, this Byte is allocated for a Line Far End Block Error (FEBE) function. Currently only Bits 3 through 0 are used. These bits are used to convey the count of errors detected by the B2 Byte. This count has nine legal values, i.e., zero through eight. The remaining seven values are interpreted as zero errors. Bits 7 through 4 are reserved for future use. The M0 Byte is only defined for an STS-1 signal.

FIGURE 24. THE M0 LINE OVERHEAD BYTE

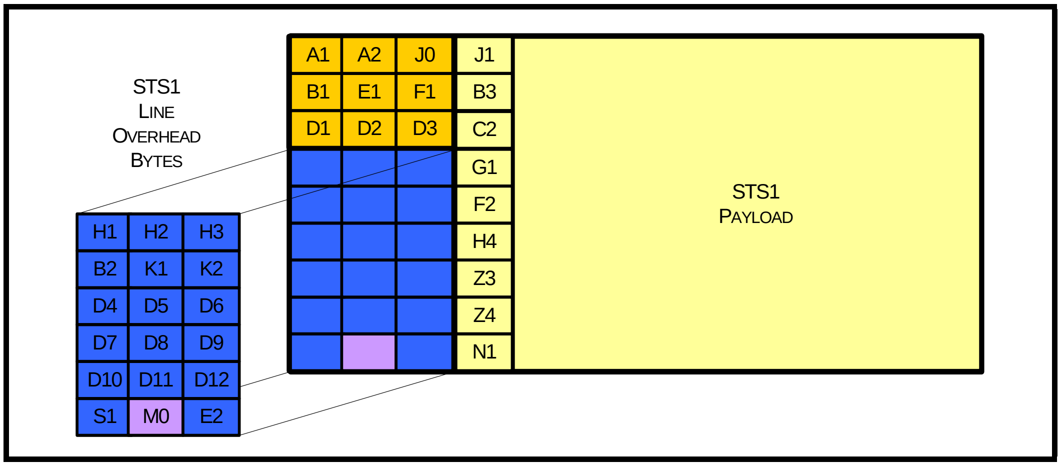


TABLE 7: M0 BYTE VALUE

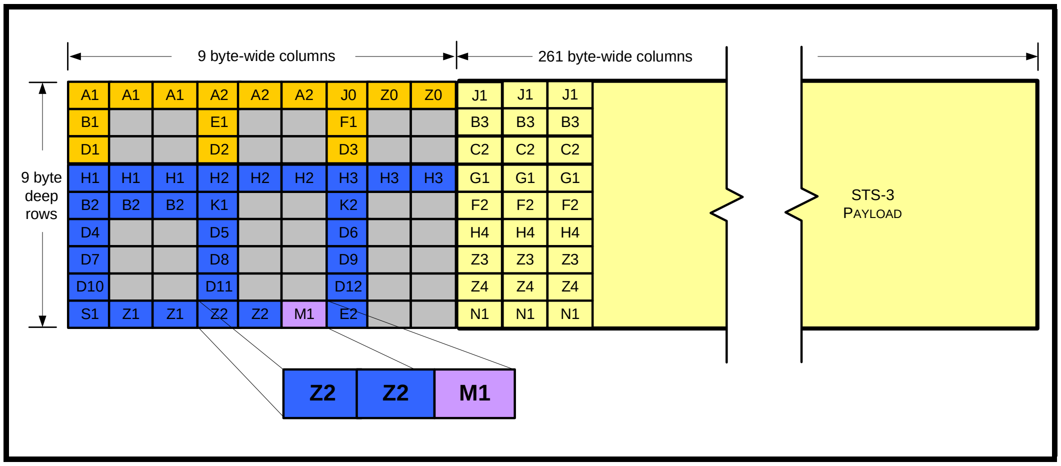
M0 BYTE VALUE								REI-L RETURN COUNT
BIT7	**BIT6**	**BIT5**	**BIT4**	**BIT3**	**BIT2**	**BIT1**	**BIT0**	**RECEIVED B2 ERROR COUNT**
Reserved				0	0	0	0	0
Reserved				0	0	0	1	1
Reserved				0	0	1	0	2
Reserved				0	0	1	1	3
Reserved				0	1	0	0	4
Reserved				0	1	0	1	5
Reserved				0	1	1	0	6
Reserved				0	1	1	1	7
Reserved				1	0	0	0	8
Reserved				1	X^0	X^0	X^0	0

***NOTE:** "X^0" denotes don't care values except 000b combination.*

The M1 STS-N/Nc Line FEBE Byte

In a signal at or above the STS-3/3c level, the M1 Byte is allocated for a Line Far End Block Error (FEBE) function. The M1 Byte is located in the third STS-1 in an STS-N/Nc signal. The entire byte is used to convey a count of errors detected by the B2 Parity Bytes. This count has (8 × N) + 1 legal values i.e., zero through (8 × N) errors. For rates at or above STS-3/3c but below STS-48/48c, the remaining possible 255 - (8 × N) values are interpreted as zero errors. At rates at and above STS-48/48c, if greater than 255 errors are detected the Line FEBE shall relay a value of 255 errors.

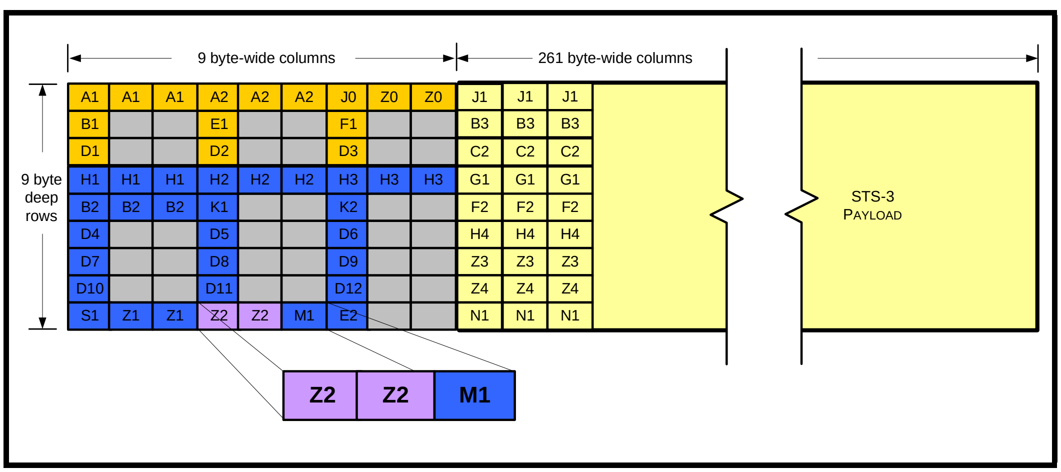
FIGURE 25. THE M1 LINE OVERHEAD BYTE IN AN STS-3 FRAME



The Z2 STS-N/Nc Growth Byte

In a SONET signal at or above the STS-3/3c level and at or less than STS-192/192c, the Z2 Byte is reserved in all STS-1s except for STS-1 number three (defined as the M1 Byte) of the STS-N/Nc signal for future growth. At rates greater than or equal to STS-192/192c, Z2 is only defined for STS-1 numbers one, two, and four through 48.

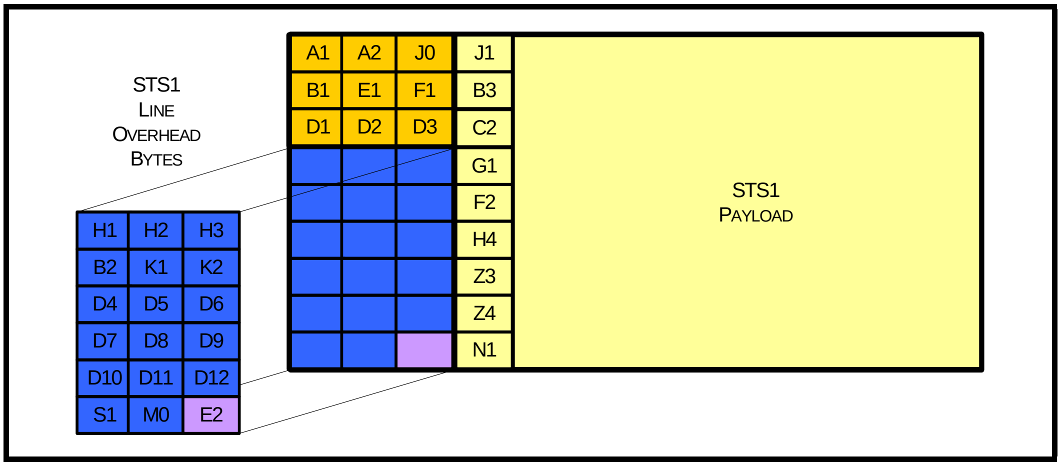
FIGURE 26. THE Z2 LINE OVERHEAD BYTES IN AN STS-3 FRAME



The E2 Orderwire Byte

One byte is allocated to be used as a Line Orderwire. This is an express order-wire channel reserved for voice communications between LTEs. It is only defined for STS-1 number one. SONET's 8000 frame repetition rate result in a 64 kilobits per second bit rate for the E2 voice channel.

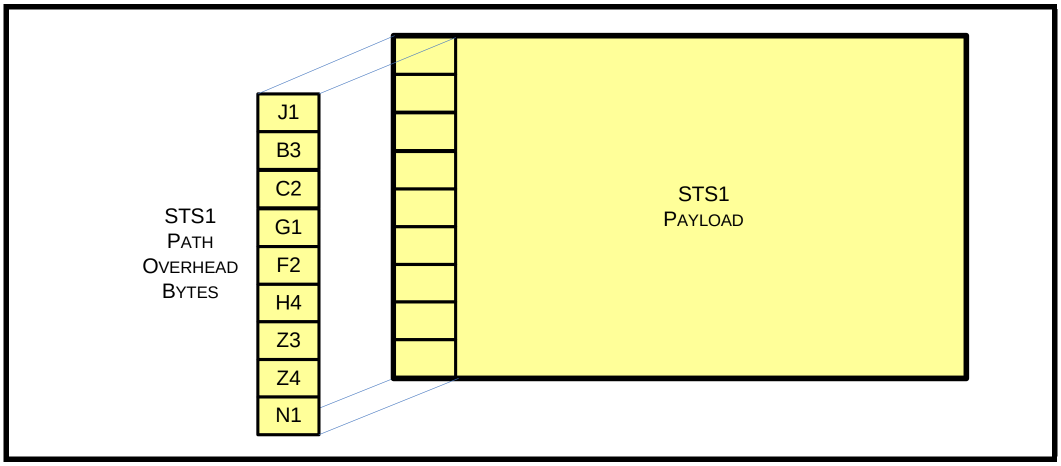
FIGURE 27. THE E2 LINE OVERHEAD BYTE



5.0 THE SONET PATH OVERHEAD BYTES

The Path Overhead Bytes are assigned to a payload by a source device (DS3 mapping circuit, DS1 to STS-1 mux, etc.) and remains with the payload until demultiplexed by the sink device. Intermediate LTEs may be required to monitor these bytes.

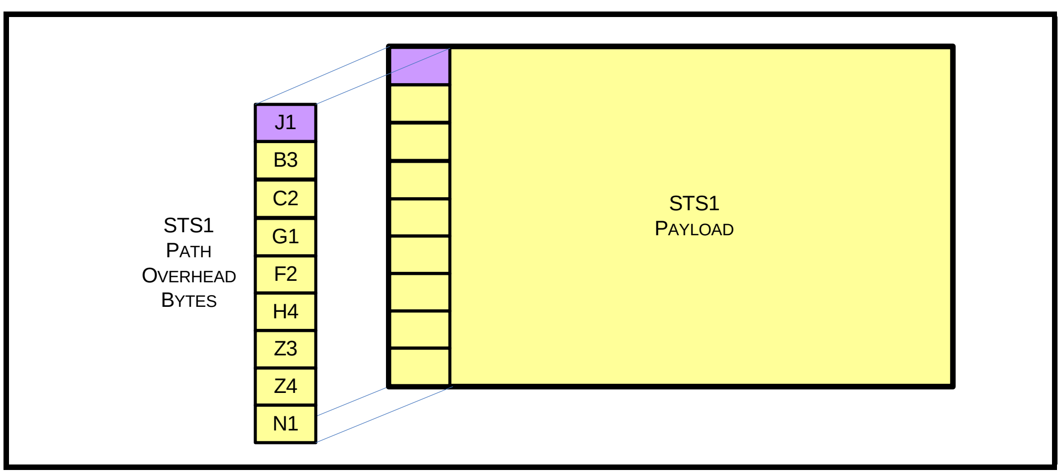
FIGURE 28. THE STS-1 SPE AND PATH OVERHEAD BYTES



The J1 Path Trace (Trail) Identifier Byte

One byte is used to repetitively transmit a 16-byte or 64-byte fixed length Path Access Point Identifier message string so that a sink device can verify its continued connection to the intended source device. The content of the message is not constrained by the SONET standards. However, it is suggested that a message consisting of eight-bit ASCII characters, padded with NULL Characters, and terminated with CR Byte (Carriage Return) value of 0x0D and LF Byte (Line Feed) value of 0x0A for a total length of 64 bytes. If no message is designated then 00[H] is to be transmitted. If the J1 Path Trace message received by the PTE is different from the value expected, a Path Trace Identifier Mismatch (TIM-P) alarm condition is declared.

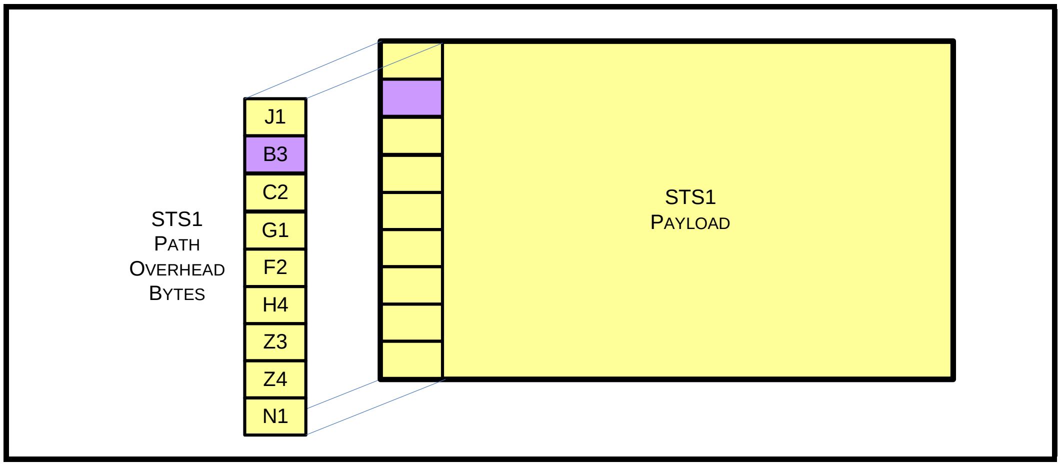
FIGURE 29. THE J1 PATH OVERHEAD BYTE



The B3 (BIP-8) Path Bit Interleaved Parity Byte

One byte is allocated for a Path Error Monitoring function. This function is a bit interleaved parity 8 code using Even Parity. The Path BIP-8 is calculated over all bits of the previous STS-1/N/Nc SPE before scrambling. The computed BIP-8 is placed in the B3 Byte before scrambling.

FIGURE 30. THE B3 PATH OVERHEAD BYTE



The C2 Path Signal Label Byte

One byte is allocated to identify the construction and payload content of the SPE as well as the Path Payload Defect Indicator (PDI-P) function. If the C2 signal label received by the PTE is different from the value expected, a Path Payload Label Mismatch (PLM-P) alarm condition is declared. Table 8 indicate the declared payload content along with the associated value of the C2 Byte. Values [E1]H to [FC]H are used for PDI-P conditions.

FIGURE 31. THE C2 PATH OVERHEAD BYTE

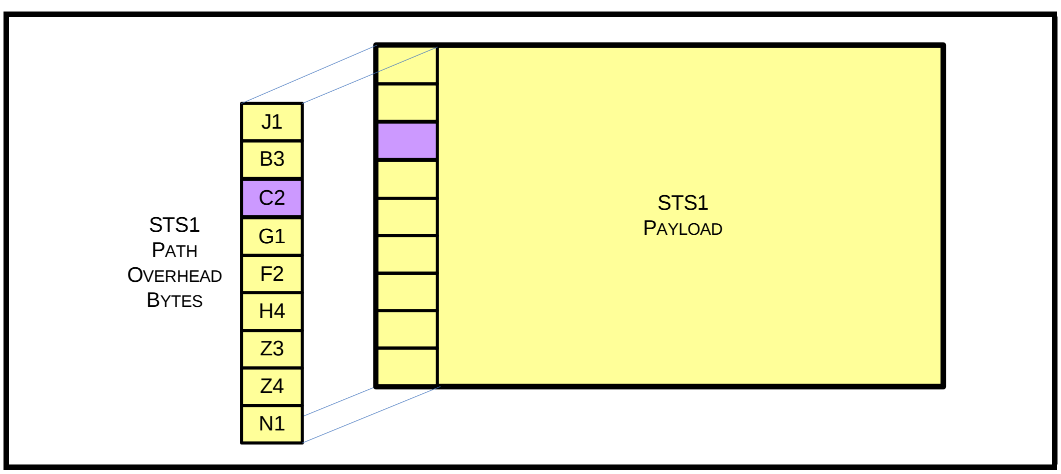


TABLE 8: C2 BYTE CODING

C2 CODE [HEX]	DECLARED PAYLOAD TYPE
00	Unequipped
01	Equipped - non specific
02	Float VT mode
03	Locked VT mode
04	Asynchronous mapping DS3
05	Experimental
12	Asynchronous mapping 139.264 Mbit/s
13	Mapping for ATM
14	Mapping for DQDB
15	Asynchronous mapping of FDDI
16	Mapping for HDLC over SONET
17	Simplified Data Link (SDL) with self-synchronizing scrambler
18	HDLC/LAPS
19	SDL with use of set-reset scrambler
1A	10 Gbit/s Ethernet (IEEE 802.3)
1B	Flexible topology Data Link mapping (GFP)
CF	Reserved (formerly HDLC/PPP over SONET mapping)
E1	STS-1 payload with 1 VT-x payload defect
E2	STS-1 payload with 2 VT-x payload defect
E3	STS-1 payload with 3 VT-x payload defect
E4	STS-1 payload with 4 VT-x payload defect
E5	STS-1 payload with 5 VT-x payload defect
E6	STS-1 payload with 6 VT-x payload defect
E7	STS-1 payload with 7 VT-x payload defect
E8	STS-1 payload with 8 VT-x payload defect
E9	STS-1 payload with 9 VT-x payload defect
EA	STS-1 payload with 10 VT-x payload defect
EB	STS-1 payload with 11 VT-x payload defect
EC	STS-1 payload with 12 VT-x payload defect
ED	STS-1 payload with 13 VT-x payload defect
EE	STS-1 payload with 14 VT-x payload defect

TABLE 8: C2 BYTE CODING

C2 CODE [HEX]	DECLARED PAYLOAD TYPE
EF	STS-1 payload with 15 VT-x payload defect
F0	STS-1 payload with 16 VT-x payload defect
F1	STS-1 payload with 17 VT-x payload defect
F2	STS-1 payload with 18 VT-x payload defect
F3	STS-1 payload with 19 VT-x payload defect
F4	STS-1 payload with 20 VT-x payload defect
F5	STS-1 payload with 21 VT-x payload defect
F6	STS-1 payload with 22 VT-x payload defect
F7	STS-1 payload with 23 VT-x payload defect
F8	STS-1 payload with 24 VT-x payload defect
F9	STS-1 payload with 25 VT-x payload defect
FA	STS-1 payload with 26 VT-x payload defect
FB	STS-1 payload with 27 VT-x payload defect
FC	STS-1 payload with 28 VT-x payload defect, STS-1, STS-3c, etc, with a non-VT Payload defect
FE	Test signal, O.181 specific mapping
FF	STS SPE AIS condition

The G1 Path Status Byte

One byte is allocated to convey back to the Source PTE the Sink PTE status and performance. Bits 7 through 4 are a Path FEBE. These bits are used to convey the count of errors detected by the B3 Byte. This count has nine legal values i.e., zero through eight. The remaining seven values are interpreted as zero errors. Bits 3, 2 and 1 are used for a Path Remote Defect Indication (RDI-P). Bit 0 is reserved for future use.

FIGURE 32. THE G1 PATH OVERHEAD BYTE

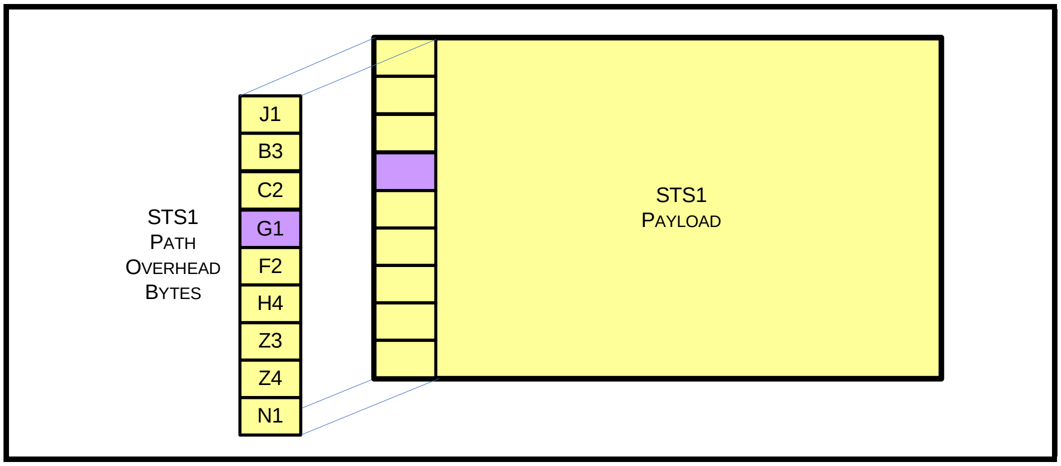


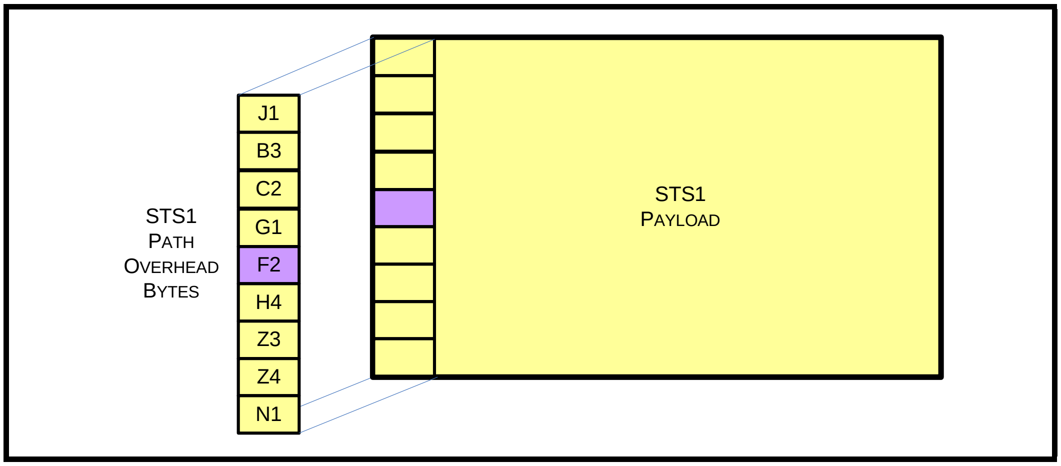
TABLE 9: G1 RDI-P DEFECTS

G1 BYTE VALUE								RDI-P CODE	TRIGGER
REI-P COUNT				RDI-P CODE			SPARE		
BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0		
REI-P Error Count				0	0	0		No remote defect	No defects
REI-P Error Count				0	0	1		No remote defect	No defects
REI-P Error Count				0	1	0		Remote payload defect	PLM-P
REI-P Error Count				0	1	1		No remote defect	No defects
REI-P Error Count				1	0	0		Remote server defect	AIS-P, LOP-P
REI-P Error Count				1	0	1		Remote server defect	AIS-P, LOP-P
REI-P Error Count				1	1	0		E-RDI connectivity defect	TIM-P, UNEQ-P
REI-P Error Count				1	1	1		Remote server defect	AIS-P, LOP-P

The F2 Path User Channel Byte

One byte is allocated for user communications purposes between PTEs. SONET's 8000 frame repetition rate result in a 64 kilobits per second bit rate for the F2 user channel.

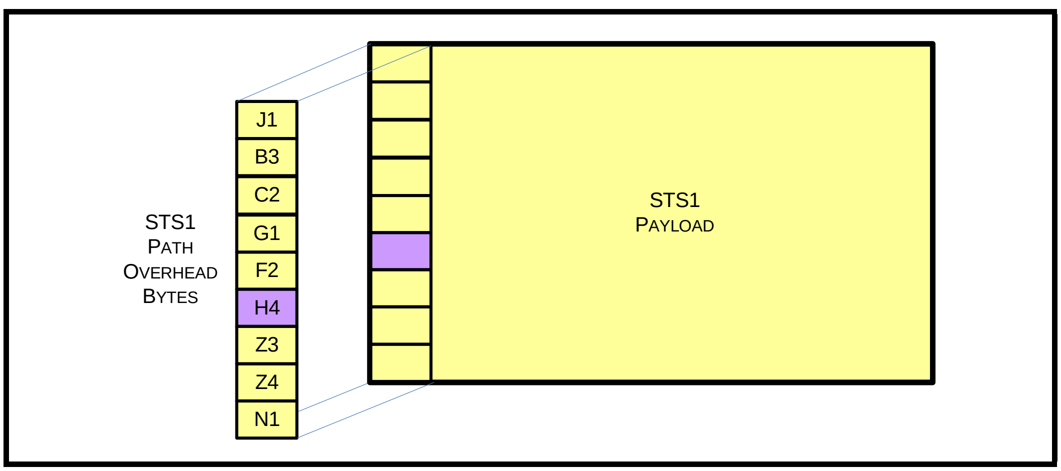
FIGURE 33. THE F2 PATH OVERHEAD BYTE



The H4 Multi-Frame Indicator Byte

This Byte provides a generalized multi-frame indicator for payloads. Currently, it is only used with VT structured payloads. The value of the H4 Byte denotes the phase of the VT Superframe.

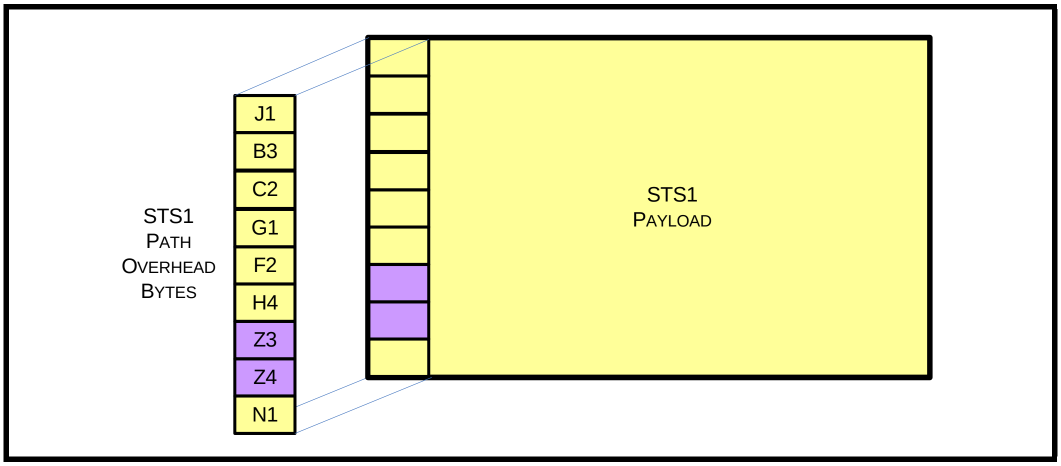
FIGURE 34. THE H4 PATH OVERHEAD BYTE



The Z3 and Z4 Growth Byte

These two bytes are reserved for future use. In SDH, these two bytes are defined as the F3 Byte used for Maintennance and K3 Byte is used for Automatic Protection Switch.

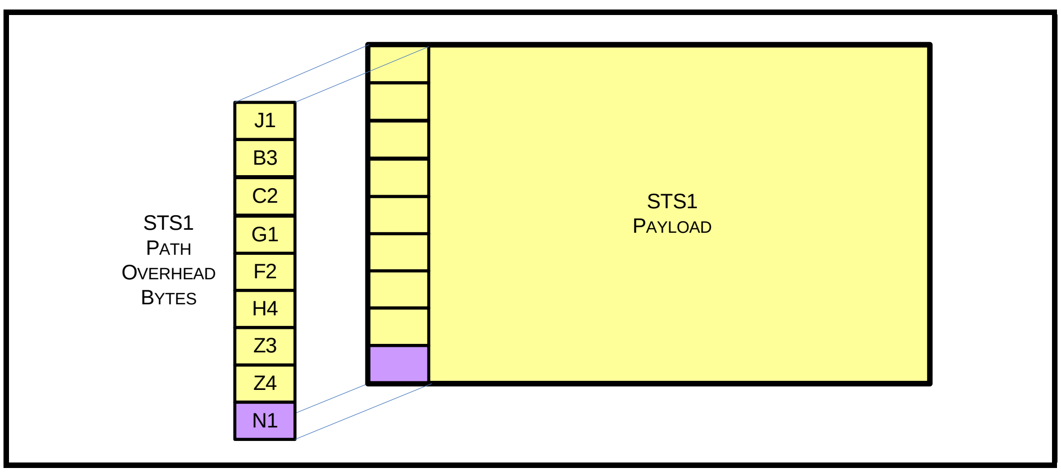
FIGURE 35. THE Z3 AND Z4 PATH OVERHEAD BYTE



The Z5 (N1) Tandem Connection, Maintennance and Path Data Channel Byte

One byte is allocated to support Tandem Connection Maintenance (TCM) and a Path Data Channel. Bits 7 through 4 are reserved for TCM functions. Bits 3 through 0 form a 32 kbps data channel that uses the LAPD protocol. The Path Data channel is used in TCM applications and is also available for communications between PTEs. However, TCM messages have priority. Since TCM terminating entities are not required to perform store and forward or Layer 2 termination for non-TCM messages, some or all of the preempted PTE to PTE messages may be lost and require re-transmission.

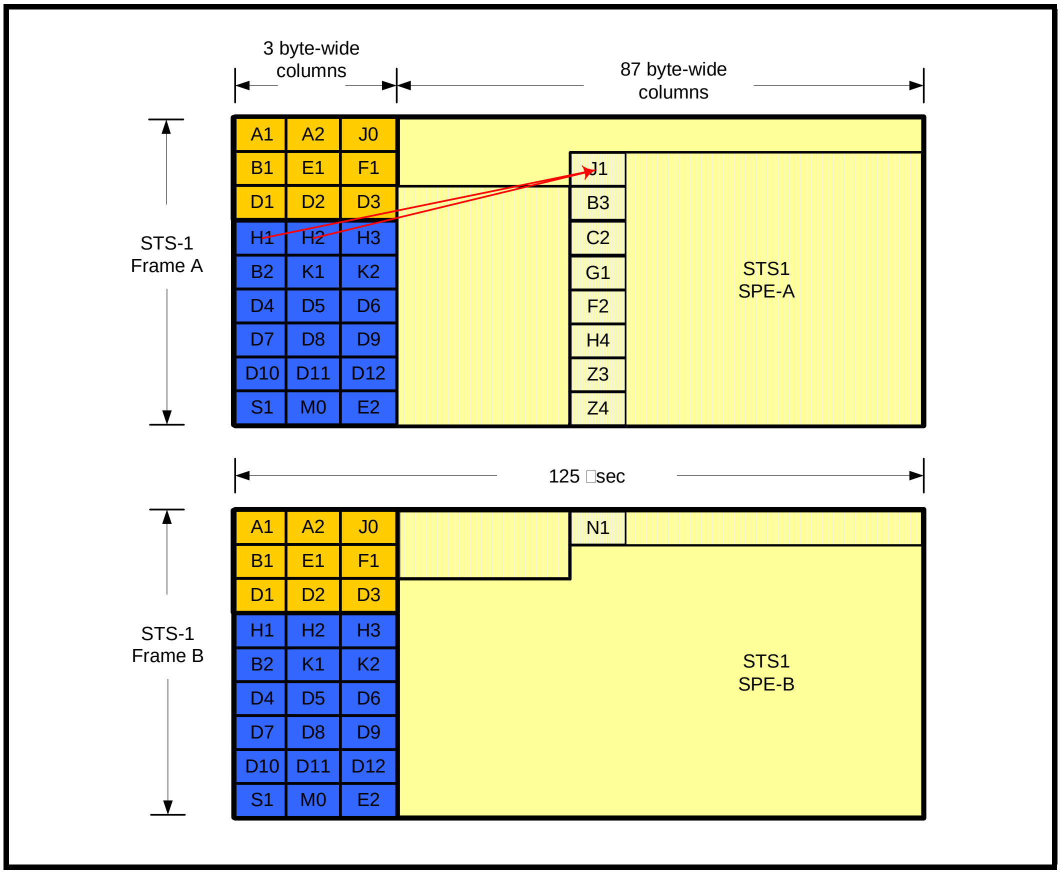
FIGURE 36. THE Z5 (N1) PATH OVERHEAD BYTE



6.0 SONET H1 AND H2 BYTE POINTERS

Pointers are defined in SONET at the STS-N and VT Levels. The STS-1/Nc Payload Pointer provides a mechanism to allow for flexible and dynamic alignment of the STS-1/STS-Nc SPE within the STS Payload Envelope Capacity. Dynamic alignment means that the STS-1/STS-Nc SPE is allowed to dynamically "float" and begin at any byte location within the STS Payload Envelope Capacity. Thus, the pointer is able to accommodate differences not only in the phases of the STS-1/STS-Nc SPE and the Transport layer, but in the frame rates as well through frequency justifications that will be discussed later in Section 6.1 and Section 6.2. The use of pointers is essential to SONET's ability to integrate and map asynchronous data into the SONET network. Because the SPE can float within the STS Payload Envelope, the SPE can actually straddle or span across 2 consecutive STS-N frames as is most often the case. **Figure 37** below illustrate the condition in which an STS-1 SPE will usually begin in one STS-1 frame and end in the following adjacent STS-1 frame.

FIGURE 37. THE STS-1 SPE SPANNING ACCROSS ADJACENT STS1 FRAMES



6.1 STS-N Pointer Operation

The H1 and H2 pointer bytes are defined according to **Figure 38** below.

The Pointer Bytes (H1 and H2) can be viewed as one 16-bit word as shown below. The last ten bits (9-0) of the Pointer Word carry the pointer value. This value is a binary number with a range of 0 to 782 that indicates the offset between the Pointer Bytes and the first byte of the SPE (J1). The TOH Bytes are not counted in the offset. A value of "0" indicates that the SPE starts in the byte position immediately following the H3 Byte. The last column of this row is indicated by a pointer value of "86". A value of "87" specifies that the SPE starts at the byte position immediately following the K2 Byte. A value of "522" would position the start of the SPE in the byte position immediately following the C1/J0 Byte as shown in **Figure 39**. The two S bits are not used in STS-1 Pointers and are set to "00".

FIGURE 38. THE H1 H2 BYTE DEFINITION

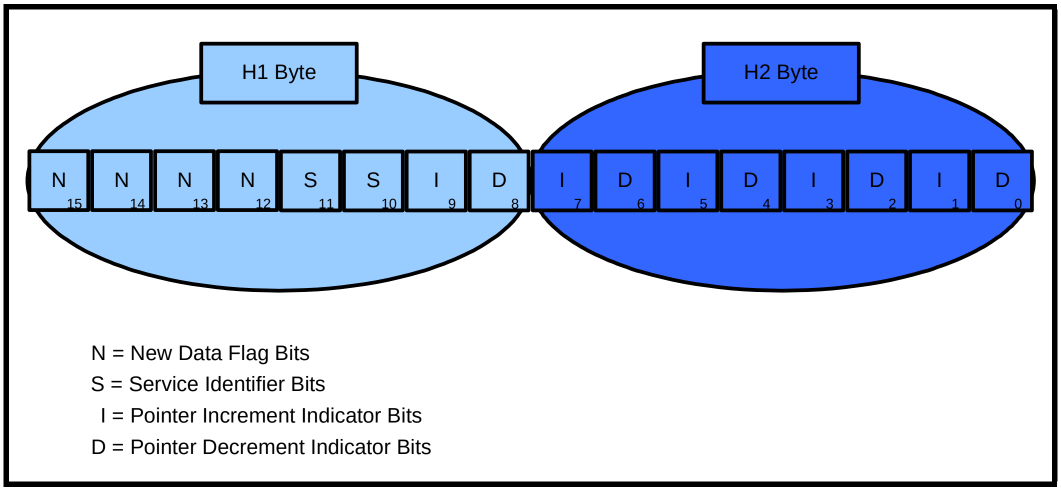
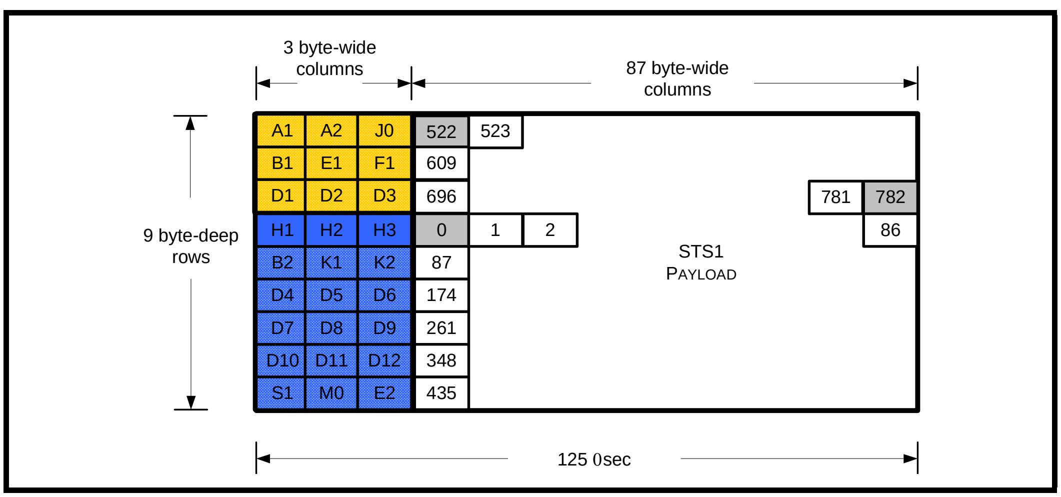


FIGURE 39. STS-1 POINTER BYTE VALUE AND CORRESPONDING POSITIONS ON SPE



6.2 Frequency Justification

If there is a frequency offset between the frame rate of the TOH and that of the STS-1 SPE, then the pointer value will be incremented or decremented, as needed, accompanied by a corresponding positive or negative stuff byte. Consecutive pointer operations must be separated by at least three frames in which the pointer value remains constant.

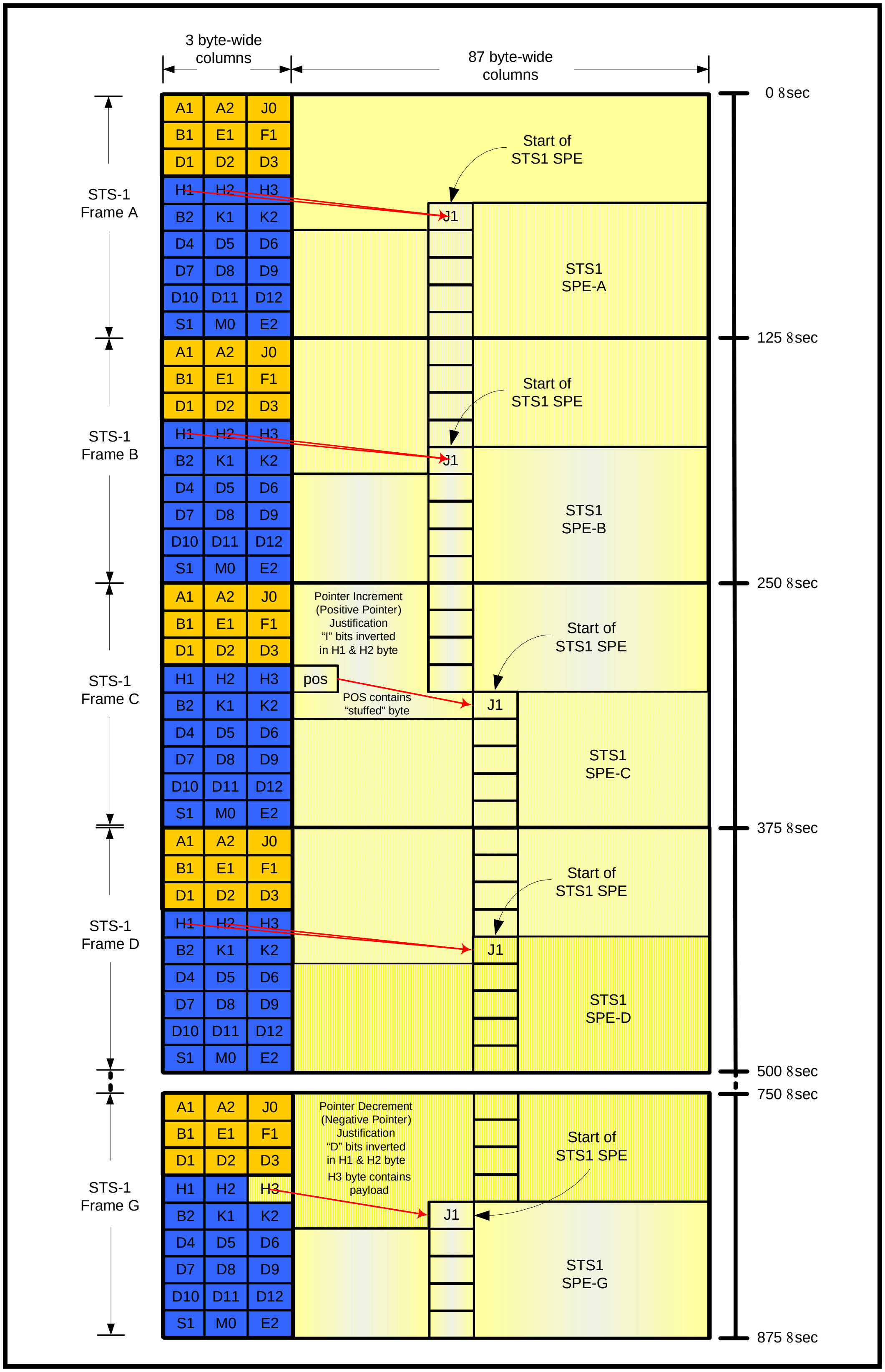
If the frame rate of the SPE is too slow with respect to the TOH, then the alignment of the envelope is periodically slipped back in time and the pointer is incremented by one. This is shown in Figure 2 33. The operation is indicated by inverting Bits 9, 7, 5, 3 and 1 (I Bits) of the Pointer Word. A positive stuff byte appears immediately after the H3 Byte in the frame containing the inverted I Bits. Subsequent pointers contain the new offset.

If the frame rate of the SPE is too fast with respect to the TOH, then the alignment of the envelope is periodically advanced in time and the pointer is decremented by one. This operation is indicated by inverting Bits 8, 6, 4, 2 and 0 (D Bits) of the Pointer Word. A negative stuff byte appears in the H3 Byte Position in the frame containing the inverted D Bits. Subsequent pointers contain the new offset. This is shown in Figure 2 33.

New Data Flag

Bits 1 through 4 (N Bits) of the Pointer Word carry a New Data Flag (NDF). This is a mechanism that allows an arbitrary change of the value of the pointer (pointer jump) if that change is due to a change in payload. Normal operation is indicated by a "0110" code in the N Bits. NDF is indicated by inversion of the N Bits to "1001". The new alignment is indicated by the pointer value accompanying the NDF and takes effect at the offset indicated.

FIGURE 40. POINTER JUSTIFICATION



6.3 Concatenation Pointer Operation

In an STS-Nc signal, the actual pointer is in the first set of H1 and H2 bytes. A Concatenation Indication contained in the Pointer Word is used to show that the STS-1 is part of an STS-Nc. H1 and H2 bytes occupying STS-1 positions two through N carry the Concatenation Indicator. The operations indicated in the pointer word of the first STS-1 within the STS-Nc apply to all STS-1s within the group. The pointer value must be multiplied by N to obtain the byte offset into the STS-Nc envelope capacity. Positive and negative justifications are performed as N byte multiples. In the remaining H1 and H2 pointer words in the STS-Nc group, the I and D Bits are set to all "1"s. The N Bits are set to "1001" and the S Bits are set to "00". Therefore, a Concatenation Indicator is defined by: H1c = 0x93 and H2c = 0xFF. **Figure 41** show the STS-3c Transport Overhead and the second and third pair of H1c and H2c Concatenation Indicators.

FIGURE 41. THE STS3C CONCATENATION INDICATOR

STS-3C TRANSPORT OVERHEAD BYTES

9 byte-wide columns

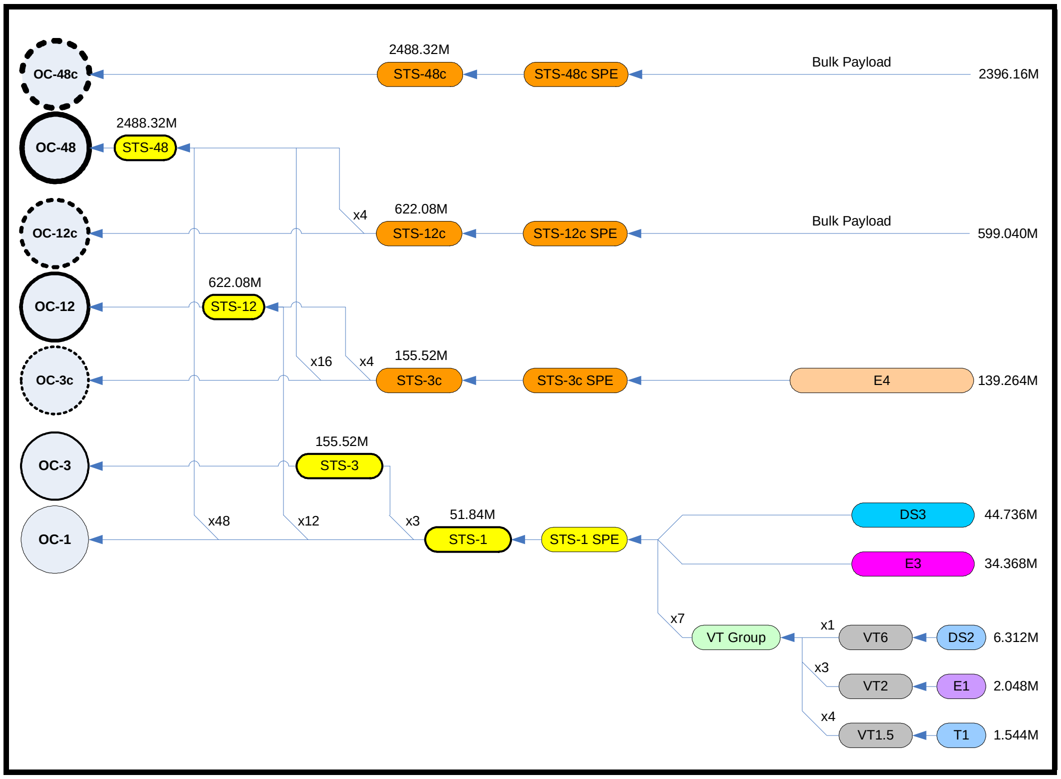
9 byte deep rows

A1	A1	A1	A2	A2	A2	J0	Z0	Z0
B1			E1			F1		
D1			D2			D3		
H1	0x93	0x93	H2	0xFF	0xFF	H3	H3	H3
B2 BIP-24			K1			K2		
D4			D5			D6		
D7			D8			D9		
D10			D11			D12		
S1	Z1	Z1	Z2	Z2	M1	E2		

7.0 AGGREGATION TOPOLOGY

The figure below show SONET's ability to map and scale across a broad spectrum of transmission protocols. Figure 42 below shows mapping topology up to OC-48 to better illustrate subrate mapping hierarchy although SONET datarates up to OC-768 are used today. SONET mapping structure scalability has a mechanism for aggregating and transporting sub-rate payloads via a combination of carrier channels organized into groups that could be sent over the STS-1 SPE.

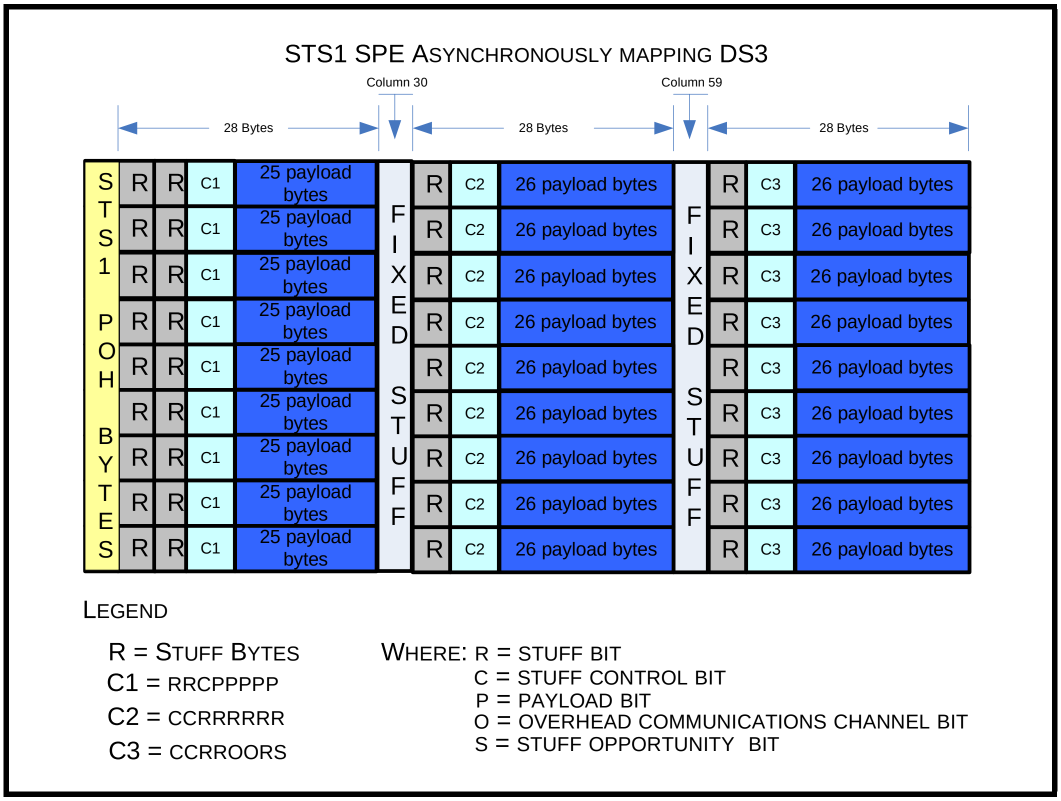
FIGURE 42. SONET AGGREGATION TOPOLOGY



7.1 Asynchronous mapping of DS3 over STS-1

The SONET STS-1 Synchronous Payload Envelope can asynchronously map DS3 datarates using a mapping format in **Figure 43** below per GR-253 section 3.4.2.1. Column 30 and 59 contain fixed stuff bytes. There a 9 subframes with each subframe consisting of 621 payload bytes, 5 stuff control bits, 2 overhead communication channel bits, and 1 stuff opportunity bit with the remainder as fixed stuff bits.

FIGURE 43. ASYNCHRONOUS DS3 MAPPING IN STS-1 SPE (GR-253 SEC 3.4.2.1)

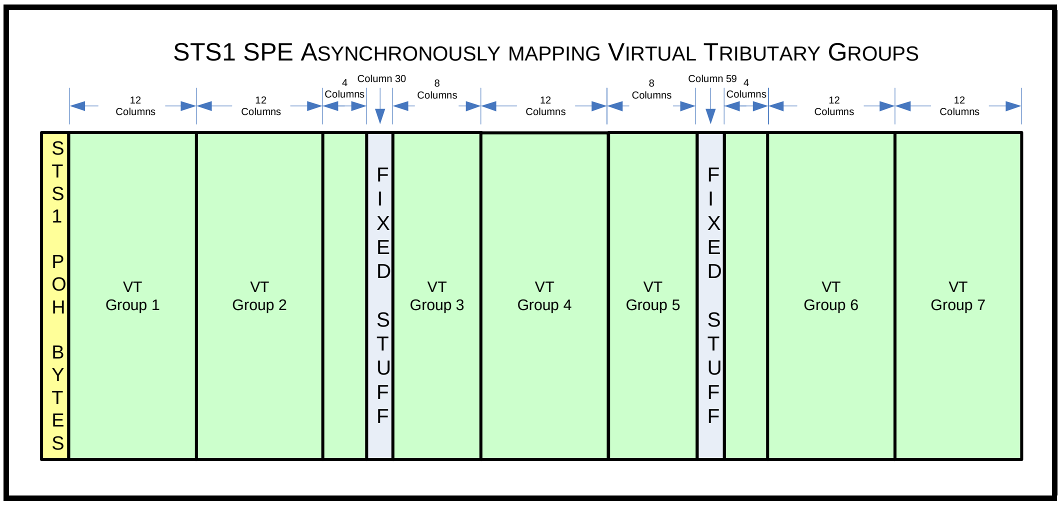


The C bits are employed to denote the presence or absence of stuffed bits. The five C bits in the C1, C2 and C3 bytes are set to 1 if stuffing occurs otherwise they are cleared to 0. If the value of the C bits are 1, the S bit contains a stuff bit. If the value of the C bits are 0, the S bit contains a payload bit. In the case of discrepancy in the five C bits such as the case of single and double bit errors within the five C bits, the majority value of the five stuff control bits shall be used to determine the stuffing event.

7.2 VT Mapping Structure

SONET transport technology can also be scaled for transporting sub-rate payloads. In order for SONET to transport lower bandwidth payloads, a mapping structure called Virtual Tributaries is utilized. Virtual Tributaries are carried only on an STS-1 SPE. Virtual Tributaries are designed to carry a specific datarate payload and is adapted in size to the particular bandwidth of the payload. To accomodate Virtual Tributary mapping in the STS-1 Synchronous Payload Envelope, the STS-1 Synchronous Payload Envelope is divided into Seven Tributary Groups, each 12 columns wide. In addition to the SONET Path Overhead Column, two columns, Column 30 and Column 59 are as assigned as "Fixed Stuff" columns. Figure 44 below illustrate the Virtual Tributary Groups in an STS-1 SPE.

FIGURE 44. STS-1 SPE ASYNCHRONOUSLY MAPPING VIRTUAL TRIBUTARY GROUPS



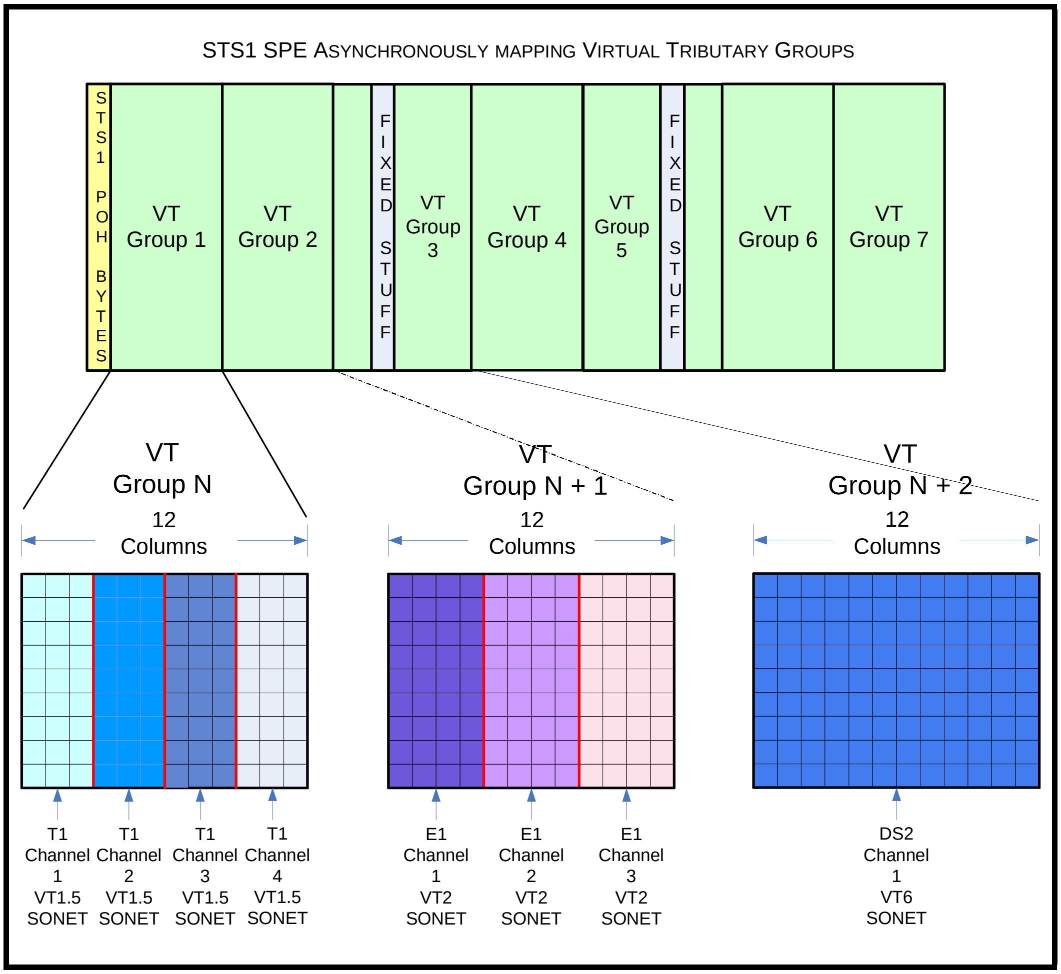
These Virtual Tributary (VT) Groups are assigned to carry one of four particular type of Virtual Tributary payloads. The four Virtual Tributaries type are defined as VT1.5, VT2, VT3, and VT6. Although the seven VT Groups can have different VT type payloads, a VT Group is restricted to a homogenous set of VT type payloads. Each Virtual Tributary type is designed to carry a sub-rate payload or a particular datarate plus some Virtual Tributary Overhead. A VT1.5 with a bandwidth of 1.728 Mbps can carry a T1 signal or an equivalent 1.544 Mbps datarate. A VT2 has a bandwidth of 2.304 Mbps and can carry an E1 signal or an equivalent 2.048 Mbps datarate. A VT3 can carry a DS1-C signal and a VT6 can carry a DS2 signal or equivalent 6.312 Mbps datarate. With a fixed size of 12 columns per VT Group, the number of VT-N per VT Group are pre-defined by it's VT bandwidth size. Table 10 define the number of VT-N and the VT column size that are carried in the VT Groups.

TABLE 10: VIRTUAL TRIBUTARIES IN SONET

VT-N TYPE	VT BANDWIDTH	VT PAYLOAD	VT COLUMN SIZE	VT BYTES	VT-N PER VT GROUP
VT1.5	1.728	DS1	3	27	4 VT1.5
VT2	2.304	E1	4	36	3 VT2
VT3	3.456	DS1-C	6	54	2 VT3
VT6	6.912	DS2	12	108	1 VT6

Figure 45 below illustrate the three of seven VT Groups in an STS-1 SPE carrying possible combinations of channelized VT1.5, VT2, and VT6 payloads. STS-Nc SPE's cannot carry VT payloads. For example, to carry 84 DS1's in SONET, an STS-3 format must be used with each STS-1 SPE organized as 28 VT1.5's.

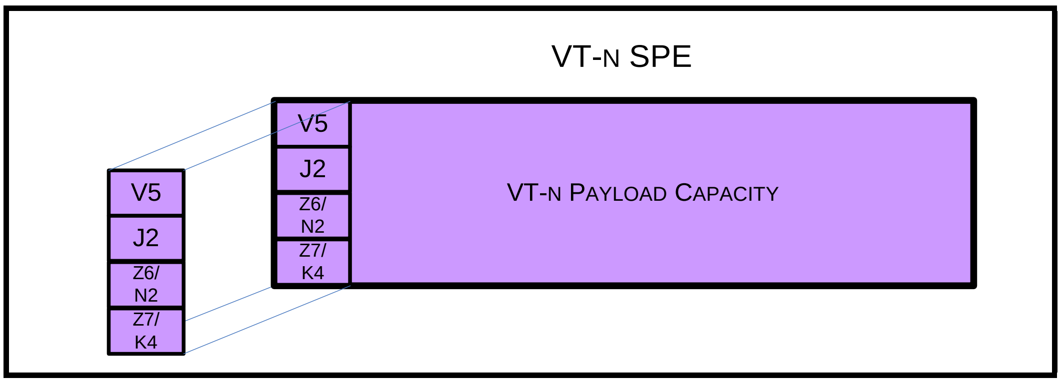
FIGURE 45. VIRTUAL TRIBUTARY GROUPS CARRYING VT1.5, VT2, AND VT6 PAYLOAD



8.0 VIRTUAL TRIBUTARY PATH OVERHEAD

Four bytes defined as the V5, J2, Z6/N2, and the Z7/K4 overhead byte are allocated for Virtual Tributary Path Overhead (VT POH). These VT POH Bytes enable communication across the networks between the VT generation equipment and the VT terminating equipment. Each VT SPE contains four bytes of VT POH (V5, J2, Z6, and Z7), and the remaining bytes constitute the VT Payload Capacity, in which the size of the VT Payload Capacity is dependent on the VT type. The first byte of a VT SPE (the byte pointed to by the VT Payload Pointer) is the V5 byte, while the J2, Z6, and Z7 occupy the corresponding locations in the subsequent 125-usec frames of the VT superframe.

FIGURE 46. THE VIRTUAL TRIBUTARY PATH OVERHEAD BYTES



The V5 VT Primary OAM and VT Path Signal Label Byte

The V5 Byte compromise several Overhead and Maintenance (OAM) functions and contain the VT path signal label. Bit-7 and bit-6 compromise the VT BIP-2 bit interleaved parity bits. This BIP-2 is an even parity calculations of the previous VT SPE. However, the V1, V2, V3, and V4 pointer bytes which will be discussed later in section.blah are not included in this BIP-2 calculation. Bit-5 is the REI-V or VT Remote Error Indicator for signalling the originating VT Path Termination Equipment when BIP-2 errors are received. Bit-4 is typically reserved for specific mapping functions and is defined as the RFI-V or VT Remote Failure Indicator during byte-synchronous DS1 mapping functions. In all other mapping cases, Bit-4 is undefined. In combination with Bit-3 and Bit-2 of the V1 pointer byte (these bits are also known as the VT Size indicator or the VT pointer SS bits), bit-3, bit-2, and bit-1 of the V5 Byte compromise the VT path signal label. These bits are used to identify the type of payload carried in the VT payload envelope. If the VT signal label received at the VT PTE is different from the expected VT signal label, a VT payload label mismatch or PLM-V error is generated. Table 11 shows the V5 Byte bit definitions and Table 12 shows the VT path signal label assigned VT classification and identification. Bit-0 is the ERDI-V or the VT Enhanced Remote Defect Indicator used to denote whether an Enhanced version of RDI-V is used or the older Standard version of RDI-V. The actual RDI-V values reside in the Z7/K4 Byte.

TABLE 11: V5 VT PRIMARY OAM AND VT PATH SIGNAL LABEL BYTE

V5 BYTE BIT DEFINITIONS							
VT BIP-2		REI-V	RFI-V	VT PATH SIGNAL LABEL			RDI-V
BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0

TABLE 12: VT SIZE AND VT PATH SIGNAL LABEL BYTE

VT SIZE		VT PATH SIGNAL LABEL			ASSIGNED VT IDENTIFICATION
V1 BYTE		V5 BYTE			
BIT3	BIT2	BIT3	BIT2	BIT1	
1	1	0	0	0	Unequipped VT1.5
1	1	0	1	0	Asynchronous mapping for DS1
1	1	0	1	1	Bit synchronous mapping for DS1
1	1	1	0	0	Byte synchronous mapping for DS1
1	1	1	0	1	Extended Signal Label
1	1	1	1	0	Test signal, ITU-T O.181 specific mapping
1	1	1	1	1	VT1.5 SPE AIS
1	0	0	0	0	Unequipped VT2
1	0	0	1	0	Asynchronous mapping for E1
1	0	0	1	1	Bit synchronous mapping for E1
1	0	1	0	0	Byte synchronous mapping for E1
1	0	1	0	1	Extended Signal Label
1	0	1	1	0	Test signal, ITU-T O.181 specific mapping
1	0	1	1	1	VT2 SPE AIS
0	1	0	0	0	Unequipped VT3
0	1	0	1	0	Asynchronous mapping for DS1C
0	1	0	1	1	Unassigned VT3
0	1	1	0	0	Unassigned VT3
0	1	1	0	1	Extended Signal Label
0	1	1	1	0	Test signal, ITU-T O.181 specific mapping
0	1	1	1	1	VT3 SPE AIS
0	0	0	0	0	Unequipped VT6
0	0	0	1	0	Asynchronous mapping for DS2
0	0	0	1	1	Unassigned VT6
0	0	1	0	0	Unassigned VT6
0	0	1	0	1	Extended Signal Label
0	0	1	1	0	Test signal, ITU-T O.181 specific mapping
0	0	1	1	1	VT6 SPE AIS

The J2 VT Path Trace Identifier Byte

Like the J1 Path Trace Identifier, this byte is used to repetitively transmit a single byte or 16-byte or 64-byte fixed length VT Path Access Point Identifier message string so that a sink device can verify its continued connection to the intended source device. The content of the message is not constrained by the SONET standards. However, it is suggested that a message consisting of eight-bit ASCII characters, padded with NULL Characters, and terminated with CR Byte (Carriage Return) value of 0x0D and LF Byte (Line Feed) value of 0x0A for a total length of 64 bytes.

The Z6/N2 VT Path Growth Byte

This byte is reserved in SONET but used for Lower Order Tandem connection monitoring in SDH.

The Z7/K4 VT Extended OAM and VT Path Concatenation Byte

The Z7/K4 byte provides an extension to the OAM functions of the V5 Byte along with the overhead for virtual concatenation. The Z7/K4 Byte bit descriptions are illustrated in Table 13 below. Bit-7 is the VT Extended Signal Label. Bit-6 is the VT Virtual Concatenation String bit. Bit-5 and bit-4 are reserved. Bit-3, bit-2, and bit-1 of the Z7/K4 Byte, in addition to ERDI-V bit-0 of the V5 Byte indicate codes to denote the Enhanced version of RDI-V and the older Standard version of RDI-V. Bit-0 is unassigned at this point. In SDH, Bit-7 thru bit-4 is used for VC Path APS Overhead Channel.

TABLE 13: Z7 VT EXTENDED OAM AND VT PATH CONCATENATION BYTE

Z7 BYTE BIT DEFINITIONS							
VT EXTENDED SIGNAL LABEL	VIRTUAL CONCATENATION OVERHEAD	RESERVED	RESERVED	VT REMOTE DEFECT INDICATOR			RESERVED
BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0

TABLE 14: K4 VC LP-APS CHANNEL AND VC LP-RDI BYTE

K4 BYTE BIT DEFINITIONS							
LOW ORDER PATH AUTOMATIC PROTECTION SWITCH				LOW ORDER PATH REMOTE DEFECT INDICATOR			RESERVED
BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0

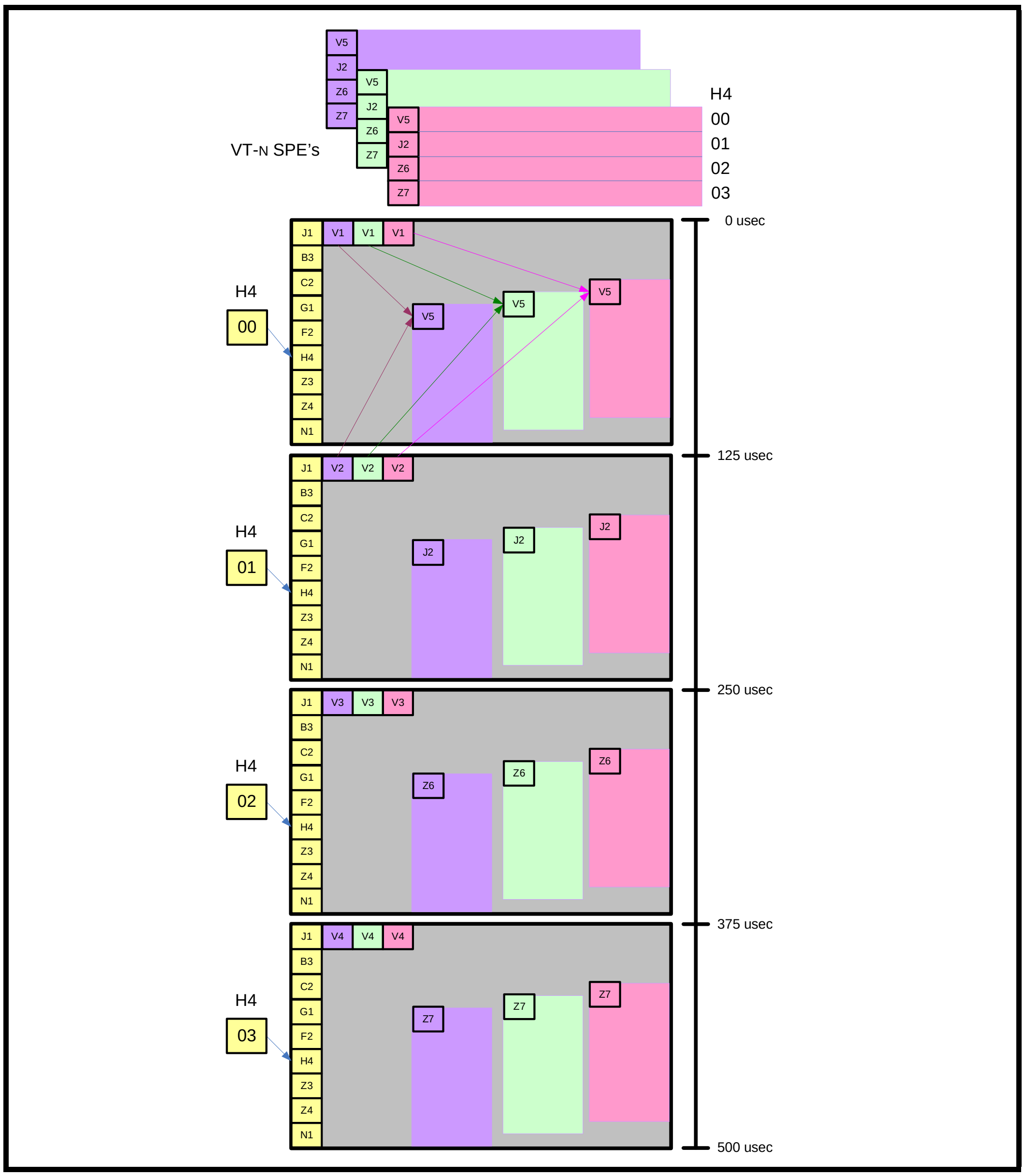
TABLE 15: Z7 RDI-V DEFECTS

RDI-V CODE			RDI-V CODE	TRIGGER
BIT3	BIT2	BIT1		
0	0	0	No remote defect	No defects
0	0	1	No remote defect	No defects
0	1	0	Remote payload defect	PLM-V
0	1	1	No remote defect	No defects
1	0	0	Remote server defect	AIS-V, LOP-V
1	0	1	Remote server defect	AIS-V, LOP-V
1	1	0	E-RDI connectivity defect	TIM-V, UNEQ-V
1	1	1	Remote server defect	AIS-V, LOP-V

9.0 THE VT SUPERFRAME STRUCTURE

The seven VT Groups in an STS-1 SPE actually operate within a superstructure called a VT Superframe. A VT superframe simply consists of four conscecutive 125-microseconds frames of the STS-1 SPE. To distinguish the frame phase or sequence of the four consecutive frames, the H4 Multiframe Indicator Byte value in the STS-1 POH is used to determine the frame phase or sequence of the VT Superframe. The VT Superframe is shown in Figure 47. The VT Superframe contains the VT Pointers and the VT SPE for each of the VT-N. The VT Pointer occupies four bytes designated V1, V2, V3 and V4 and the remaining bytes define the VT SPE. The V1 pointer bytes always appear immediately adjacent to the J1 byte of the STS-1 SPE, starting with the V1 pointer byte of the first VT SPE followed by the V1 pointer byte of the second VT SPE and so on. V2 through V4 pointer bytes also appear adjacent to the J1 byte as the first bytes in the following frames of the VT superframe, regardless of the VT size.

FIGURE 47. THE VIRTUAL TRIBUTARY SUPERFRAME



9.1 The VT Pointers

Each VT-N (regardless of size) mapped into the STS-1 SPE contains a set of VT pointers defined as the V1, V2, V3, and V4 pointer bytes, which indicates the start of the VT SPE. The VT Pointer provides for flexible and dynamic alignment of the VT SPE within the VT, independent of other VT's in the STS-1 SPE. The V1, V2, and V3 are defined and function in much the same way as the H1, H2, and H3 pointer bytes in the Line Transport Overhead. The V1 and V2 bytes are the VT Payload Pointer, the V3 byte is the VT Pointer Action byte also used for frequency justification, and V4 byte is undefined at this moment.

The V1 and V2 pointer bytes are defined according to **Figure 48** below. The Pointer Bytes (V1 and V2) can be viewed as one 16-bit word as shown below. The first nibble are the New Data Flag identifier bits. The two S bits are used to indicate the VT type or size as defined in **Table 16**. The last ten bits (9-0) of the Pointer Word carry the pointer value. This value is a binary number with a range of 0 to a maximum value of 103 for a VT-1.5 that indicates the offset between the Pointer Bytes and the first byte of the VT SPE (V5). **Table 16** also shows the possible range of pointer values for each VT type. The VT payload byte immediately following the V2 pointer byte is the zero pointer offset location. The V1, V2, V3, and V4 Pointer Bytes are not counted in the offset. It would help to remember that each VT-N is allotted a fixed number of columns within the VT Group. With four STS-1 SPE's per VT Superframe, the total number of bytes per VT-N, less the four VT pointer bytes gives the pointer range value for each VT-N.

FIGURE 48. THE V1 V2 VT PAYLOAD POINTER BYTES DEFINITION

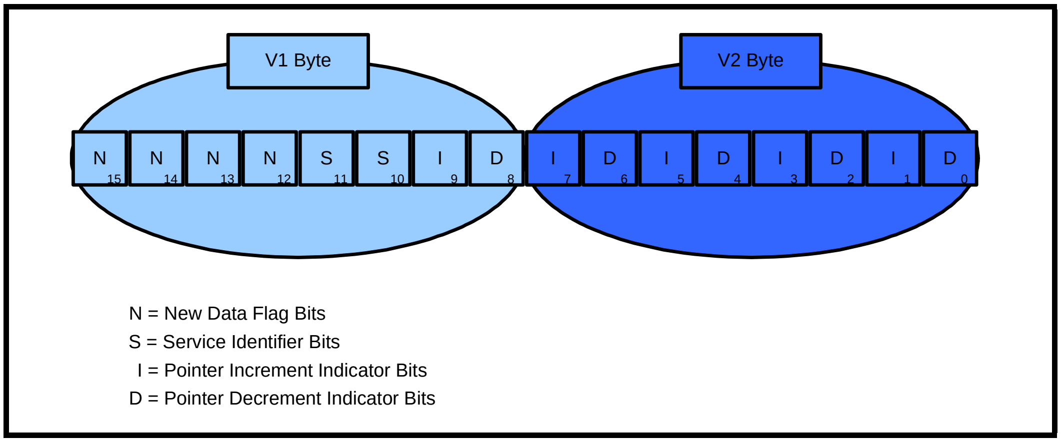


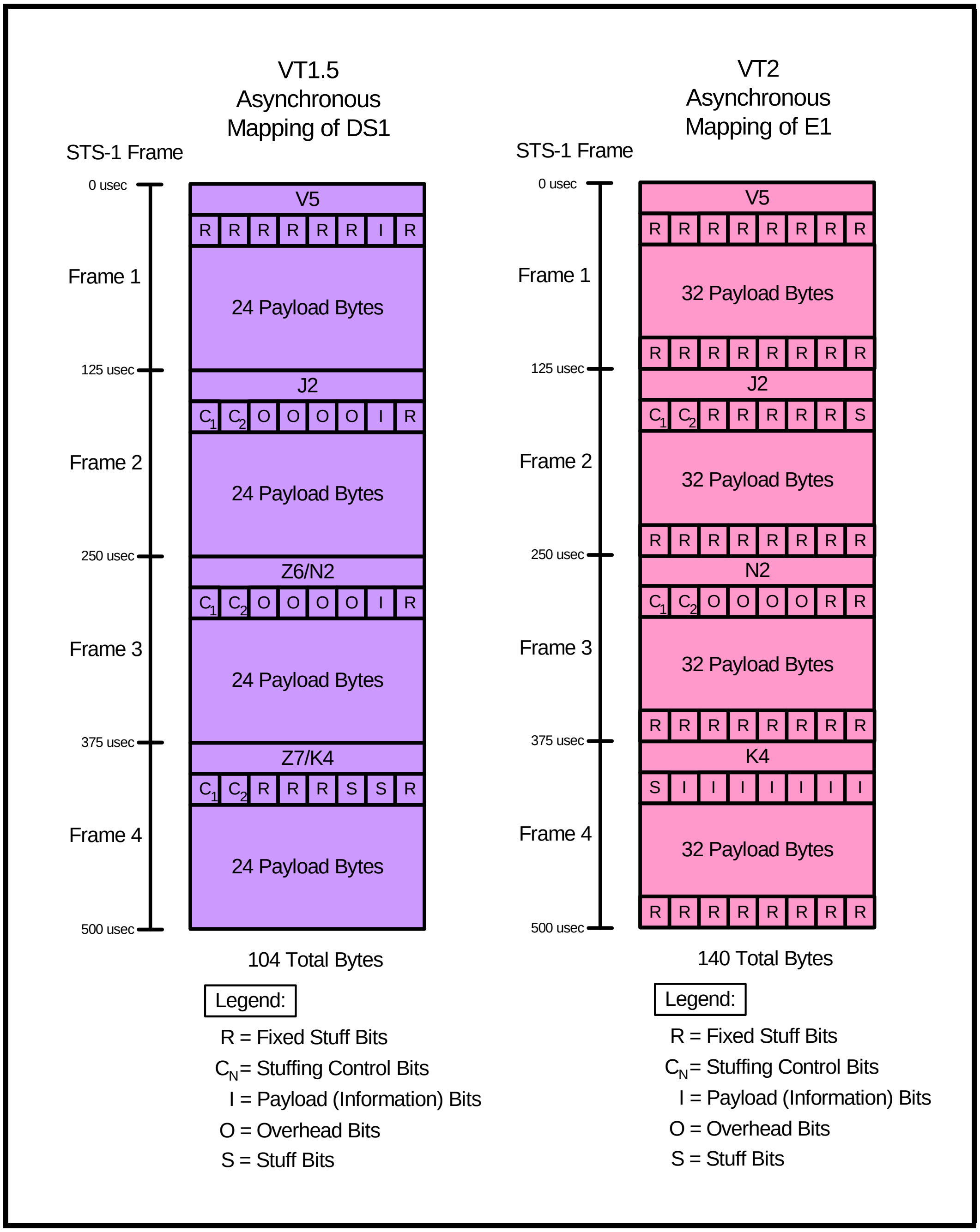
TABLE 16: VT SIZE AND POINTER RANGE

V1 BYTE		VT SIZE DESIGNATION	SDH EQUIVALENT	VT COLUMN SIZE	VT BYTES PER SUB-FRAME	VT BYTES PER SUPERFRAME	VT POINTER RANGE VALUE
BIT11	BIT10						
1	1	VT1.5	TU-11	3	27	108	0 - 103
1	0	VT2	TU-12	4	36	144	0 - 139
0	1	VT3	--	6	54	216	0 - 211
0	0	VT6	TU-2	12	108	432	0 - 427

9.2 Asynchronous mapping of DS1/E1 over VT1.5/VT2

The VT1.5 and VT2 Payload Capacity Envelope can asynchronously map DS1 and E1 datarates respectively using the mapping format structure shown in Figure 49. The four VT pointer bytes for the VT1.5 and VT2 are never shown since they reside outside the VT SPE.

FIGURE 49. DS1/E1 ASYNCHRONOUS MAPPING OVER VT1.5/VT2



10.0 REFERENCES

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