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**JungleMUX  
SONET Multiplexer**

**SONET 101  
FOR JUNGLEMUX USERS**

**Self-Paced Workbook**

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# **SONET 101 for JungleMUX Users**

## **Self-Paced Workbook**

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## **1. BEFORE YOU START...**

The purpose of this unit of instruction is to provide you with SONET knowledge necessary for understanding JungleMUX equipment operation, as well as performing JungleMUX equipment maintenance and troubleshooting tasks.

Understanding material covered in this workbook and completion of exercises provided in Section 3 are prerequisites for JungleMUX Training Course.

This unit of instruction will take approximately 5 hours to complete.

### ***Learning Objectives***

After completing this unit of instruction, you will be able to:

- Name SONET hierarchical signals, their rates and capacities
- Describe SONET STS-1 frame format and its content
- Name SONET layers and explain their purpose
- Identify SONET overhead bytes and explain their purpose
- Understand the operation of pointers
- Describe the structure of STS-1 SPE frame
- Describe the structure of VT1.5 superframe

### ***Prerequisites***

The prerequisites for this self-paced training are:

- Basic digital transmission theory
- Principles of Time Division Multiplexing (TDM)
- Familiarity with asynchronous digital transmission hierarchy rates and signals (DS0, DS1, DS1C, DS2, DS3)

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## 2. INTRODUCTION TO SONET

SONET is an acronym for Synchronous Optical NETWORK and is a standard for optical communication. The SONET standard was initiated by Bellcore on behalf of the Regional Bell Operating Companies (RBOCs) for the following purposes:

- optical interconnectivity in multi-vendor environment (mid-span meet)
- eliminating the need for multi-stage multiplexing
- positioning the network for transport of new services
- synchronous networking
- enhanced Operations, Administration, and Maintenance (OAM)
- bandwidth management capabilities

In Phase 1 (1988) of SONET standardization ANSI (American National Standards Institute) defined a hierarchy of synchronous rates and formats, overhead definitions and layering, frequency justification principles, scrambling algorithm, and payload mapping schemes for signals from asynchronous multiplexing hierarchy.

In Phase 2 (1991) ANSI defined additional payload mapping schemes for some new services. Also, further definitions in OAM capabilities were provided and some aspects on Automatic Protection Switching were clarified.

### ***Digital Hierarchy***

SONET defines optical carrier (OC) levels and their electrical equivalent - Synchronous Transport Signals (STS). The base rate is 51.84 Mb/s (STS-1). The STS-1 is a basic building block for higher SONET rates and the higher rates are direct integer multiples of the base rate. STS-N has exactly N times the rate of 51.84 Mb/s. For example, STS-12 is exactly  $12 \times 51.84 = 622.080$  Mb/s.

The bit rate and capacity for each level is shown in Table 1.

Note that STS-N and OC-N signals have the same bit rate and frame formats; STS-N signals become OC-N signals after electrical to optical conversion and vice versa.

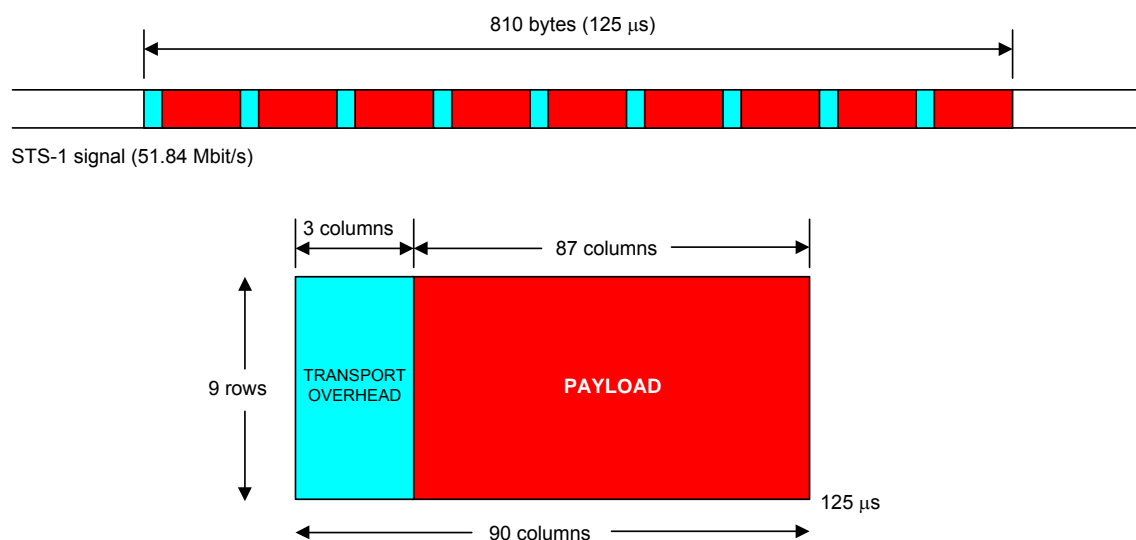
STS Level	OC Level	Bit Rate (Mbit/s)	# of 64 kb/s Channels
STS-1	OC-1	51.84	672
STS-3	OC-3	155.52	2016
STS-12	OC-12	622.08	8064
STS-48	OC-48	2488.32	32,256
STS-192	OC-192	9953.28	129,024
STS-768	OC-768	39,813.12	516,096

**Table 1:** Bit rates in SONET

### STS-1 Frame Format

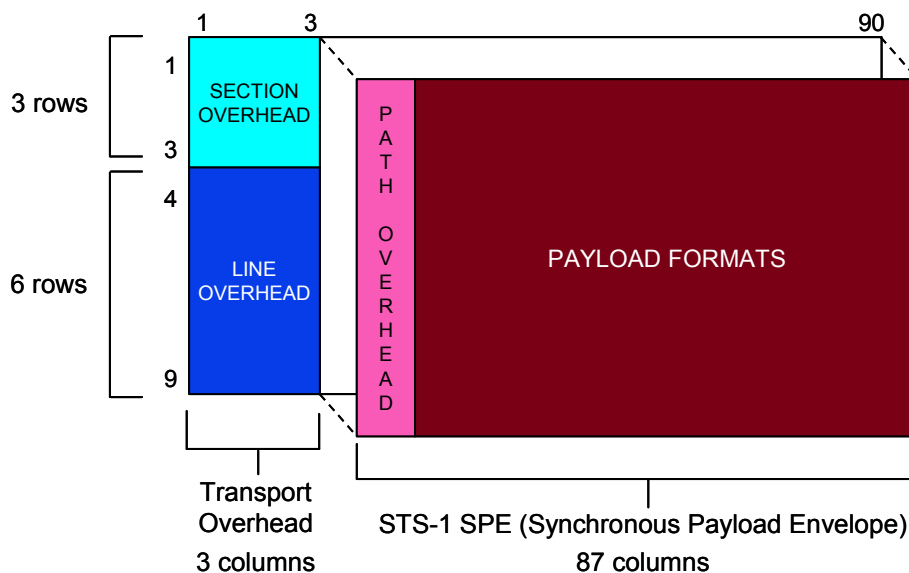
A SONET signal, as any other digital multiplex signal, is made of continuous stream of frames. The STS-1 frame (Figure 1) consists of 810 bytes (8 bits in a byte) and its duration is 125  $\mu$ s. It is usually represented in a 9-row matrix form. The bytes are transmitted row by row; the first byte of the first row is transmitted first and the last byte of the ninth row is transmitted last.

The STS-1 frame is divided into two main areas: Transport Overhead and Payload. The Transport Overhead helps managing the STS-1 frame and is located in the first three columns (27 bytes). The payload is used to carry tributary signals (traffic) and consists of 783 bytes (87 columns x 9 rows).



**Figure 1:** STS-1 Frame Structure

The first three rows of the Transport Overhead make up the Section Overhead (Figure 2). The rest of the Transport Overhead (last 6 rows) makes up Line Overhead.



**Figure 2:** Types of Overhead

The STS-1 frame carries one STS-1 Synchronous Payload Envelope (STS-1 SPE) in its payload area.

Higher rate SONET signals are produced by byte-interleaving N STS-1s to form an STS-N signal. The STS-N signal is then scrambled and converted to an optical carrier level OC-N. In general, STS-N frame is a 9 row matrix with N x 90 columns and its Transport Overhead occupies first N x 3 columns. The STS-N payload area occupies N x 87 columns and carries N STS-1 SPEs.

### ***Sub-STS-1 Synchronous Signals***

The STS-1 SPE can be used to carry a tributary signal requiring large bandwidth, e.g. a DS3 signal (45 Mb/s), or can be formatted to carry a number of smaller "containers" (sub-STS-1 synchronous signals) called Virtual Tributaries (VTs). There are four sizes of "containers" (different VT types): VT1.5, VT2, VT3 and VT6.

The number associated with each VT type depicts the rate of a signal from the asynchronous transmission hierarchy that can be carried in it. A VT1.5 has the capacity to transport one DS1 signal (1.544 Mb/s) or 24 DS0 signals (64 kb/s). Similarly, the capacities of VT2, VT3 and VT6 are tailored to carry one CEPT 1 (2.048 Mb/s), DS1C (3.152 Mb/s) and DS2 (6.312 Mb/s) respectively.

The STS-1 payload has the capacity to transport up to the following:

- 28 DS1s, or
- 14 DS1Cs, or
- 7 DS2s, or
- 1 DS3, or
- 21 CEPT 1s (2.048 Mb/s ITU-T type signal, well known as E1 signal), or
- combinations of the above signals.

A VT can also be used to carry a signal (service) other than the signal it is originally targeted for if its bit rate does not exceed the capacity of the VT. For services that require more bandwidth than a VT can provide, it is possible to concatenate two or more VTs in order to provide the required bandwidth.

As the JungleMUX equipment uses VT1.5s only, other types of VTs will not be discussed in this document. Therefore, whenever a VT acronym is used, it is referring to VT1.5.

### ***STS Concatenation***

If the tributary signal's bit rate exceeds the capacity of STS-1 SPE ( $\approx 50$  Mb/s), multiple STS-1 SPEs are needed for its transport. For that purpose, SONET defines *STS-Nc SPE* ( $N=3, 12, 48$ ) consisting of  $N$  STS-1 SPEs that are linked together (concatenated) and carried by an STS-N/OC-N or higher rate signal. SONET also defines standard interfaces for mapping common high capacity tributary signals into STS-Nc SPEs.

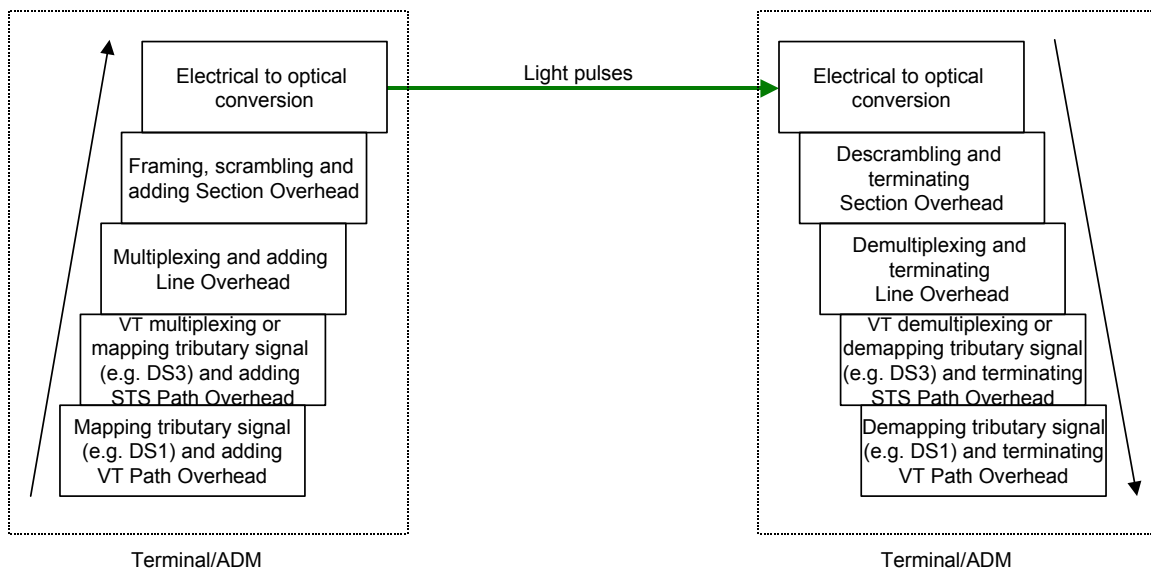
JungleMUX uses multiple independent STS-1 SPEs and proprietary interfaces for mapping high capacity tributaries. With exception of OC-48 units, JungleMUX cannot process STS-Nc signals originated by foreign SONET nodes.



## SONET Layers

SONET processing functions are divided into layers. The layers defined are Section, Line, STS Path<sup>1</sup> and VT Path. The Section is the highest while the VT Path is the lowest in this hierarchy.

There is overhead information associated with each of these layers: Section Overhead associated with Section layer, Line Overhead associated with Line layer, STS Path Overhead associated with STS Path layer, and VT Path Overhead associated with VT Path layer.



**Figure 3: SONET Processing Functions**

When a tributary signal is transmitted through a SONET network, it is mapped, depending on its bit rate, into a VT or an STS-1 SPE. At the same time, the corresponding Path Overhead information is generated and the tributary signal enters a Path layer (VT Path or STS Path).

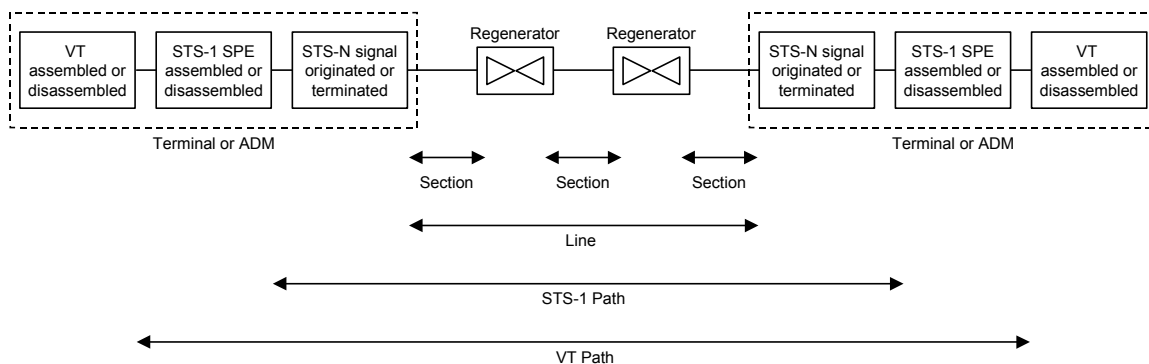
Once the VT has been multiplexed with other 27 VTs into an STS-1 SPE, the STS-1 Path layer is entered. Obviously, the STS-1 Path may be shared by a number of VT Paths.

N STS-1 SPEs are multiplexed into an STS-N signal. The Line Overhead is added first at which point the signal enters the Line layer. Note that N STS-1

<sup>1</sup> STS path refers to both STS-1 and STS-Nc paths. JungleMUX can originate and terminate only STS-1 paths.

Paths share the same Line. Finally, when the Section Overhead is added, the signal enters the Section Layer.

Access to the overhead information is restricted in a SONET network. As shown in Figure 4, only the Section Overhead (framing, scrambling, and performance monitoring) is processed at a regenerator site. At a terminal or add/drop multiplexer (ADM) site, in addition to the Section Overhead, the Line Overhead is processed to control synchronization, multiplexing, protection switching, and performance monitoring. STS-1 Path Overhead is processed at the terminal or ADM if the STS-1 SPE is to be assembled/disassembled at that site. VT Path Overhead is processed only for the VTs that are to be added/dropped at the site.



**Figure 4: SONET Layers**

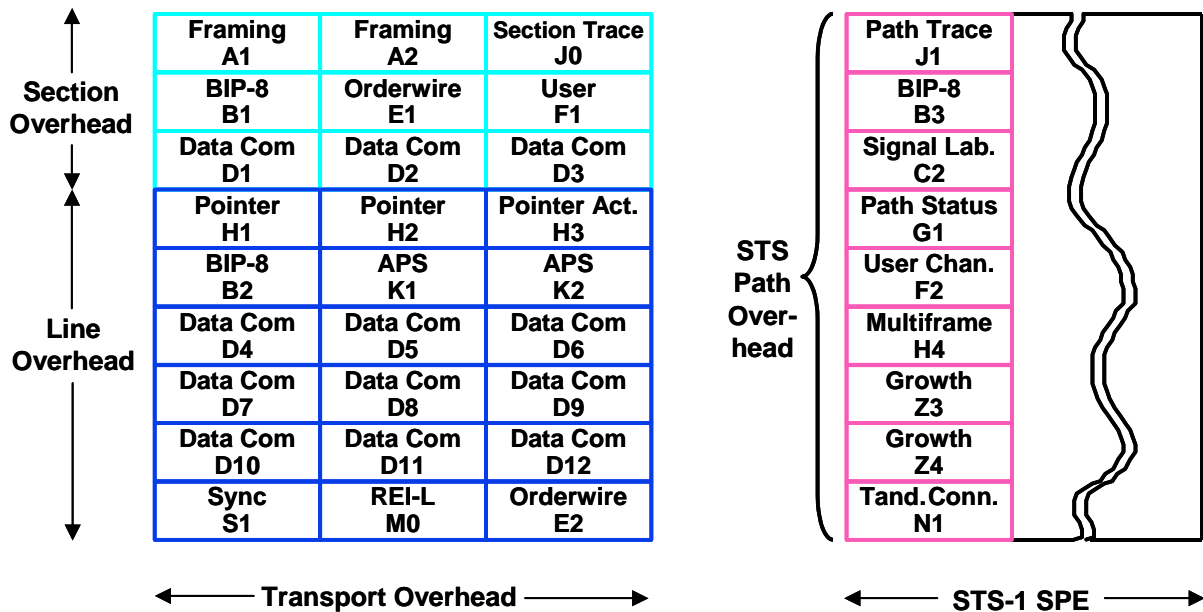
Note that if there is no regenerators on a span, the Section and Line overlap<sup>2</sup>.

The SONET layers significantly facilitate troubleshooting in a SONET network. In general, an alarm at certain layer will cause alarms at all lower layers while higher layers and peer layers may not be in alarm. For example, an abnormal condition of received STS-1 signal carried within OC-3 signal will cause all VTs carried in that STS-1 to be in alarm but other two STS-1 signals and OC-3 signal need not be in alarm. Similarly, a fiber cut will cause alarms at all layers, while a failure on a card terminating a VT will cause an alarm on the affected VT path only.

<sup>2</sup> As the JungleMUX equipment does not have regenerators, the Section and Line layers overlap for all spans in a JungleMUX network.

**Overhead Information**

The byte assignments for Transport Overhead and STS Path Overhead (STS POH) are shown in Figure 5.



**Figure 5:** Transport Overhead and STS Path Overhead Layout

Definitions for the bytes depicted in Figure 5 are given in Table 2.

Byte	Location	Function
Framing	A1, A2	Indicates beginning of an STS-1 frame. Contains the value '1111011000101000'.
Section Trace	J0	Used to repetitively transmit a section access point unique identifier so that a section receiver can verify its continued connection to the intended transmitter.
BIP-8	B1	The Bit Interleaved Parity 8 code is used to determine if a transmission error has occurred over the Section.
Orderwire	E1	Provides a 64 kb/s channel between section entities. Used as a voice communication channel for maintenance personnel.
User	F1	Set aside for network user purpose. Passed from one section entity to another.
DCC	D1, D2, D3	Provides a 192 kb/s Data Communication Channel for OAM purposes.
STS-1 Pointer	H1, H2	These two bytes specify the beginning of the STS-1 SPE within the frame.
Pointer Action	H3	Used as a negative justification opportunity byte.

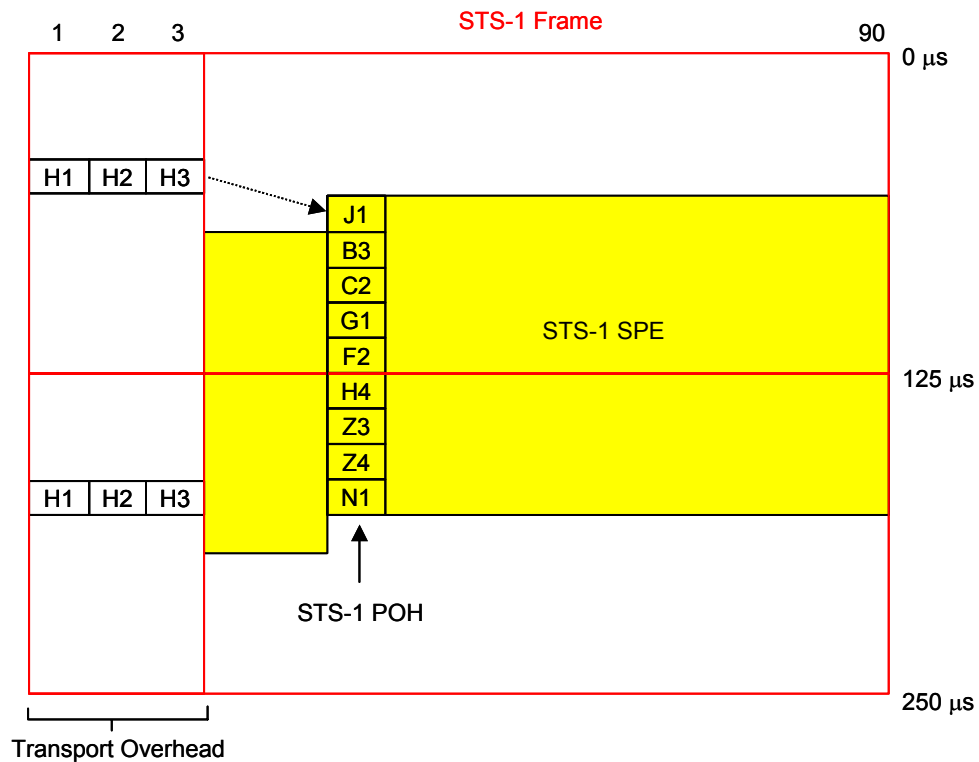
BIP-8	B2	The Bit Interleaved Parity 8 code is used to determine if a transmission error has occurred over the Line.
APS	K1, K2	Used in systems using automatic protection switching at Line level (e.g. BLSRs) and for detection of Line AIS and Line RDI.
DCC	D4 to D12	Provides a 576 kb/s Data Communication Channel for OAM purposes.
Sync	S1	Carries synchronization status message information.
REI	M0	Carries the count of errors detected by line BIP-8 (B2) byte at the far-end line terminal.
Orderwire	E2	Provides a 64 kb/s channel between line entities. Used as a voice communication channel for maintenance personnel.
Trace	J1	User defined to identify that the correct connection is made between two end points of the STS path.
BIP-8	B3	The Bit Interleaved Parity 8 code is used to determine if a transmission error has occurred over the STS path.
Signal Label	C2	Used to indicate the payload type in the STS-1 SPE.
Path Status	G1	Used to convey STS path status information between the destination terminating equipment and the originating terminating equipment.
User Channel	F2	Allocated for network provider purposes.
Multiframe Indicator	H4	Used for VT structured payloads.
Growth	Z3, Z4	For future use.
Tandem Conn. Maintenance	N1	Bits 1-4 are used to provide the Tandem Connection Incoming Error Count (ANSI T1.105.05). Bits 5-8 are used to provide the Path Data Channel. JungleMUX does not use this byte.

**Table 2:** Transport Overhead and STS Path Overhead Byte Definitions

**Pointers**

Different synchronizing techniques are used for multiplexing. In asynchronous systems, since the timing for each multiplexer is not locked to a common clock, there are large frequency variations. Bit stuffing is used to synchronize the various low speed signals to a common rate before multiplexing.

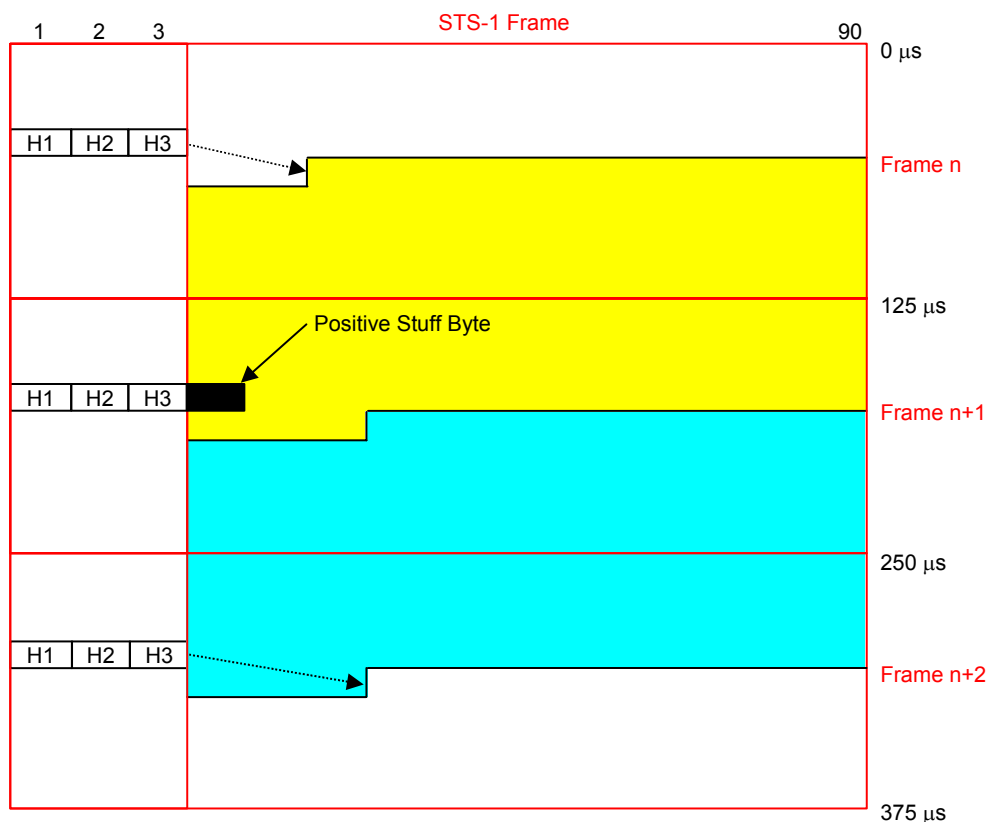
SONET uses a new concept called "pointers" to compensate for frequency and phase variations. Figure 6 shows an STS-1 pointer that allows the STS-1 SPE to be separated from the STS-1 frame. The STS-1 pointer is located in the Line Overhead (bytes H1 and H2) and is a binary number that indicates the offset between the pointer and the first byte of the STS-1 SPE. In other words, it points to where the SPE begins (in relation to Transport Overhead). The STS-1 pointer range is 0 to 783. Figure 6 depicts the typical case of the SPE overlapping onto two STS-1 frames. It starts in one STS-1 frame and ends in another.



**Figure 6: STS-1 Pointer**

If there are any frequency or phase variations between the STS-1 frame and its SPE, the SPE can slide forward or backward. In such cases, the pointer value is increased or decreased accordingly to keep track of the SPE and maintain synchronization. The change of pointer value is accomplished by either positive stuffing (positive justification) or negative stuffing (negative justification).

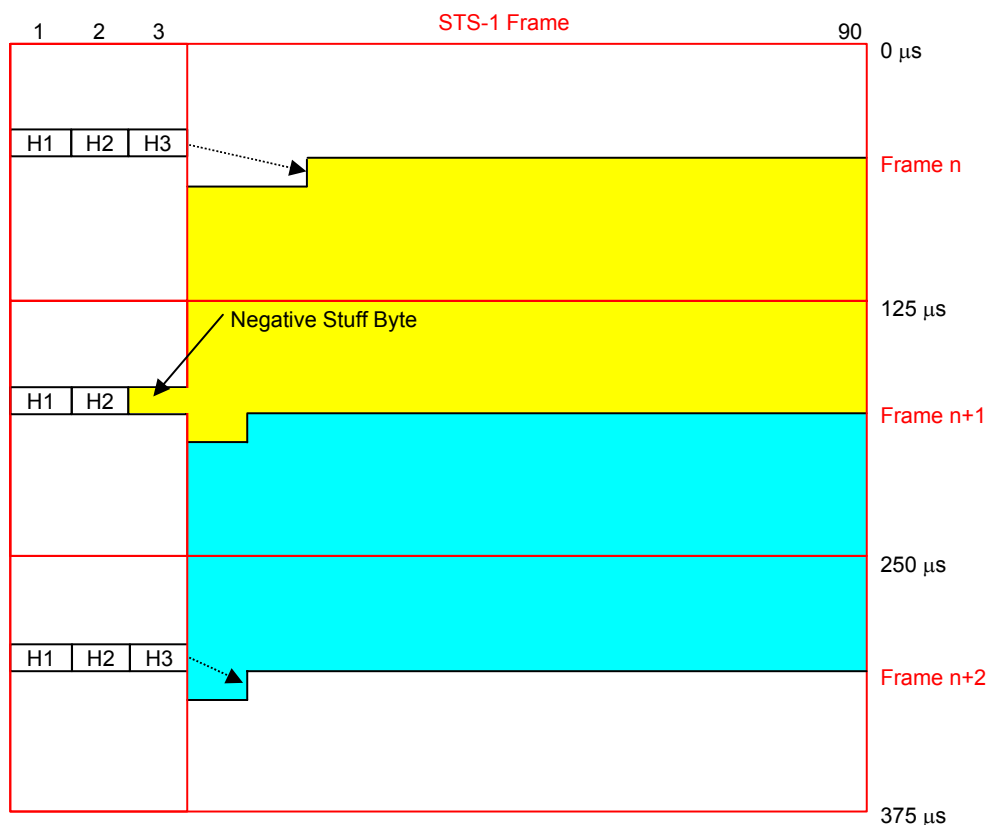
*Positive stuffing* (Figure 7) occurs when the STS-1 SPE frame rate is slower than the frame rate of the STS-1 signal. The positive stuff byte appears immediately after the H3 byte. Subsequent pointers contain a new, incremented pointer value.



**Figure 7: Positive Stuffing**

*Negative stuffing* (Figure 8) occurs when the STS-1 SPE frame rate is faster than the frame rate of the STS-1 signal. The negative stuff byte (actual data) appears in the H3 byte. Subsequent pointers contain a new, decremented pointer value.

The larger the difference between STS-1 and STS-1 SPE frame rates is, the more frequent pointer activities are. Since the maximum frequency of pointer activities that can be handled in a pointer processor is limited, the frequency offset between SONET nodes must not exceed certain values. However, large number of pointer activities degrades the wander characteristic of transported tributary signals so it is very important to keep the SONET network "as synchronous as possible". Therefore, in a SONET network, normally, all individual node clocks are referenced back to a single clock reference source.



**Figure 8: Negative Stuffing**

There are also VT pointers which allow individual low-speed signals (mapped in VTs) to be separated from STS-1 SPE. These pointers will be discussed later in this document.

The use of pointers provides the following advantages:

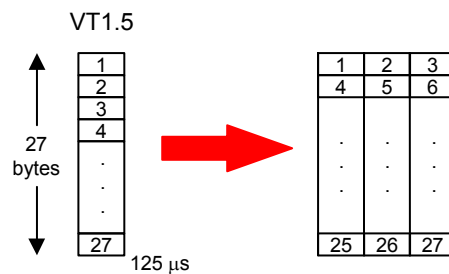
- Pointers provide dynamic and flexible phase alignment of STS-1 and VT payloads (SPEs), thereby permitting ease of dropping, inserting, and cross-connecting these payloads in the network.
- Pointers allow the transparent transport of SPEs (either STS-1 SPEs or VT SPEs) across network boundaries with plesiochronous<sup>3</sup> timing sources, i.e. between nodes with slightly different clock rates. Also, transmission signal wander (low frequency jitter) can be readily accommodated with pointers.
- The use of pointers avoids the delays and loss of data associated with the use of large (125 μs frame) slip buffers for synchronization.

<sup>3</sup> Plesiochronous means "almost synchronous".

### **VT1.5 Capacity**

A VT1.5 frame consists of 27 bytes that are transmitted every 125  $\mu$ s. The VT frame is represented as a byte matrix of 9 rows by 3 columns (Figure 9). The VT1.5 bit rate is  $27 \times 64 \text{ kb/s} = 1.728 \text{ Mb/s}$  and it can transport a DS1 signal (1.544 Mb/s) or 24 DS0 (64 kb/s) channels.

A VT1.5 frame occupies three columns of an STS-1 SPE.

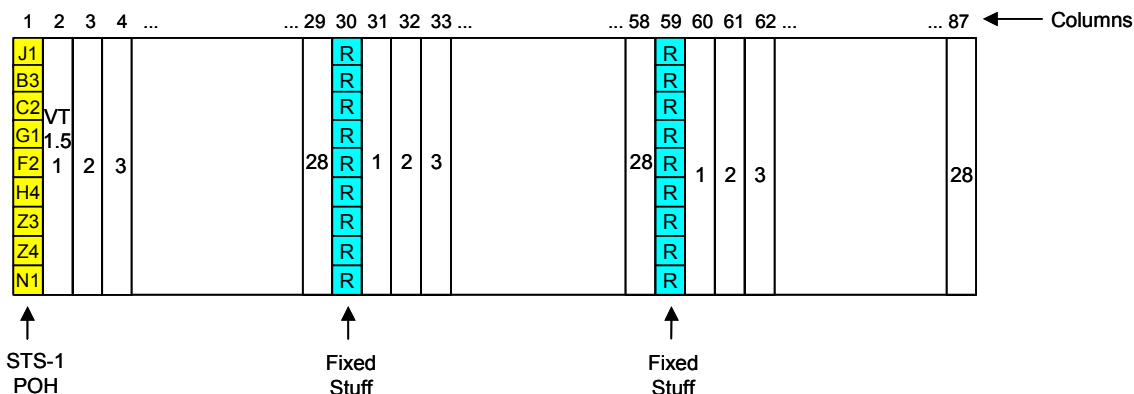


**Figure 9:** VT1.5 frame

### **STS-1 SPE carrying all VT1.5s**

An STS-1 SPE frame consists of 87 9-byte columns. The virtual tributaries carried in an STS-1 SPE are byte interleaved, i.e. they are multiplexed byte by byte. The first column of an STS-1 SPE is used for STS Path Overhead, 84 columns are used for transmitting VTs, and two columns (30 and 59) are unused. A maximum of 28 VT1.5s can be carried in an STS-1 SPE (Figure 10). Hence, a maximum of 28 DS1 signals or 672 DS0 channels can be transported in a VT1.5 structured STS-1 signal. In general, STS-N (OC-N) signal can transport up to  $N \times 28$  DS1 signals ( $N \times 672$  DS0 channels).





**Figure 10:** VT1.5 Structured STS-1 SPE

### VT Mapping

VTs use the VT pointers to allow the VT payload (VT SPE) to float within the VT capacity. Therefore, each VT can be individually added/dropped at a node and VT switching is supported. A VT has the VT Path Overhead.

There are three types of VT mapping: *asynchronous*, *bit synchronous*, and *byte synchronous*.

Asynchronous mapping of tributaries is mandatory if the tributaries are not synchronous to the SONET network clock. Bit synchronous and byte synchronous mapping require tributaries to be synchronous with the SONET network clock.

Byte synchronous mapping allows each byte of a byte structured tributary signal frame to be mapped into a dedicated byte in a VT frame thus providing visibility of each tributary signal's byte after mapping.

In the JungleMUX system, DS1 tributaries are mapped into VT1.5s using asynchronous mapping while DS0 applications are mapped into VT1.5s using byte-synchronous mapping.

### VT Superframe

The VTs are organized in 500  $\mu$ s structures called *superframes*. A VT superframe consists of the same VT over four consecutive STS-1 SPE frames.

Although all 28 VT1.5s in a floating VT mode structured STS-1 SPE are organized in superframes, only one VT (VT#3) is highlighted in Figure 11.

The VT superframe consists of 108 bytes (four 27-byte VT frames) and is divided into two areas: VT pointer (bytes V1, V2, V3, and V4) and VT capacity (104 bytes).

The VT payload (VT SPE) is a 104-byte structure that may float within the VT capacity of two consecutive VT superframes. The operation of the VT pointer is similar to the STS-1 pointer and it indicates the offset of the VT payload with respect to the V2 byte, i.e. it points to where the VT payload begins. The V1 byte is '6C' hex ('01101100') if there is no pointer activity in the current superframe. The V2 byte carries a VT pointer value (range for VT1.5 pointer is 0 to 103 decimal)<sup>4</sup>. V3 byte is a negative justification opportunity byte (positive justification opportunity byte is the first byte in the VT capacity after the V2 byte, i.e. byte #26). The V4 byte is not used and is set to a fixed value.

The VT1.5 payload is a 104-byte structure that, in the case of byte-synchronous mapping, consists of VT Path Overhead (bytes V5, J2, N2, K4), PSFR bytes, and DS0 channels (Figure 12). The content of the VT1.5 Payload is transmitted in 500  $\mu$ s time frame.

The first byte of the VT1.5 Payload is the V5 byte which is a VT Path Overhead byte. This byte is identified by the pointer carried in the V2 byte. Other three VT POH bytes (J2, N2, K4) are currently unused and are carrying fixed stuff (all '1's).

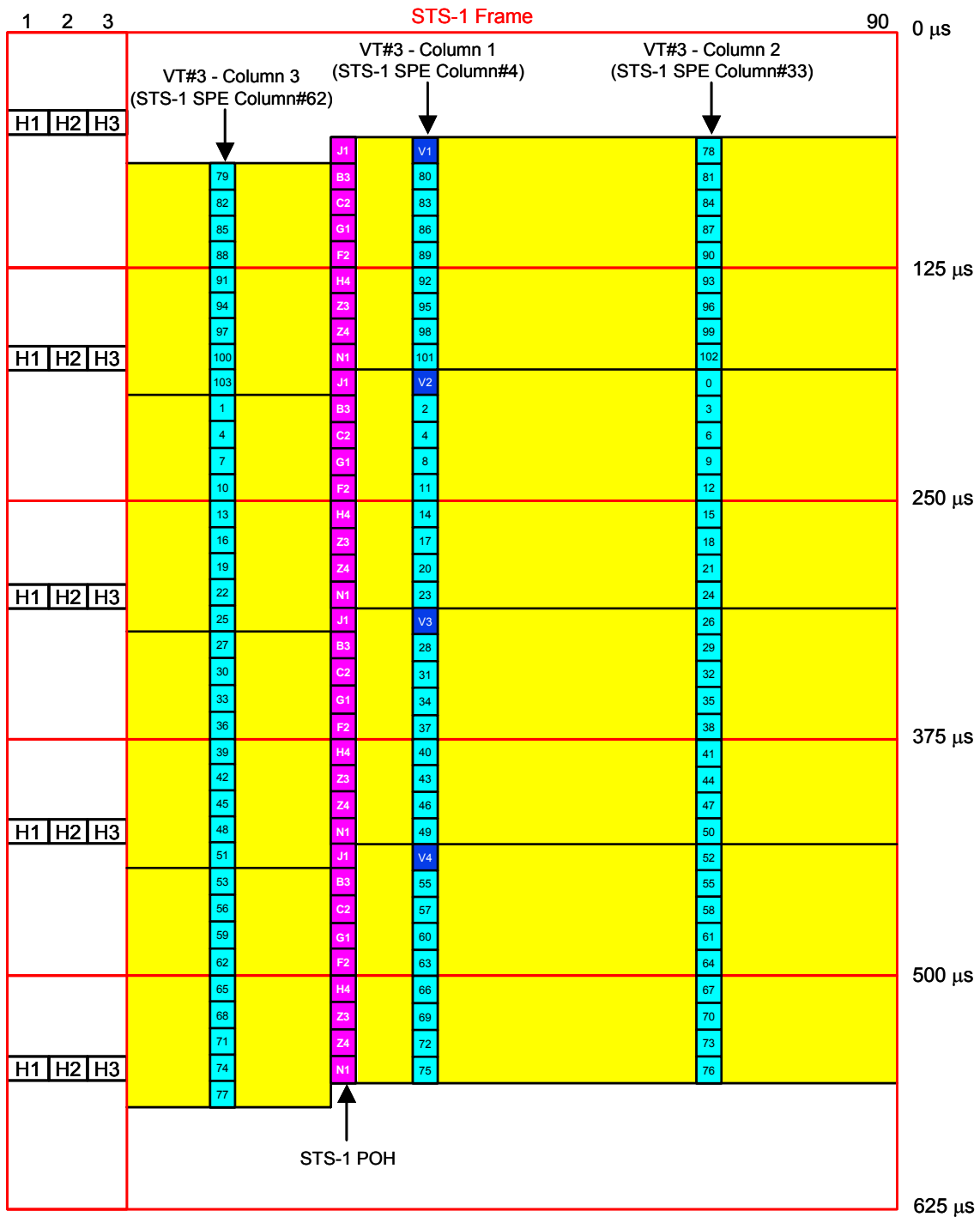
The PSFR bytes are used to transport:

- signaling information for VF channels (common channel signaling),
- signaling phase information, and
- content of the F bit of the byte-synchronously mapped DS1 signal (if applicable<sup>5</sup>).

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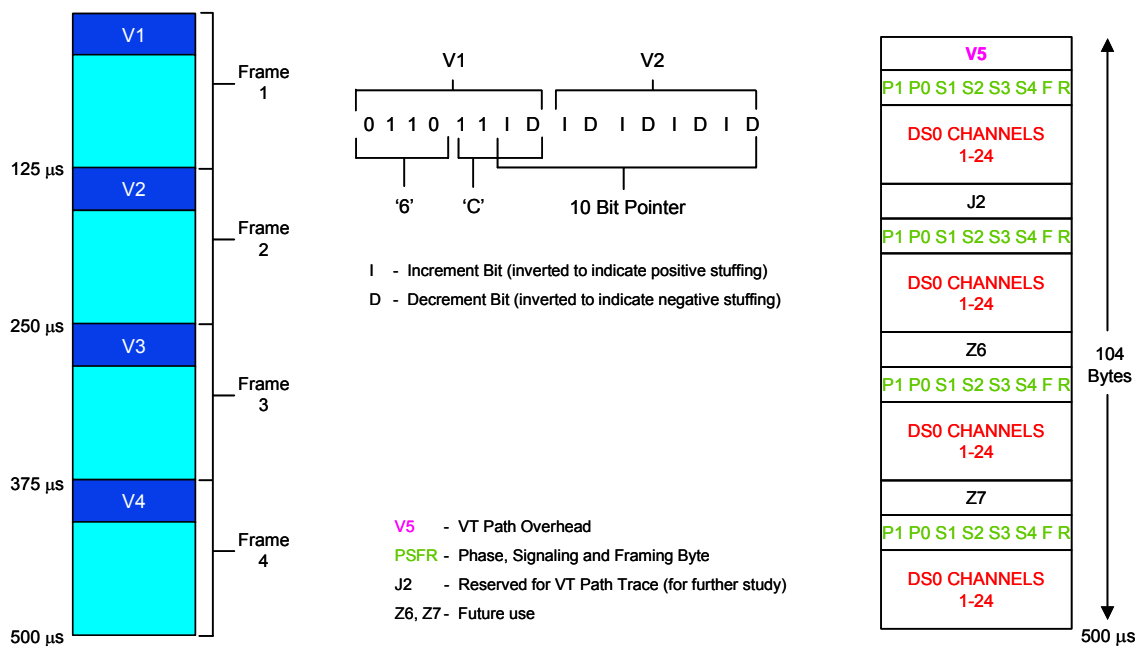
<sup>4</sup> Although 10 bits have been allocated for a VT pointer value (two least significant bits in byte V1 and all 8 bits in byte V2), in the case of VT1.5 pointer, only 7 bits (7 least significant bits in byte V2) are used for full pointer range (0 to 103 decimal).

<sup>5</sup> As the JungleMUX uses the byte-synchronous mapping only for direct mapping of DS0 applications into VTs, bit F is not used for the stated purpose.



**Note:** VT#3 in JungleMUX VT designation scheme corresponds to VT#1 in VT Group #3.

**Figure 11:** Position of a VT Superframe



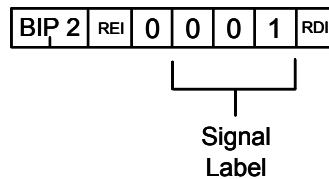
**Figure 12: VT1.5 Superframe Structure for Byte-Synchronous Mapping**

The rest of the VT Payload is used to carry 24 DS0 channels. Note that four bytes assigned to each channel are equally spaced out in time (125 μs) and they keep the same four locations in every VT payload (for example, DS0 channel#1 uses third, twenty-ninth, fifty-fifth, and eighty-first byte in every VT1.5 Payload frame) which ensures visibility of the DS0 channels. The JungleMUX uses byte synchronous mapping, hence it is able to add/drop individual DS0 channels directly to/from the SONET signal.

Figure 13 provides the information on the typical content of the V5 byte in JungleMUX originated VT1.5s.

Most of the JungleMUX originated VT1.5s carry the signal label set to '001' (equipped non-specific). The exceptions are VTs carrying DS1 signals whose label is set to '010' (asynchronous mapping)<sup>6</sup> and VTs carrying VMapper-10 signals whose label is set to '101' (when indicating a "no ring failure condition") or '111' (when indicating a "ring failure condition").

<sup>6</sup> The older of the two JungleMUX unit types providing DS1 interface (JIF-DS1) is user programmable to insert either "equipped non-specific" label ('001') or "asynchronous mapping" label ('010'). The newer version of DS1 interface unit (Quad DS1) sets the label to "asynchronous mapping" ('010').



- BIP-2 - Error Detection
- REI - Remote Error Indication (CV info from the far end)
- Signal Label: '001' - Equipped Non-Specific  
 '010' - Equipped – Asynchronous Mapping (DS1)
- RDI - Remote Defect Indication ("VT Path Yellow Alarm")

**Figure 13: V5 Byte Content**

The least significant bit of the V5 byte carries the RDI information ("VT yellow alarm") i.e. the status of the received VT at the far end. Thus, for example, for a VT carrying DS0 applications, the four least significant bits of the V5 byte may be received either as '0010' (hexadecimal '2') if there is no yellow alarm or as '0011' (hexadecimal '3') if the yellow alarm is present.

**Multiframe Indicator – H4 byte**

Byte H4 in STS POH is a VT multiframe (superframe) phase indicator. It carries the information on which 27-byte frame of the VT superframe is transmitted in the current STS-1 SPE. Note that all VT superframes in an STS-1 SPE are "in phase", so the H4 byte is indicating the phase for all of them. Only two lowest significant bits of this byte are used for this purpose. Values '00', '01', '10', and '11' indicate that the next STS-1 SPE frame will be carrying frames with V1, V2, V3, and V4 bytes respectively (Table 3).

Bit:	1	2	3	4	5	6	7	8	Next Frame
	1	1	1	1	1	1	0	0	1
	1	1	1	1	1	1	0	1	2
	1	1	1	1	1	1	1	0	3
	1	1	1	1	1	1	1	1	4

**Table 3: H4 Byte Coding Sequence**

Figure 14 shows the relationship between H4, V1, V2, V5, PSFR bytes and their position in a byte-synchronously mapped floating mode VT1.5 superframe.

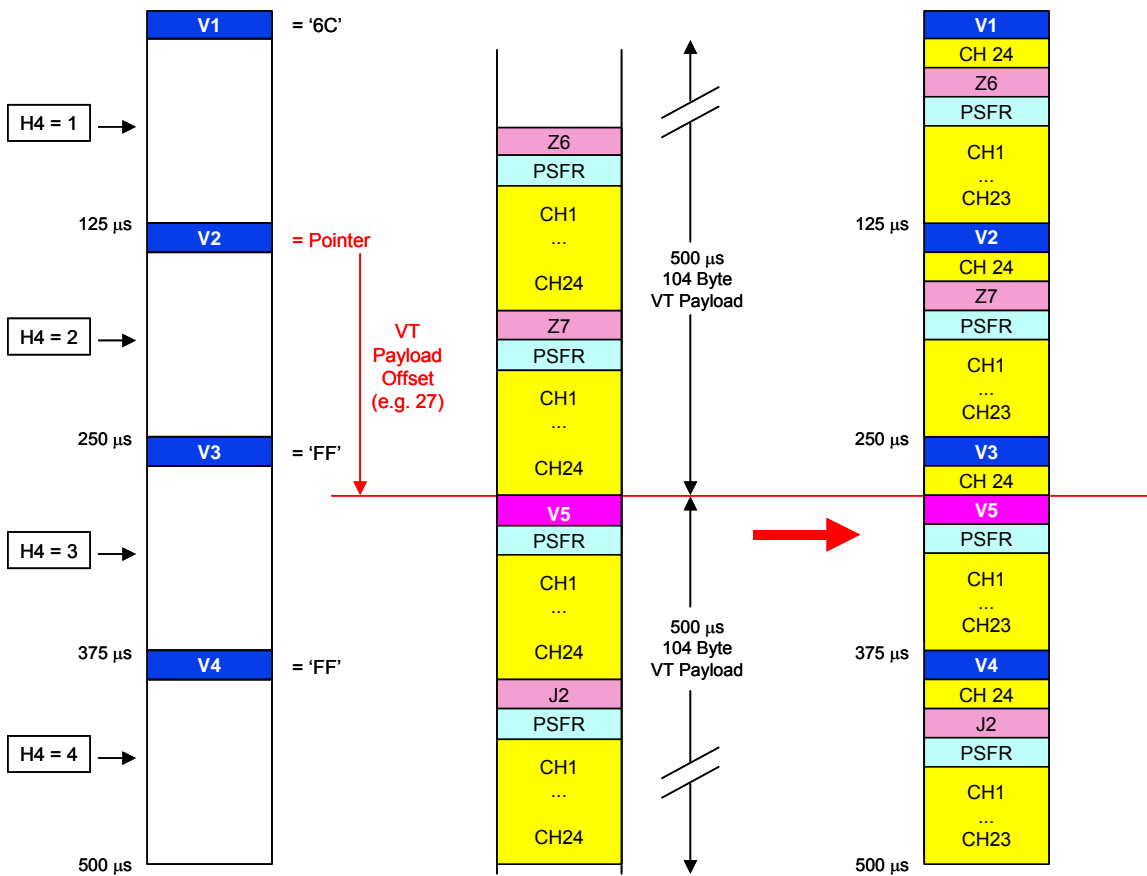


Figure 14: VT1.5 Payload Offset

### 3. EXERCISES

Students are required to have these exercises completed before the start of the JungleMUX training course. Instructor will review answers at the beginning of the training course.

**Please circle more than one answer if applicable.**

1. What are the bit rates of OC-1, OC-3 and OC-12 signals?

OC-1: \_\_\_\_\_ OC-3: \_\_\_\_\_ OC-12: \_\_\_\_\_

2. How many bytes of an STS-N frame does the Section Overhead occupy?

- a)  $N \times 3$
- b)  $N \times 9$
- c)  $N \times 27$
- d)  $N \times 81$

3. How many STS-1 SPEs are carried in an OC-12 signal? \_\_\_\_\_

4. What is the maximum number of VT1.5s that can be transmitted in OC-1, OC-3 and OC-12 signals? What is the corresponding maximum number of DS0 channels?

	VT1.5s	DS0 channels
OC-1		
OC-3		
OC-12		

5. Which of the following traffic combinations can be transported via a single OC-3 signal?

- a) 1 DS3 and 72 DS1s
- b) 2 DS3s and 26 DS1s
- c) 2 DS3s and 29 DS1s
- d) 80 DS1s

6. What column of the STS-1 frame is used for STS POH transport?
- a) STS-1 column 1
  - b) STS-1 column 4
  - c) depends on the VT pointer value; can spread across two or more STS-1 columns
  - d) depends on the STS-1 pointer value; any STS-1 column between 4 and 90
7. What SONET layer(s) will be affected by a fiber cut?
- a) Line layer
  - b) Section layer
  - c) Section and Line
  - d) All layers
8. a) What layer is a DS3 signal entering immediately after mapping?
- \_\_\_\_\_
- b) Can the STS-1 signal formatted for carrying a DS3 signal support any signals in the VT Path layer?
- Yes                  No
9. If a unit providing DS1 signal mapping/demapping has failed, what layer(s) is affected?
- a) STS-1 Path
  - b) VT Path and STS-1 Path
  - c) VT Path
  - d) All layers



10. a) What is the purpose of DCC (Data Communication Channel) bytes?

\_\_\_\_\_

b) What part of the STS-1 frame are DCC bytes located in?

\_\_\_\_\_

c) How many DCC bytes have been defined?

\_\_\_\_\_

11. Match the following bytes with the proper name/description. Fill in the blanks with the correct letter.

- |  |           |
|--|-----------|
| ___ Used for determining BER on STS Path | a) S1     |
| ___ Sync Messaging Byte (Sync Marker)    | b) H4     |
| ___ Orderwire Byte                       | c) H1, H2 |
| ___ STS Path Status Byte                 | d) E1, E2 |
| ___ Multiframe Indicator                 | e) B3     |
| ___ STS-1 pointer                        | f) G1     |

12. What byte is pointed by the STS-1 pointer?

- |       |       |
|-------|-------|
| a) H2 | c) V1 |
| b) V5 | d) J1 |

13. What column(s) of a VT-structured STS-1 SPE is not defined for any particular use (defined as a fixed stuff)?

- |              |                                 |
|--------------|---------------------------------|
| a) column 1  | c) column where byte V4 resides |
| b) column 88 | d) columns 30 and 59            |

14. How many bytes does the VT1.5 superframe have?

- a) 27
- b) 103
- c) 104
- d) 108

15. How many bytes does the VT1.5 Payload have?

- a) 26
- b) 103
- c) 104
- d) 108

16. Match the following bytes with the proper name/description. Fill in the blanks with the correct letter.

- |  |         |
|--|---------|
| ___ VT1.5 pointer value                | a) V5   |
| ___ VT Path Overhead                   | b) PSFR |
| ___ Used for transport of VF signaling | c) V2   |

17. What is the decimal range for the VT pointer value?

- a) 0-26
- b) 0-103
- c) 1-104
- d) 1-108

18. What is the hexadecimal two-digit value of a healthy VT1.5's V1 byte?

\_\_\_\_\_

19. What hexadecimal digit represents the value of the four least significant bits of the V5 byte of an alarm-free VT1.5 (carrying DS0 channel applications)?

- a) '6'
- b) '2'
- c) 'C'
- d) '3'

## APPENDIX A

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## APPENDIX B

### LIST OF ACRONYMS

- ADM Add/Drop Multiplexer
- AIS Alarm Indication Signal
- BER Bit Error Rate
- BIP Bit-Interleaved Parity
- BPV Bipolar Violations
- CV Code Violations
- DCC Data Communication Channel
- DS1 Digital Signal 1
- ESF Extended Superframe Format
- LOF Loss Of Frame
- LOP Loss Of Pointer
- NMS Network Management System
- OAM Operations, Administration, Maintenance
- POH Path Overhead
- RBOC Regional Bell Operating Companies
- RCV Receive
- RDI Remote Defect Indication
- REI Remote Error Indication
- SONET Synchronous Optical NETwork
- SPE Synchronous Payload Envelope
- STS-1 Synchronous Transport Signal 1
- ITU-T International Telecommunication Union – Telecommunication Standardization Sector
- VF Voice Frequency
- VT Virtual Tributary
- XMT Transmit