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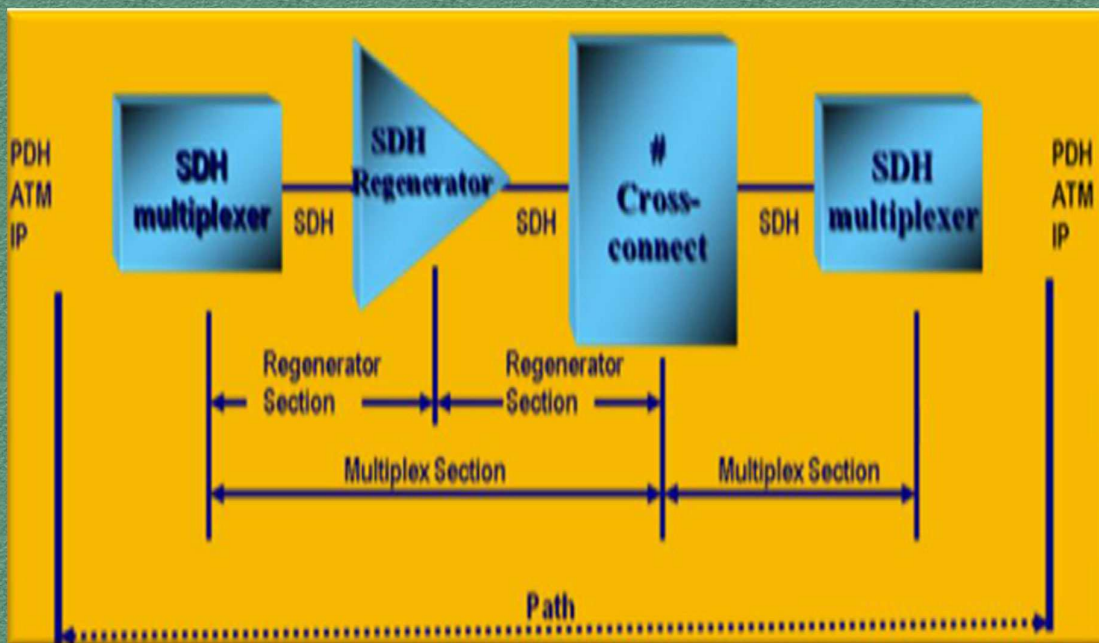
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SDH PRINCIPLES

Indian Railways Institute of Signal Engineering and Telecommunications

SECUNDERABAD - 500 017

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INDIAN RAILWAYS INSTITUTE OF SIGNAL ENGINEERING & TELECOMMUNICATIONS, SECUNDERABAD - 500 017

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TCT5

SDH PRINCIPLES

CONTENTS

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CHAPTER-1

Synchronous Digital Hierarchy (SDH)

Objectives: By going through this chapter, the trainee must be in a position to understand

1. The objectives of SDH.
2. The relative advantages of SDH when compared with PDH.
3. Other features of SDH hierarchy.

1.1 Introduction

Telecommunication is the central nervous system of modern society. No other technology as digital communication has had such a worldwide impact of putting people in touch around the world through voice, video, data etc.

The goal of worldwide telecommunication is free exchange of information throughout the global community. North America, Europe, Japan and India all have different communication standards and hierarchies. Digital networks of these nations cannot be freely connected. The technology of these nations competes with each other and remains incompatible. This not only obstructs telecommunications from one country to the other but also slows down the development.

On a little closer look at the long distance network, it is evident that the present system of independent point to point transmission needs adequate network management capabilities and on line control of network configuration, so that the transport layer is strengthened to match the future requirements of the customers as well as operators. It is particularly true when the multimedia is all set to offer the mega band width services like video on demand. Multimedia service is characterized as integrated computer controlled generation, processing, display, storage, and transmission of text, data, graphics, voice, sound and images including moving picture etc. Obviously the telecom services sector is going to thrive, there by leading to a requirement of a lot more capability on the part of transport to handle variable and much larger bandwidths with better rates and higher availability. The solution, perhaps, lies in the concept of Synchronous Digital Hierarchy (SDH), which can be termed as transport backbone of the broadband era. The Network Node Interface (NNI) operating in Synchronous Digital Hierarchy (SDH) recommended by ITU (T)/CCIR offers a clear solution and sets an international standard for high speed digital transmission.

One of the most important aspects of SDH as a standard for international network is that wide band signals that can be transported with in a Plesiochronous (10^{-11} frequency offset) environment without any loss of data, just like in PDH, with benefits of a Synchronous Frame Structure that simplifies drop and insert and cross connect functions. Note that SDH does not deal with the multiplexing of individual 64 kbps signals. SDH only defines mapping for byte structured first level PDH, which does not alter the characteristics of 64 kbps PDH multiplexing method.

1.2 Evolution

Current public telecommunication networks are based on the long established ITU (T) Plesiochronous Digital Hierarchy (PDH) of transmission which is not well suited to support the advanced signal processing and control techniques now possible and increasingly in demand.

The SDH is designed to overcome the limitations of PDH.

ITU (T) adopted SDH in 1988. The original version was known as SONET -– Synchronous Optical Network that was in use in North America 2 or 3 years prior to ITU (T) adopted it and changed the name as SDH.

1984 : T1X1 American Standardization agency was made responsible for defining   interfaces of optical lines for interconnection of high bit rates between operators.

1985 : Feb 1985, Bell core introduced SONET (Sync Optical Network) concept of T1X1. It defined a new transmission hierarchy, which permits direct access to the lower level tributaries of a multiplex system. The activities of SONET are divided into 3 parts, Frame format, Optical interface and Measurement.

1988 : Feb 1988. The ITU (T)'s G.707, G.708, G.709 recommendations for SDH were approved. Bit rate 155.520 mbps was standardized as basic frame of SDH and the structure remained compatible with utilization of the SONET frame at 51.840 mbps in USA

1989 : The recommendations of ITU (T) working group XVIII were published in Blue Book 1989.

1990 : New versions of the recommendations G.707, G.708, G.709 were approved basing on the decisions of European Telecommunication Standards Institute (ETSI) regarding multiplexing structure. Other recommendations concerning multiplexing equipment, optical interfaces, subscriber loop equipment, network management were approved. The recommendations for cross connection equipment, architecture of synchronous network, and performance data of the network were being drawn up.

The maximum band that can be provided by PDH is 565 mbps and the number of speech channels is 7680, and not in a position to meet any further demand.

The stages of multiplexing and demultiplexing required for higher orders are more which contributes for higher costs, more maintenance where as in SDH system the whole job of multiplexing to higher orders is done by a single multiplexer, there by the cost is less, space occupied is less, maintenance is less.

Bit interleaving multiplexing system adopted in PDH, scatters the bits at every stage, making the identification of the location of each bit very difficult and at the same time to bring them back to the original sample shape, as many stages of demultiplexing are to be carried out to return to its primary mux stage,

Over and above to this, addition of justification bits at every mux stage, further complicates the identification of the location of the already scattered bits.

The present challenge is to migrate from PDH to SDH and the cost constraints of the network. The success of SDH in future is possible because of the following reasons.

- Bandwidth of Fibre Optics can be increased and there is no limit for it.

- Microwave system can transmit digital signals with bit rates extending into the gbps range because of new modulation techniques 256 QAM, Stepped Square QAM(SSQAM) and 1024 QAM.

- Using the ever-increasing capabilities of VLSI technique to have more and more functional integration, which is also very cost effective.

- Availability of cheaper memory opens new possibilities.

- Requirement of customer services can be easily met without much additional equipment.

- The mind boggling penetration of software into every walk of life, and increasing stress on distributed processing with the development of object oriented software.

1.3 Long Distance Network Requirements

- Greater Bandwidth handling capacity due to emergence of broadband services including multimedia.

- Better Bit Error Rates due to merger of Voice & Data Communication.

- Higher availability due to information transfer having attained a state of criticality.

- Enhanced flexibility to accommodate various types of signals available today.

1.4 General Objectives Of SDH

- Creation of a world standard for bit rates above 140 mbps.

- To enable synchronous higher order digital multiplexing.

- Normalization of auxiliary data (overhead).

- More flexibility for networking.

- Direct access to tributaries

- Transport of both American (T) and European (E) PDH tributaries.
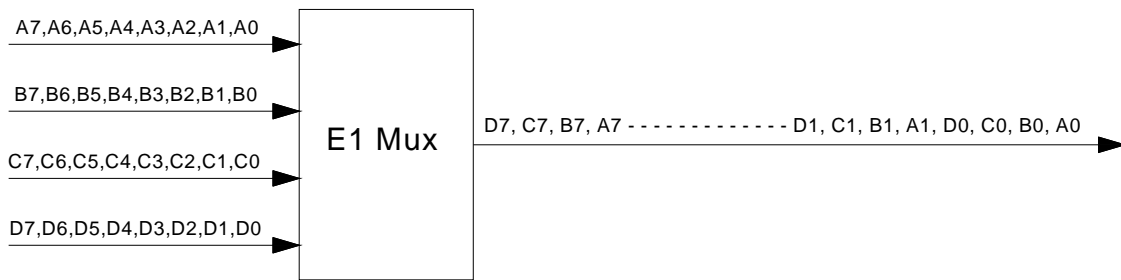
ITU (T) has now standardized SDH recommendations related to Network Node Interface (NNI), network architecture, multiplexing equipment, line equipment etc, thus creating a world wide standard on transmission technology, simultaneous transmission of bit rates of different hierarchy levels and international transfer of information without complicated modification.
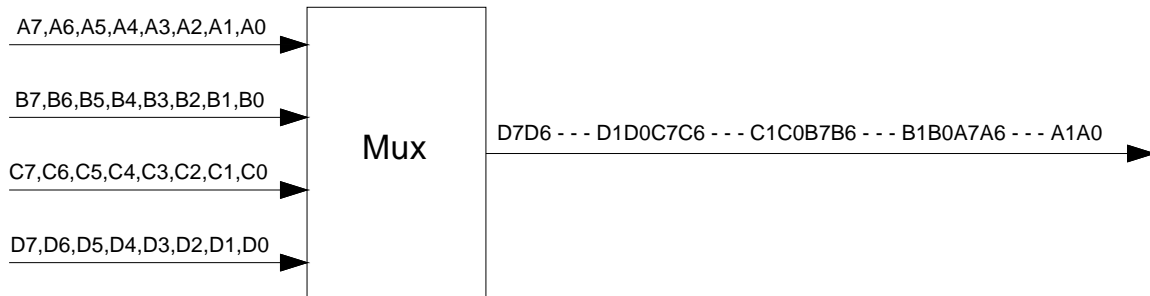

1.5 SDH Advantages

Worldwide Standard Bit Rates: An international hierarchy shared worldwide and creation of worldwide standard rates above 140 mbps

Synchronous Clock: The SDH system maintains a synchronous clock throughout a defined area. All clocks in the system gets synchronized with a centralized clock known as Primary Rate Clock. For example in India BSNL has the Primary Rate clock in the VSNL headquarters Worli, Mumbai. All the clocks in SDH system of BSNL get synchronized with respect to this clock. This feature gives of the advantage of avoiding the errors in streams due to different clock speeds. The addition of justification bits such as positive justification, negative justification, justification control bits is not needed at each MUX stage for error identification and correction.

Byte Interleaving Multiplexing: In SDH system the multiplexing is done by byte interleaving instead of bit interleaving as followed in PDH systems. This maintains the transparency of each bit stream and any bit stream can be dropped from any stage of SDH. For example a 2 Mbps tributary can be dropped even from STM-64, without any necessity of disturbing the other tributaries.

A7,A6,A5,A4,A3,A2,A1,A0

B7,B6,B5,B4,B3,B2,B1,B0

E1 Mux

D7, C7, B7, A7 - - - - - - - - - - - - - D1, C1, B1, A1, D0, C0, B0, A0

C7,C6,C5,C4,C3,C2,C1,C0

D7,D6,D5,D4,D3,D2,D1,D0

Figure 1.1 Bit Interleaving Multiplexing

A7,A6,A5,A4,A3,A2,A1,A0

B7,B6,B5,B4,B3,B2,B1,B0

Mux

D7D6 - - - D1D0C7C6 - - - C1C0B7B6 - - - B1B0A7A6 - - - A1A0

C7,C6,C5,C4,C3,C2,C1,C0

D7,D6,D5,D4,D3,D2,D1,D0

Figure 1.2 Byte Interleaving Multiplexing

Direct Access to Lower Speed Tributaries: In PDH to drop a 2mbps stream from say E5 (565 mbps) 4 stages of demultiplexing is necessary, that is from 565 to 140, 140 to 34, 34 to 8, 8 to 2 mbps. The needed 2mbps is dropped and for carrying out the transmission of remaining tributaries, again multiplexing is to be done from 2 to 8, 8 to 34, 34 to 140, 140 to 565 mbps, where as in SDH any tributary for example an E1 (2 mbps) stream can be dropped from any stage, even from STM 64 without the necessity of demultiplexing or multiplexing at any stage or disturbing the other tributaries.
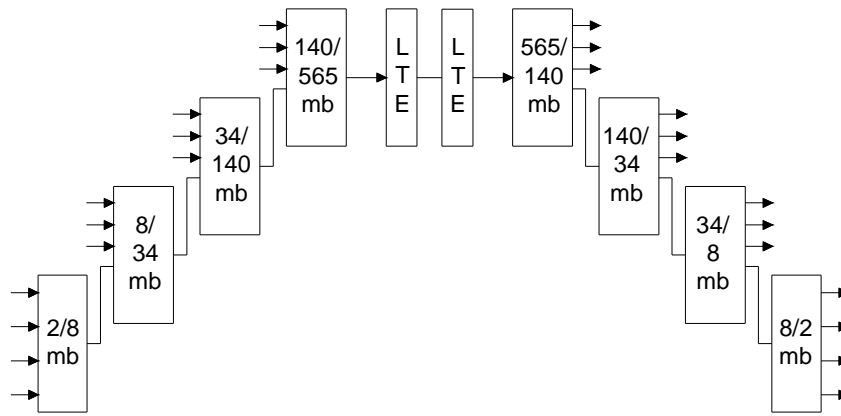
Figure 1.3 PDH Multiplexing & Demultiplexing Stages
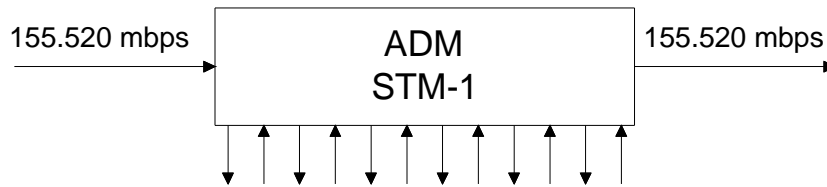
Figure 1.4 SDH Add & Drop Mux

Drop & Insert Mux: Individual tributaries of any bandwidth can be dropped or inserted at any multiplexer at any stage, even from STM-64, without any need for demultiplexing.

World Wide Compatibility: SDH can transport both E and T hierarchy tributaries without the need of using any additional interfacing equipment. Any tributary of E system or T system can be introduced at any stage of SDH system. The tributaries standardized by ITU (T) for introduction to SDH are E1 (2mbps), E3 (34 mbps), E4 (140 mbps), T1 (1.544 mbps), T2 (6.312 mbps), T3 (45 mbps).

Table 1.1 shows the standard transmission rates in USA, Canada, Europe/India, Japan in a Plesiochronous Digital Hierarchy (PDH).

Hierarchy level number	USA/Canada		Japan		Europe/ India	
	Bit Rate in mbps	Chls	Bit Rate in mbps	Chls	Bit Rate in mpbs	Chls
1	1.544	24	1.544	24	2.048	30
2	3.152	48	6.312	96	8.448	120
3	6.312	96	32.064	480	34.368	480
4	44.736	672	97.728	1440	139.264	1920
5	91.053	1344	396.200	5760	564.992	7680
6	274.175	4032	810.000	11520	2400.000	30720
7	405	6048				
8	565	8064				

Table 1.1 E & T Hierarchies Of PDH

Standardization: SDH is a highly standardized system as Open System Interface by ITU (T) such as standardization of optical interface, standardization of frame format, standardization of auxiliary channels and control bits, standardization of multiplexing, standardization with flexible section that be a part of networks LAN, WAN, broad band ISDN, creation of open network structure increasingly required in today's competitive environment where as PDH is standardized upto primary level only other than bit streams. Beyond this the standardization of PDH is as manufacturer system, not an open system. The standardization of equipment interfaces enables the use of multi vendor end equipment.

Performance Monitoring: SDH enhances fault detection. Continuous error and quality analysis is integrated into the system by adding some overhead bytes at every stage of SDH system to monitor, identify errors and correct them. Parity checks permit localization of error on every specific section of line and at all levels of hierarchy. This minimizes the failures resulting from impairments. So to say SDH is an almost error free, transport system.

Path Over Head (POH): The POH added at VC level, makes each tributary transparent with respect to its flow and provides the necessary data needed while dropping any tributary. POH contains 9 Bytes. The first Byte is path trace, which contains the origin of path, details of its flow, a low order path access point identifier, which enables the receiving terminal to check its continued connection to the intended transmitter. The second byte is a bit interleaving parity check over the entire stream frame for subsequent error performance monitoring. The other 7 bytes serve different functions as described latter.

Pointer Technology: The pointer technology used in SDH to identify the actual starting byte of each tributary, which facilitates easy dropping of channels. When a tributary is multiplexed into a larger tributary, its phase offset in bytes can be identified relative to some reference point in this larger tributary. There is also a mechanism for allowing the value of this pointer to change if there is a loss of synchronization and the smaller capacity tributary is running either slightly slower or slightly faster than the larger tributary. Each of the smaller capacity tributaries have their own pointers, which can change independently. Although the use of these pointers still entails some input buffers, these are very much smaller than would be required if there were no mechanism for changing the phase of a small capacity tributary within a larger one, hence the problem of excessive delays can be contained. In SDH the majority of tributaries both large and small are well synchronized to each other but at the same time, there are a few which are not so well synchronized and every so often the increasing strain of their asynchronism has to be relieved by a byte sized slip relative to the majority of the other tributaries in the network. The pointer value associated with tributary is recalculated whenever a slip occurs.

The pointer mechanism is the heart of the SDH standard. It is this mechanism that enables us to construct networks that are nearly, but not completely synchronous and still allows us to easily locate each traffic channel, together with its associated management and control information but without incurring large penalties in transmission delay. SDH networks are not really synchronous at all but are actually very tightly controlled asynchronous networks. The fact is that we have quantized the slips due to this asynchronism means that it is possible to locate and route any of the traffic paths within an SDH network. This together with network management software gives the traffic routing flexibility that was very difficult to achieve using PDH based equipment. In terms of actual network hardware, it opens the way to the production of economically viable drop and insert multiplexers and cross connects.

Frame Structure: The SDH frame structure of 125 microseconds transmission has 270 columns and 9 rows gives easy identification of tributary for the purpose of dropping & adding

Section Over Head (SOH): Each frame is added with SOH of 9 rows and 9 columns, which contains some Overhead bytes for communication between regenerators, multiplexers, for error correction etc. Sufficient spare locations are kept for future needs and expansion.

Automatic Protective Systems: The K1 and K2 bytes in SOH are key bytes for ensuring uninterrupted communication in spite of major breakdowns of equipment, medium, network systems etc. The self-healing, automatic traffic rerouting methods shall ensure no interruption in communication, which gives a higher reliability.

Optical Fibre As Medium: Another advantage of SDH lies in it's being using Optical Fibre as the medium which is inherently being immune to electromagnetic noise and is ideally suited for the much better error performance expected of SDH. Of late, SDH on Microwave is also being talked about and this will give another push to the acceptability of the SDH in variety of terrain.

Dynamic Network Capacity Management: The system can adopt the varying traffic needs. It is possible to dynamically allocate bandwidth on demand to users any where within the network, at a short notice.

Network Management System: The O, A and M of the transmission network is carried out by an automatic and centralized NMS which provides features like easy network management, advanced end to end management to customer connections, flexible access and management of varied fixed bandwidth services to the customer, decreased out lays for personnel and test equipment, rapid computer controlled access to the desired transmission capacity with high transmission quality. NMS is fully software controllable.

The first and foremost advantage lies in the capability of on line network management, traffic management etc. This is possible because SDH provides a significant percentage of bit rates as control bits. With sufficient number of overhead bits, SDH has tremendous power and future scope for network management functions like performance monitoring, configuration management, resource optimization, network security, remote provisioning & centralized maintenance, which are going to be the pronounced features leading to a significant competitive advantage. The multiplex structure for SDH includes functions that allow continuous performance monitoring and information exchange concerning the network status, should lead to more effective network management in future. Performance monitoring can be done at any of the three levels

1. End to end.
2. Multiplex section
3. Regenerator section.

Synchronous Multiplexing Structure: This gives the advantage of interaction of terminals and multiplexers, development of new generation of multiplexers (ADMs) and Digital Cross Connects (DXCs), flexibility for networking and up gradation, easy growth of higher bit rates and network expansion up to 10Gbps, capability for transporting ATM bit rates and even non standard tributaries, lesser power consumption, reduced quantity of equipment, cost effective and less maintenance, provision of end to end customer services on demand.

Network Simplification: The concept of Add-Drop multiplexing in SDH is able to greatly simplify the existing network by replacing the PDH mux mountain which leads to reduction in network elements, resulting drastically reduced fault liability and parallel reduction in operating and maintenance costs. Further more efficient Drop & Insert of the channels offered by SDH network, together with it's powerful network management capabilities will lead to better provisioning of high & variable bandwidth requirements of the broadband services.

Survivability: The deployment of optical fibre throughout the network and adoption of the SDH network elements make end-to-end monitoring and maintenance possible. The management capability of the synchronous network will enable the failure of the links or nodes to be identified immediately. Using self-healing ring architectures, the network shall be automatically re-configured with traffic instantly re-routed until such a time as the faulty section has been repaired. As a result failures do not disrupt services, allowing network operator to commit to extremely high availability of service figures, and guarantee high levels of network performance.

Objective:

1. The SDH is designed to overcome the limitation of PDH. **T**/F
2. It is not compulsory that the synchronous word should signify that all multiplex levels have come from one and the same clock **T**/F
3. In SDH data transmission system the signal of different rates cannot be recovered or inserted without having to carry out Multiplexing /De-multiplexing operation for each rate. T/**F**
4. Synchronous digital transmission equipments from different manufacturers cannot inter work on the same line. T/**F**
5. SDH networks capable to drop and insert of channels efficiently with its powerful network management system. **T**/F
6. Provision of network management channels allows performance monitoring, configuration management, resource management and network security. **T**/F
7. The SDH does not offer future – proof platform for new services such as broadband ISDN. T/**F**
8. SDH standards define fiber-to-fiber interfaces at the physical level. **T**/F
9. In SDH system the multiplexing is done by bite inter leaving. **T**/F

Choose the correct answer:

1. In SDH system the multiplexing is done by- (b)
   a) Bit interleaving   b) Byte interleaving

2. A single synchronous multiplexer can performs the function of- (a)
   a) The entire Plesiochronous - multiplexing mountain.
   b) Specific plesichronous - multiplexing mountain.

3. Synchronous digital transmission equipments from different manufacturers- (b)
   a) Cannot inter work on the same line.   b) Can inter work on the same line

4. In SDH data transmission system the signal of different rates- (b)
   a) Cannot be recovered or inserted without having to carry out Multiplexing /De-multiplexing operation for each rate.
   b) Can be recovered or inserted without having to carry out Multiplexing /De-multiplexing operation for each rate.

Subjective:

1. What are the objectives of SDH?
2. What are the reasons basing on which the success of SDH in future depends?
3. What are the disadvantages of PDH system and why it is not suitable in present scenario?
4. What are the long distance network requirements?
5. What are the advantages of SDH system?
6. What is byte interleaving multiplexing and how it is advantageous when compared with bit interleaving multiplexing?
7. What do you understand by direct access to lower speed tributaries in SDH and why it is not possible in PDH?
8. What is the worldwide compatibility, a feature of SDH, which is not available in PDH?
9. What do you understand by pointer and how it is useful in SDH?
10. What are the advantages of network management system used in SDH?

*****

CHAPTER-2

SDH Multiplexing Structure

Objectives: By going through this chapter, the trainee must be in a position to understand

1. The SDH bit rates as per ITU-T's Rec. G.707.
2. The meaning of Synchronous Transport Module
3. Multiplexing structure of STM – N, as per ITU – T's Rec. G.709.
4. The meaning and functions of different stages of SDH multiplexing structure
5. SDH Multiplexing principle

2.1 SDH bit rates: As per ITU(T)' s recommendation G.707.

Sl.No.	SDH level	Bit Rates		No. of Speech Chls
1.	STM 1	155.520 mbps	-	1890
2.	STM 4	622.080 mbps	-	7560
3.	STM 16	2488.320 mbps	2.5 Gbps	30,240
4.	STM 64	9953.280 mbps	10.0 Gbps	1,20,960

Table 2.1 SDH Bit Rates

2.2 Synchronous Transport Module (STM): An STM is the information structure. It consists of information payload and overhead bits in block frame structure, which repeats at every 125 microseconds. The information is suitably conditioned for serial transmission on the selected media at a rate, which is synchronized to the network.

- STM followed by an integer, which indicates the level of SDH.
- STM 1 is the first level of SDH bit rates
- Higher SDH bit rates are obtained as integer multiples
- Higher rate levels are denoted by the corresponding multiplication fraction of the first level

STM 1 with 155.520 mbps is the basic rate. STM 4 indicates that it contains 4 STM 1s and each STM 1 is independent in all respects. Similarly STM 16 means 16 Nos of STM 1s and STM 64 is 64 Nos of STM 1s.
STM 4 = 155.520 x 4 = 622.080 mbps

It is to be noted that no justification bits are to be added as is done in PDH.

2.3 SDH Multiplexing Structure: As per ITU (T)'s recommendation G.709: The inputs to SDH system are PDH bit streams. ITU (T) has standardized E1, E3, E4 of E hierarchy and T1, T2 and T3 of T hierarchy as inputs into SDH. The block diagram of SDH multiplexing structure shown in figure 2.1, shows the making of STM1 or STM N where N indicates the integer of the SDH level.

2.3.1 Container(C): The first entry point of the PDH signal. It is the basic packing unit for tributary channels, is filled with the information from a plesiochronous signal. The process is called as mapping. Justification facilities are provided to adapt plesiochronous tributaries to the synchronous network clock. Each container is suitable for the rate of the signal inputted into it and for the structure of the synchronous frame. Fixed stuffing bits are inserted for synchronous tributaries. Signal is prepared so as to enter into the next stage i.e. virtual container. Containers are Basic Containers and Higher Order Containers. As per recommendation G.709, C-11, C-12,C-2,C-3 & C-4 are the containers for PDH bit rates of 1.544 mbps, 2.048 mbps, 6.312 mbps,34 mbps or 45 mbps and 140 mbps respectively.
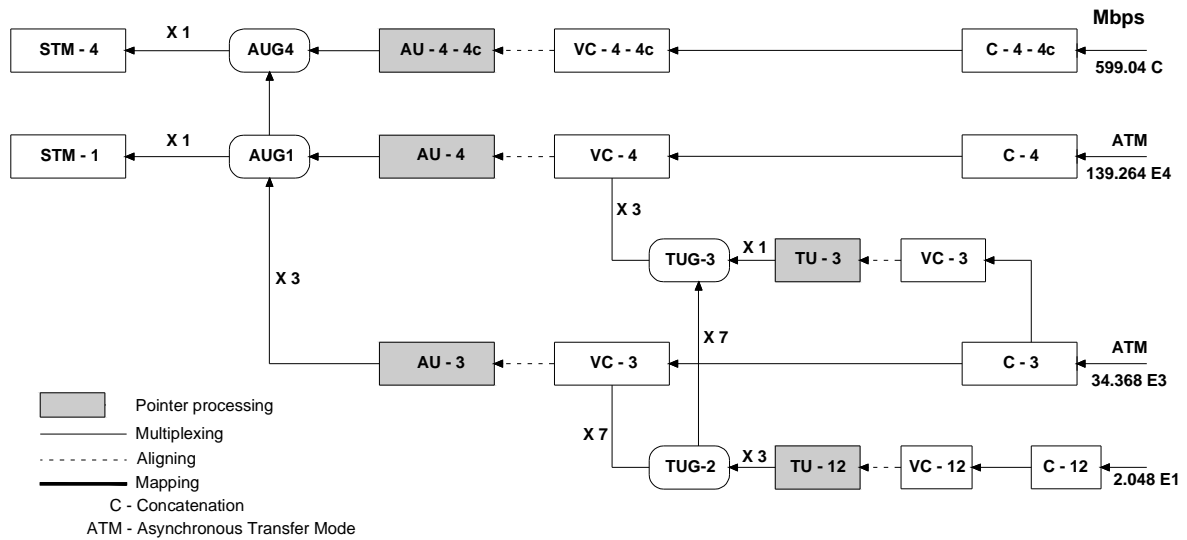
Figure 2.1 SDH Multiplexing Structure

2.3.2 Virtual Container (VC = C + POH): Each container is added with control information known as Path Over Head (POH), which helps the service provider to achieve end-to-end path monitoring. The container and the path overhead are together called as Virtual Container (VC). The POH is 1 column X 9 rows. In Virtual Container the POH fields are organized in a block frame structure either in 125 microseconds or in 500 microseconds. The functions of each byte in POH are shown in figure 2.2

Two types of virtual containers have been identified.

- Basic virtual containers: VC11, VC12.
- Higher order virtual containers: VC3, VC4.

2.3.3 Tributary unit (TU = VC + Pointer): This unit is an information structure, which provides adaptation between the lower order path layer and the higher order path layer. It consists of information payload of virtual container and the tributary unit pointer. TU-2 for VC-2, TU-3 for VC-3 etc.

2.3.4 Tributary unit group (TUG): One or more tributary units are grouped or multiplexed by byte interleaving to form higher bit stream rate as part of multiplexing structure. TUG-2 is a group of 3 TU-12s or 4 TU11s or 1 TU2. TUG-3 consists of homogenous assembly of TUG-2s or TU-3, either seven TUG-2s or one TU-3.

2.3.5 Pointer: It is an indicator whose value defines frame offset of a virtual container with reference to the frame reference of transport entity on which it is supported. It indicates the phase alignment of the virtual containers (VC-n) with respect to the POH of the next higher level VC in which it resides. The tributary Unit Pointer location is fixed with respect to this higher level POH.

During decomposition of multiplex group, pointer technology makes it possible to directly locate each data channel from every STM-N frame. This considerably simplifies drop and insert mode at network nodes. This is unlike the PDH, where complete demultiplexing is required to be done at each level to access the desired data channel.

2.3.6 Administrative Unit: It is the information structure, which provides adaptation between higher order path layer and the multiplex section layer. It consists of information payload and AU pointer, which indicates the offset of the payload frame start relating to the multiplex section frame start. AU location is fixed with respect to STM-frame.

2.3.7 Administrative Group Unit: It consists of a homogenous assembly of AU-3s or AU-4.

2.3.8 Multiplexing Principles of SDH: 1.5 mbps, 2.048 mbps, 6.312 mbps enter their respective containers C-11, C-12 & C-2. These signals are prepared and inserted into their respective VCs and to the tributary unit pointers. TUG-2 can be either four C-11s with TU-11 or three VC-12s with TU-12 or one VC-2 with TU-2. The C-3 container input may be 34 mbps or 44.7 mbps. VC-3 container with AU-3 can directly go to AUG and enter STM frame. Similarly seven TUG-2s can be mapped into one TUG-3, otherwise one VC-3 with one TU-3 can be mapped into one TUG-3. Three TUG-3s can be mapped into VC-4. VC-4 with AU-4 go to AUG and then to STM frame. 3 AU-3s also can go to AUG and then to STM frame.

- Standardization of line optical interface.
- Standardization of frame format.
- Standardization of auxiliary channels and control bits.
- Implementation of system with flexible structure that can become part of new networks (LAN, WAN, B-ISDN).
- A reduced quantity of equipment, cost effective, less maintenance. Reduction of costs allowed by the synchronous frame structure due to following reasons.
  1. Automatic and centralized management of the transmission network.
  2. New network topologies.
  3. Integration of terminals and multiplexers
  4. New generation of multiplexers, ADMs (Add/Drop Multiplexers).
  5. Introduction of DXCs (Digital cross Connects).
  6. Lesser power consumption of the equipment.
  7. Greater flexibility for transporting non-standard tributaries.

- Continuous error and quality analysis integrated into the system.
- Minimization of failures resulting from impairments.
- Direct access to lower speed tributaries without demultiplexing and multiplexing
- Entire high-speed signal.

- Mid section meets.
- Capable of transporting the existing PDH signals. Compatible with PDH. Various hierarchy levels are interconnected by means of digital multiplexing, employing justification methods.
- Capable of transporting the future broadband ATM bit rates.
- Rapid computer controlled access to the desired transmission capacity with high transmission quality.
- Easy network expansion up to 2.5 gbps.
- Decreased outlays for personnel and test equipment.
- High reliability. Self-healing, automatic traffic rerouting without service interruption.
- Service on demand, fast provision of end-to-end customer services on demand.
- Flexible access, flexible management of varied fixed bandwidth services to the customer premises.
- Creation of open network structures increasingly required in today's competitive environment
- SDH provides advanced end-to-end management to customer connections.
- Easy network management. More flexibility for networking and upgradability.
- Enhanced operation, administration & maintenance (O,A & M) capabilities.
- Easy growth to higher bit rates in steps with the evolution of transmission technology.

Objective:

1. An STM consists of information payload and overhead bits in block frame structure. **T**/F
2. The container and path overhead of SDH frame together form a virtual container. **T**/F
3. The standardized E1 rate of ITUT is mapped in C12 container of SDH frame structure. **T**/F
4. J1 byte of POH in STM1 frame allows receiver to verify the connection of path with the transmitter. **T**/F
5. TUG-3 is a multiplexer that multiplexes 3 number of TUG - 2 or 7 number of TU-3. T/**F**

Choose the correct answer

1. An STM consists of information payload and overhead bits- (a)
   a) In block frame structure   b) In non-block frame structure

2. The standardized E1 rate of ITUT is mapped in – (a)
   a) C12 container of SDH frame structure b) C11 container of SDH frame structure

3. The data rate of STM-4 – (a)
   a) 622.080 Mbits/s   b) 2.488 Mbits/s   c) 155.52 bits/s

4. The path overhead bytes of SDH – (b)
   a) Indicates the position of the beginning of the VC in relation of the STM-1 frame.
   b) Allow the network operator to achieve end-to-end monitoring such as error monitoring.

5. The Administrative unit is an information structure- (a)
   a) Provides adoption between higher order path layer and the multiplex section layer.
   b) Provides adoption between lower order path layer and higher order path layer.

6. TUG-3 is a multiplexer that multiplexes-
   a) 7 number of TUG - 2   b) 3number of TU – 3

Subjective:

1. What are the bit rates used in SDH hierarchy?

2. Explain the SDH multiplexing structure with a diagram.

3. What are the standardised inputs to STM? In STM – N, what does the N indicates?

4. Explain what do you understand by Container? What does C11, C12, C2, C3 & C4 indicate?

5. Explain about POH and its 9 bytes structure.

6. What is the use of pointer?

7. Write the multiplexing principles of SDH.

8. Show with a block diagram how TUG-3 is made up from C12s.

9. Explain briefly about TU, TUG, AU and AUG.

CHAPTER-3

SDH Synchronous Frame Structure

Objectives: By going through this chapter, the trainee must be in a position to understand

1. The Synchronous frame structure
2. The functions of Section Over Head
3. Make up of C4, C3 and C12
4. Generation of VC4 from TUG-3s
5. Mapping up of C4 & C3
6. Higher order STM - N s

3.1 Basic Frame:

The basic frame of STM 1 is shown in Figure 3.1, contains 270 columns X 9 rows in a duration of 125 micro seconds. It is divided into three main areas.

1. **Section Over Head (SOH):** 9 columns X 9 rows, which includes, regenerator section overhead (RSOH) - 9 columns X 3 rows, AU Pointer - 9 columns X 1 row, and multiplexer section overhead (MSOH) - 9 columns X 5 rows.

2. **Path Over Head (POH):** 1 column X 9 rows.

3. **Pay Load:** 260 columns X 9 rows.
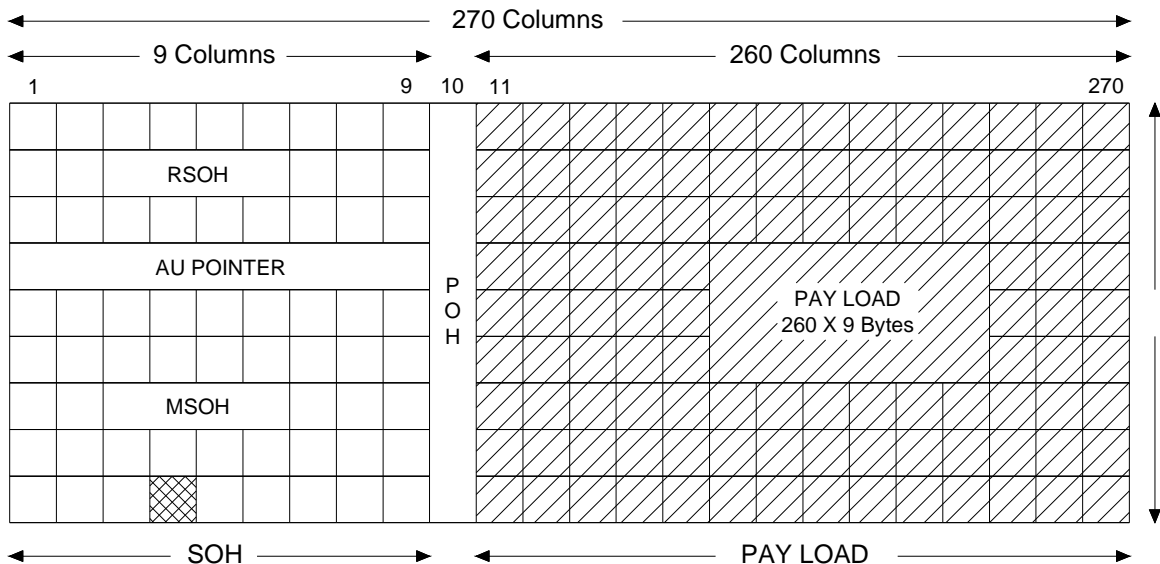
Figure 3.1 STM Frame With Over Heads & Pay Load

The details of bytes in frame and bit rates are shown in Para 3.2.

3.2 Bytes In Frame & Bit Rates:

Frame Duration	= 125 Micro seconds	
Frame Length	= 270 X 9 = 2430 Bytes ⟶	155.520 mbps
Pay Load	= 260 X 9 = 2340 Bytes ⟶	149.760 mbps
POH	= 1 X 9 = 9 Bytes ⟶	0.576 mbps
AU Pointer	= 9 X 1 = 9 Bytes ⟶	0.576 mbps
RSOH	= 9 X 3 = 27 Bytes ⟶	1.728 mbps
MSOH	= 9 X 5 = 45 Bytes ⟶	2.880 mbps

3.3 Section Over Head (SOH = RSOH + MSOH): SOH excluding AU pointer, contains O, A&M signals, bytes for the functions of frame alignment, network management, performance monitoring, protection switching, order wire and block framing. STM – N multiplexing uses a simple byte interleaving scheme. The SOHs of individual tributaries are also combined into a byte interleaving block structure.
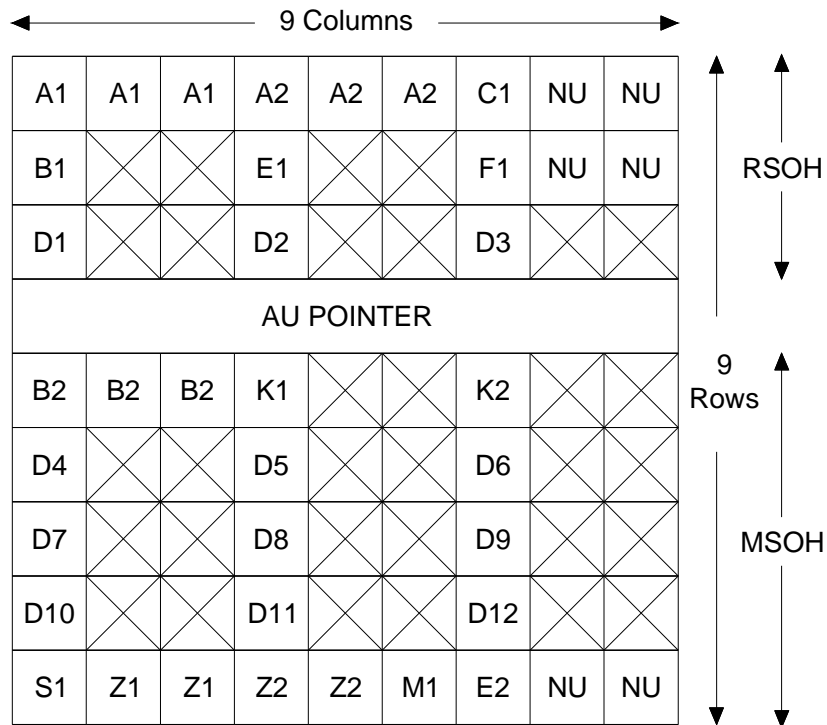

Figure 3.2 Section Over Head

3.3.1 Regenerator Section Over Head (RSOH): Terminated at regenerators as shown in figure 3.3. The RSOH bytes are described as under.

A1, A2: Frame Alignment Words   A1= 11110110   A2=00101000

6 bytes for each STM – 1. These bytes shall be provided in all STM – 1s.

J0: Path trace between regenerators. This byte transmits a Section Access Point Identifier so that a section receiver can verify its continued connection to the intended transmitter.

B1: Bip-8. Bit Interleaving Parity (even parity) check, used to monitor the errors between the regenerators. One byte is provided for each STM – 1. This byte performs the bit error monitoring function for elementary regenerator section. BIP – 8 is computed over all the bits of the previous STM – 1 after scrambling and is placed in byte B1. This byte is monitored and recomputed at every regenerator.
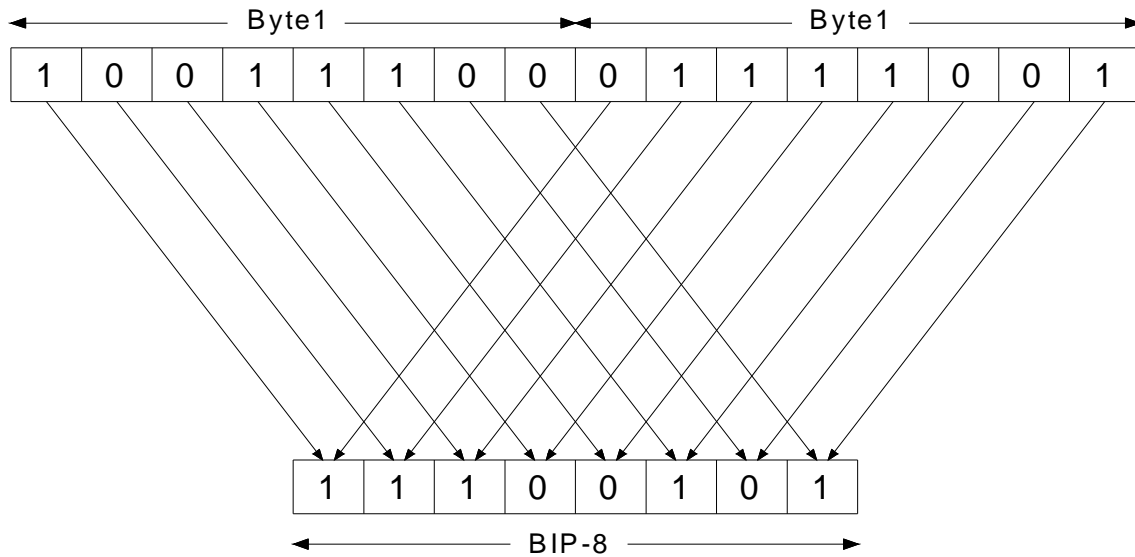

Figure 3.3 Bit Interleaving Parity Check (BIP-8)

E1: EOW channel for voice communication. User channel.

F1: User channel for special maintenance purposes or for the use of network operators.

C1: An unique number assigned to STM –1, prior to it being multiplexed to a higher STM level. On demultiplexing, this byte is used to identify the position of any particular STM – 1, within the incoming STM – N signal.

D1,D2,D3: Data communication channel for maintenance purpose between regenerators.
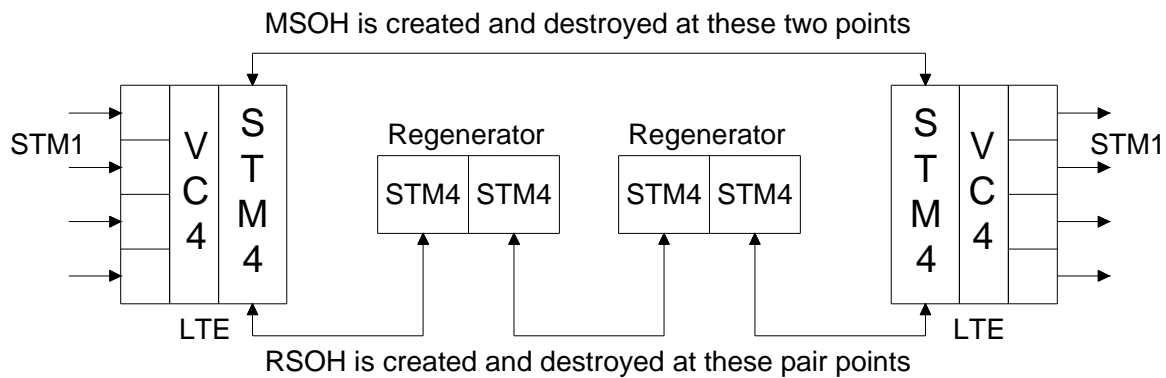
Figure 3.4 Utilization Of MSOH & RSOH

3.3.2 Multiplexer Section Over Head (MSOH): Terminated where AUGs are assembled and dissembled. MSOH passes transparent through regenerators. The MSOH bytes are described as under.

B2: Bip-24 Bit Interleaving Parity (Even parity) check, used to monitor the errors between multiplexers. Computed over all the bits of the previous STM –1 frame except for the first three rows of SOH (A1 to D3). Provided in all STM – 1s with in a STM – N.

K1, K2: Automatic Protective Switching (APS) command & remote alarm command.

D4 To D12: Data communication channel for maintenance purpose between multiplexers.

D1 to D12, the data communication bytes in both RSOH & MSOH are used for network management system (NMS) and are called as Embedded Communication Channel (ECC)

S1: Synchronous Status Message. This byte is used to indicate the synchronization reference at each network element.

Z1, Z2: Reserve bytes

E2: EOW. Voice channel. User Channel between multiplexers.

M1: Transmits the information of the number of errors detected by B2 to the remote equipment

NU: Bytes reserved for Local or National use

⊠ **:** Bytes Reserved for future use. Presently not used.

3.3.3 Administrative Unit (AU) Pointer: Indicates the beginning of VC-4 or 3 VC-3s in relation to STM-1 frame.

AU-4 is VC-4 + Pointer, within STM-1 basic frame. The pointer indicates the beginning of VC-4. In case there is a speed variation between VC-4 and STM-1 due to different working clocks, the pointer is responsible to manage the losses to maintain VC-4 and STM-1 at the same speed. The number of pointer actions is in relation with the difference of bit rate between the VC-4 and STM-1. The pointer adapts Positive / Nil / Negative justification process to manage the loss of synchronization. The justification is accompanied by incrementation or decrementation of pointer bits.

Positive Justification: VC-4 is slower than STM-1 payload. The justification bytes are used to carry the information bits of VC-4.

Justification: VC-4 is at the same speed of STM-1 payload. The justification bytes are used as just stuffing bits do not carry any intelligence.

Negative Justification: VC-4 is faster than STM-1 pay load. The justification bytes are adjusted by using additional bytes to increase the capacity of VC-4.

3.4 Path Over Head (POH): VC-4 = C-4 + POH, is located in the 10th column of STM-1 frame. It provides the path trace, performance monitoring in addition to other details with regard to the STM-1. The functions of POH are discussed in chapter 1, Para 2.3.

J1	**J1:** Path trace. It enables that the receiver is able to identify the details of stream flow and the receiver is able to verify the connection of the path with the transmitter.
B3	**B3:** BIP-8 Bit Interleaving Parity check. It performs the function of monitoring errors on path and maintains the quality of path
C2	**C2:** Indicates the make of the tributary
G1	**G1:** It informs the remote equipment about path errors detected
F2	**F2:** For the use of network operator.
H4	**H4:** Indicates about any special type of payload
Z3, Z4	**Z3, Z4:** Spare
Z5	**Z5:** Monitoring of low level network

Fig. 3.5 Path Over Head

3.5 Payload: This is the data area. The bytes containing data from the tributaries are transferred to the pay load area without buffering and are in relation with the STM-N frame. These tributaries come from all levels of the plesiochronous (free running) hierarchy, E1, T1, T2, T3, E3, and E4. The payload transports the corresponding virtual containers VC12, VC11, VC2, VC3 or VC4.

3.5.1 Make Up Of Pay Load: This is a low level multiplexing of low rate plesiochronous signals, by inserting them into synchronous frame or putting them in contact, which varies as per the flow rates of input signals. To adapt the flow rates of the plesiochronous signals to the required rates of them in VCs, some additional bits are added as pointers as per the process of justification. The entry point of the plesiochronous tributaries is container. In the following paragraphs the insertion of tributaries into containers is described.

3.6 Container C4 (Fig. 3.6): The input to container C4 is E4 -139.264 mbps. After clock recovery and regeneration of the tributary, the data is placed in container.

1   2 0
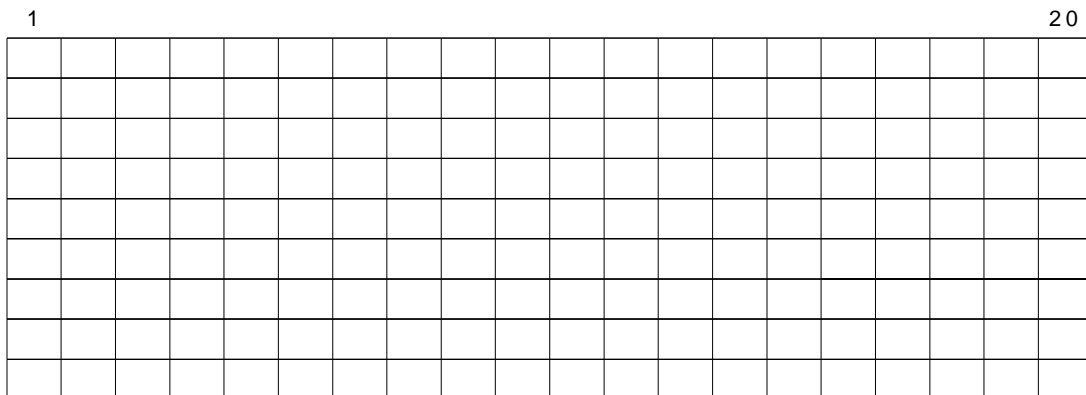
Figure 3.6 Container C4

The container is of duration of 125 microseconds and frame structure of 20 blocks X 9 rows

Frame   : 20 Blocks (In each row) X 9 Rows = 180 Blocks.

Row   : 20 Blocks.

Block   : 13 Bytes – Information bytes 12 & Over head bytes 1.

Bytes in Frame: 13 X 20 X 9 = 2340.

Frame duration : 125 microseconds

Bit Rate   : 2340 X 8 X 8000 = 149.760 mbps.

The bit rate is 149.760 mbps and is higher than input to C4, which is 139.264 mbps. Hence all the bits carried are not information bits. Some additional bits are added for justification and other purposes.

Justification: It is an operation, which makes it possible to fit a variable rate signal into a fixed rate frame.

Suppose the normal rate of a tributary = X bits / sec

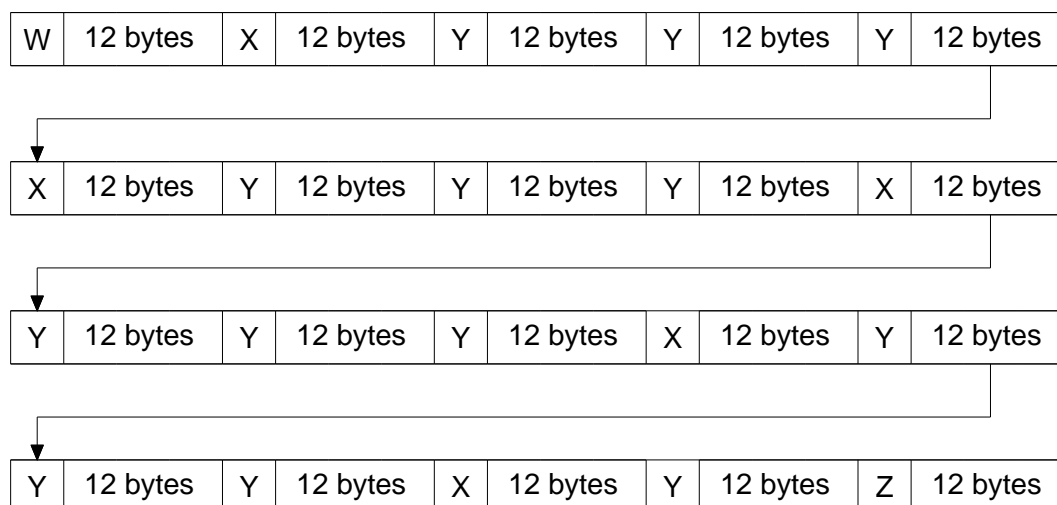The variation of rate   = $\pm \Delta$ bits / sec

To transmit the tributary with in S frame, it is necessary to allocate highest possible bit rate.

S   = X $\pm \Delta$ bits / sec.

E4   = 139.264 mbps $\pm$ 15 ppm = 139264 $\pm$ 2.088 kbps.

1 justification bit is added in a row in Z byte.

3.6.1 Mapping Of C4: (Each row)

W	12 bytes	X	12 bytes	Y	12 bytes	Y	12 bytes	Y	12 bytes

X	12 bytes	Y	12 bytes	Y	12 bytes	Y	12 bytes	X	12 bytes

Y	12 bytes	Y	12 bytes	Y	12 bytes	X	12 bytes	Y	12 bytes

Y	12 bytes	Y	12 bytes	X	12 bytes	Y	12 bytes	Z	12 bytes

Figure 3.7 Mapping Of Container C4

W = IIIIIIII   X = CRRRRROO   Y = RRRRRRRR   Z = IIIIIISR

I   = Information bit at 140 mbps;   O   = Service element bit reserved for future needs
R   = Fixed stuffing bit;   S   = Justification bit (1 per line in Z)
C   = 5 Justification indicator bits (by majority detection)
C   = 00000 ⟶ S = Information bit   C   = 11111 ⟶ S = stuffing bit

Total information bits are [(12 x 8 x 20) + (1 X 8) + (1 X 6)] X 9 X 8000 = 139.248 mbps. This bit rate is the rate of C4 bits, which is less than the E4 - 139.264 mbps. To add some more information bits, S bit in Z byte is used as information bit (as justification bit) to the extent necessary, which gives a max. bit rate of139.320 mbps.

On mapping the container, POH of 9 bytes is added at VC4 & Pointer of 9 bytes is added at AU4 and transmitted to AUG.
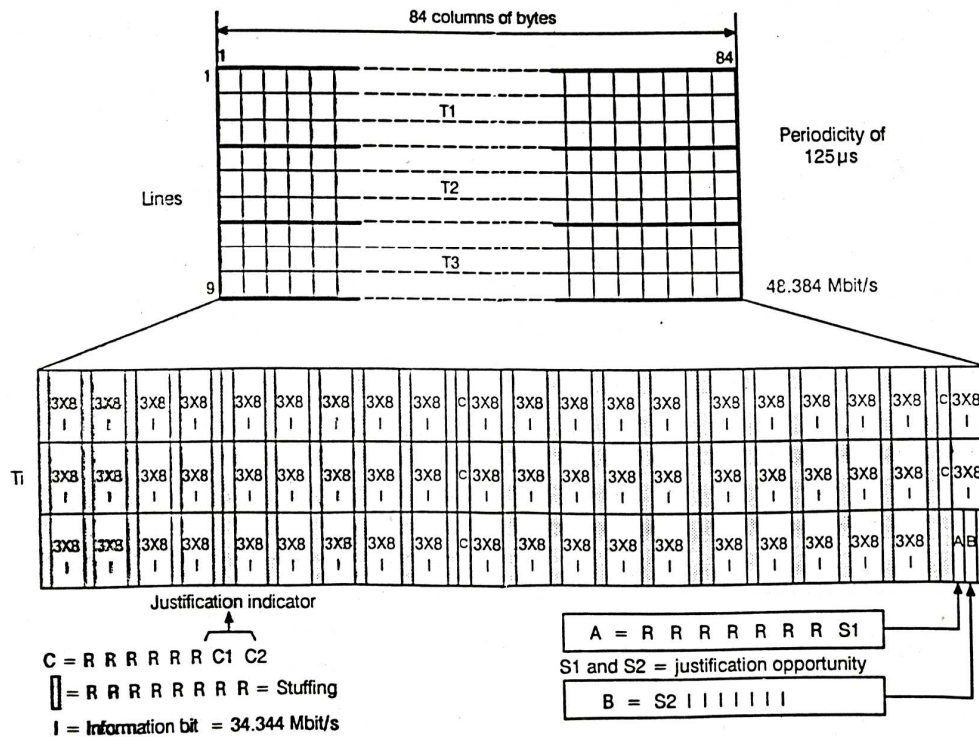

Figure 3.8 (A) C4 With POH & Pointer

3.7 Container C3: The C3 input is 34.368 mbps. C3 consists of 9 rows, 84 bytes in each row and 756 bytes in total.
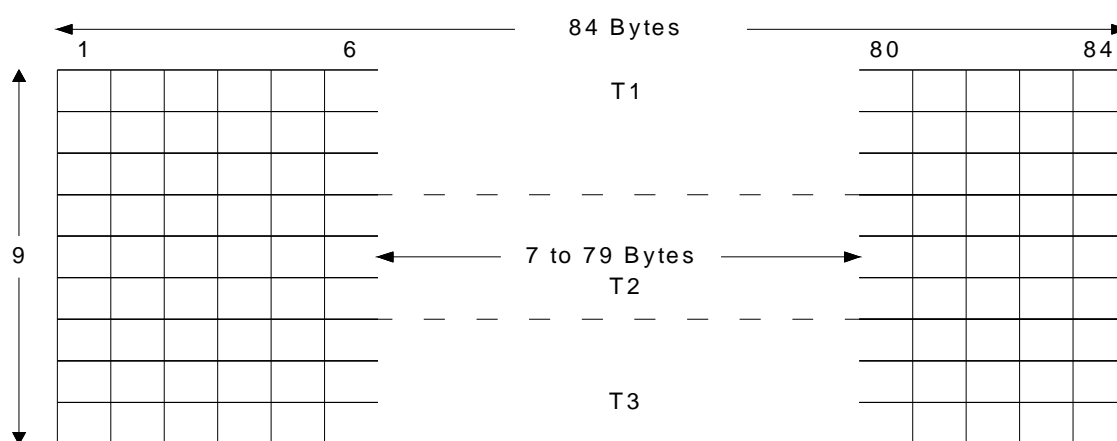
Figure 3.8 (B) Container C3

C3 is divided as 3 blocks T1, T2, T3, each block containing 84 bytes in a row and three rows. The blocks and 84 x 3 = 252 bytes in each block are as shown in figure.

Figure 3.9   Mapping of Container C3

The block T1 contains information bytes 178, stuffing bytes 67, C bytes 5, A & B bytes one each, a total of 252 bytes = 252 X 8X 8000 = 16.128 mbps.

Number of information bits in T1 = 178 x 8 + 7 bits of S = 1431 bits

Number of information bits in C3 = 1431 X 3 = 4293 bits.

Information bit rate   = 4293 x 8000 = 34.344 mbps

Total number of bits in T1   = 252 X 8 = 2016 bits

Total number of bits in C3   = 2016 X 3 = 6048 bits.

The frame duration of C3   = 125 microseconds.

Bit rate of C3   = 6048 x 8000 = 48,384 mbps

The total bit rate of C3 48.384 mbps is higher than the information bit rate of C3 34.344 mbps. Hence all the bits carried are not information bits. Some additional bits are added for justification and other purposes.

3.7.1 Generation Of TU3 / TUG3: TU-3 with 9 X (84 columns pay load + 1 column pointer + 1 column POH = 86 columns) is shown in figure 3.10. The TU3 is made of the whole of the VC3 + a pointer

The TUG3 defines the locations of the TU3s with in the VC4. The TU3 pointer bytes H1, H2 and H3 are the bytes of lines 1,2 and 3 of columns 4,5 and 6 of VC4. The other 6 bytes of these columns are stuffing bytes.
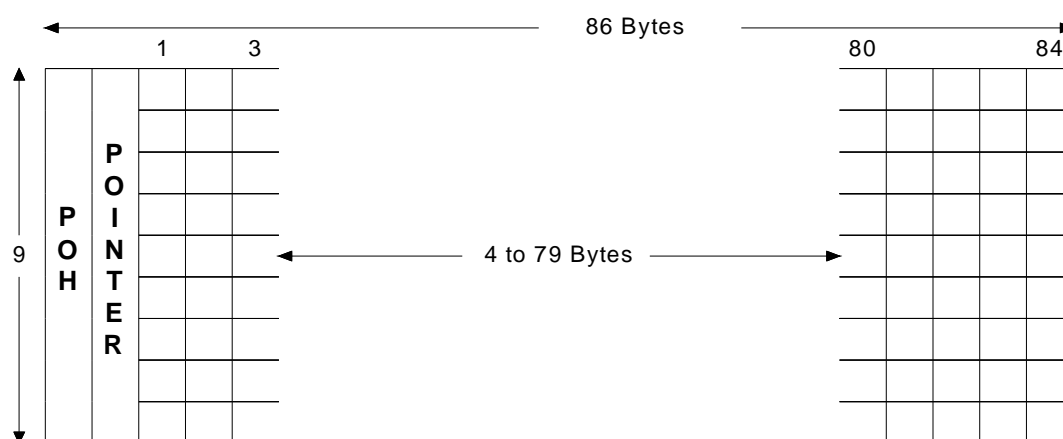
Figure 3.10 Tributary Unit (TU-3) With POH & Pointer

3.7.2 Generation Of VC-4 from 3 TUG-3s: (Figs 3.11 & 12)

3 C-3s make the pay load equivalent to VC-4. Each VC-3 is added with its separate POH for its path trace & performance monitoring etc and added with a separate pointer to adjust its offset in the VC-4.
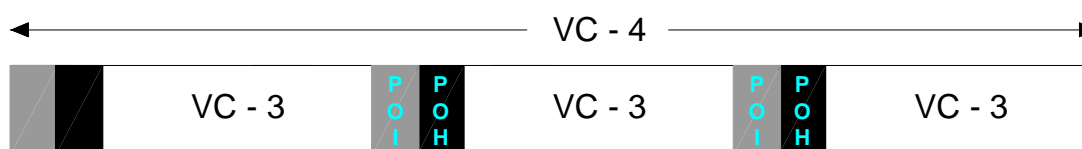

Figure 3.11 VC4 With 3 Nos. Of C3s With POH & Pointers
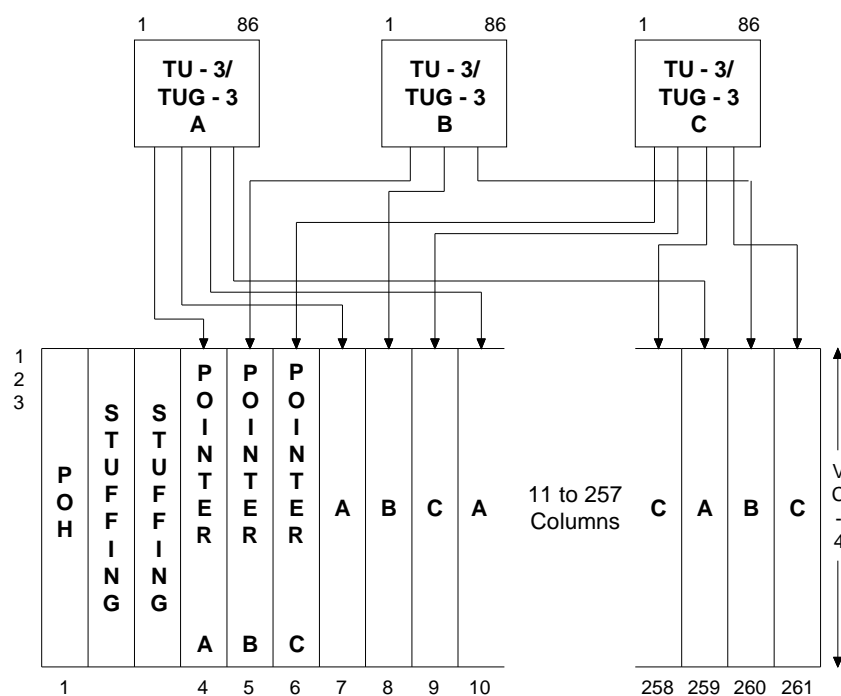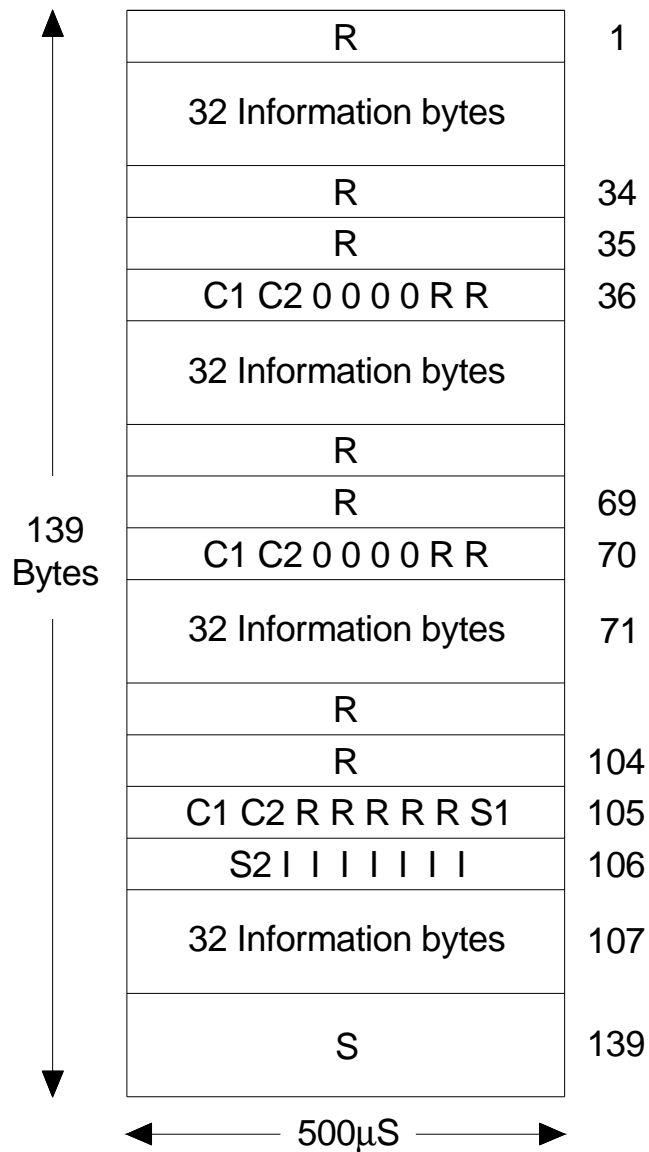

Figure 3.12 Generation Of VC-4 From Three TU-3 / TUG-3 Tributaries

The VC-4 is generated by carrying out multiplexing by interlacing the columns of the 3 TUG-3s A, B, and C, after adding the VC-4 POH and two columns with stuffing bytes.

3.8 Container C12 & its Mapping: C-12 input is 2.048 mbps, which can be unstructured – asynchronous (G.703) or structured – synchronous (G.704).

R	1
32 Information bytes	
R	34
R	35
C1 C2 0 0 0 0 R R	36
32 Information bytes	
R	
R	69
C1 C2 0 0 0 0 R R	70
32 Information bytes	71
R	
R	104
C1 C2 R R R R R S1	105
S2 I I I I I I I	106
32 Information bytes	107
S	139

139 Bytes

← 500μS →

Figure 3.13 Container C12

R = Stuffing bits   I = Information bits   S1, S2 = Justification Opportunity bits

In asynchronous input, the bits are put into C-12 as and when they arrive, the justification takes place at the bit level within C-12.

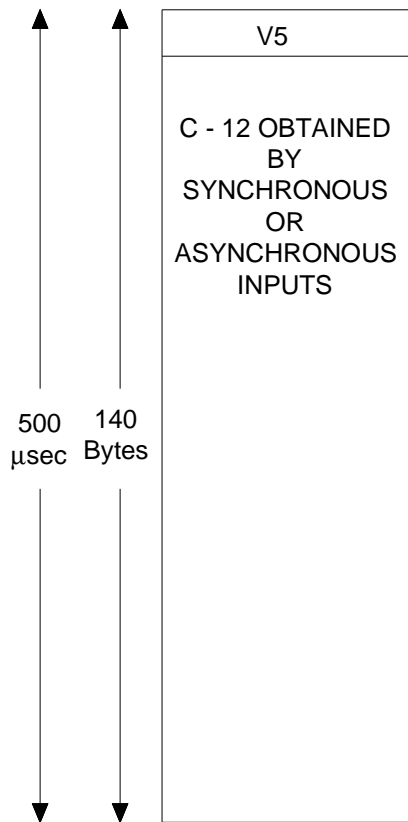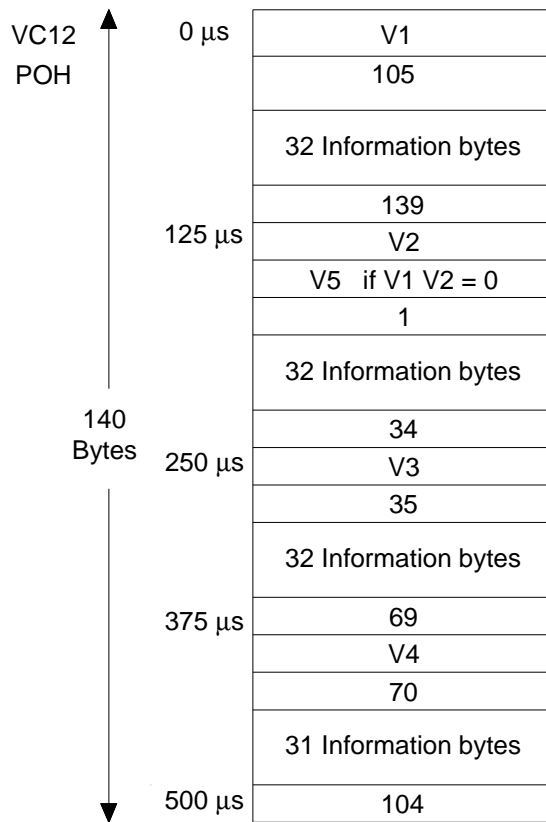The duration of combined frame for 4 X E1 tributaries is 500 microseconds.

Figure 3.14   VC-12

Figure 3.15 TU-12

The asynchronous C-12 of duration 500 microseconds is shown in Fig.T.13D.3.11. One C-12 is spread in 4 X 125 = 500 microseconds along with 3 more C-12s, to reduce the overheads.

Information bits : (3 X32 X 8) + (1 X 31 X 8) = 1023

Information rate of each C-12 : 1023 X 2000 = 2.046 mbps.

Input to C-12 : 2.048 mbps

The input rate is higher than the container rate hence the justification is negative.

In synchronous input, the bits are structured and organized in bytes and frame.

V1 and V2 constitute the VC-12 pointer.

V3 Negative justification opportunity

V4 presently not used.

Vi & V2 : Identification mark of the location of the start of VC-12 i.e. V5

**N N N N S S I D I D I D I D I D**

Value Of Pointer

3.9 Generation OF AUG:

AUG is generated, by adding AU-4 to VC-4. AU-4 is a pointer of STM-1 and AUG is the entity, which contains AU-4 + VC-4 payload. AUG is put into STM-1 along with SOH.
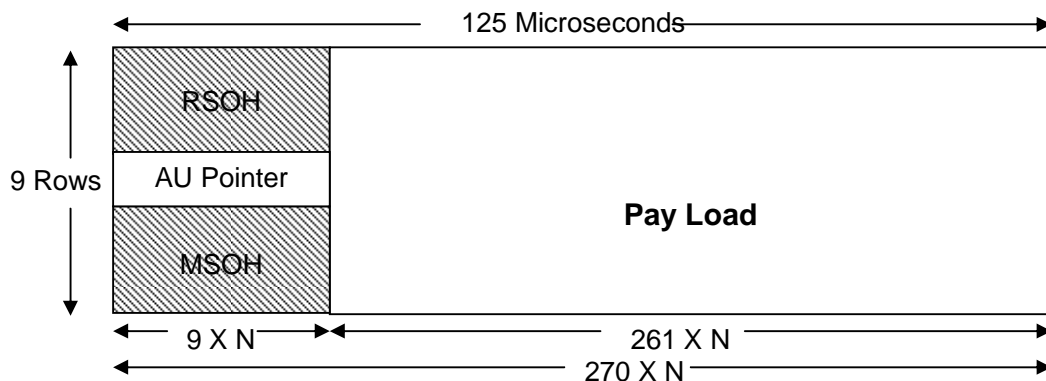
3.10 Higher Order STM-Ns: Higher order STMs are STM-4, STM-16 & STM-64. High rate multiplexing with STMs as inputs makes them. STM-1 frames of each 155.520 mbps of N numbers are multiplexed by byte interleaving to give STM-N.
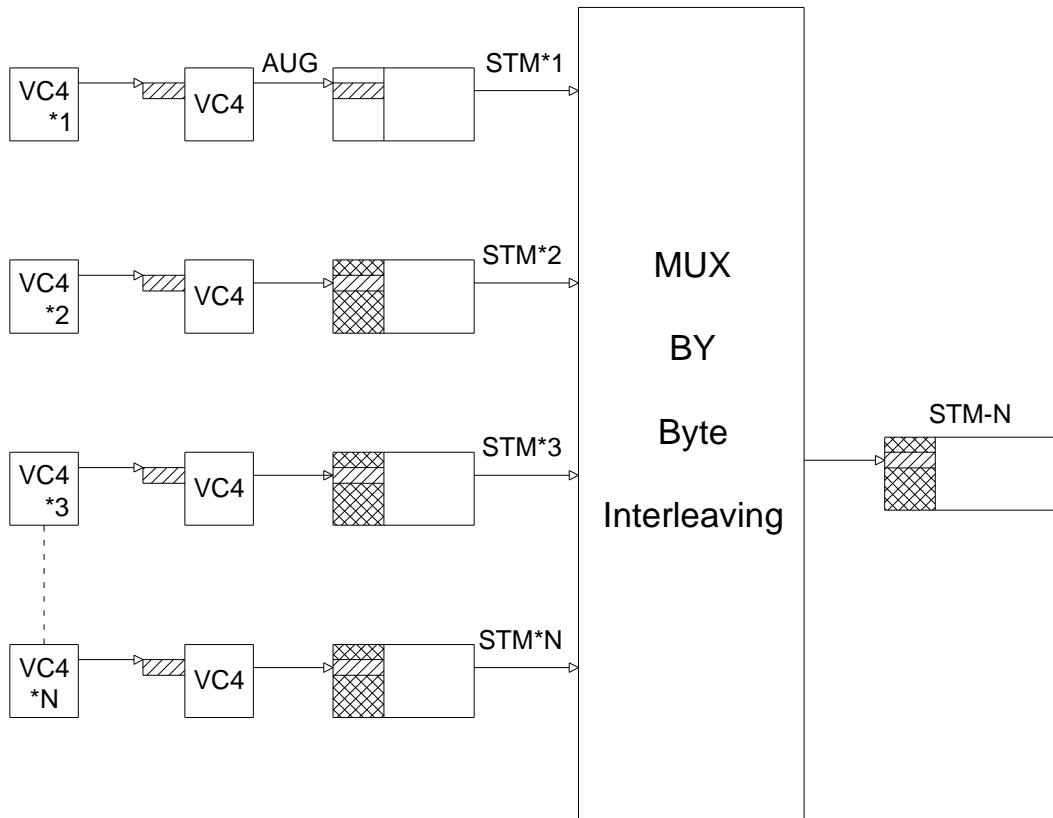
Figure 3.16 Formation Of STM-N By High Order Multiplexing

The smallest element in STM-N frame is a byte, represented by a square, which represents a 64 kbps channel that ensures direct access to each individual channel. The transmission of frame is from left to right and top to bottom.

STM-N shall have 270N Columns X 9 Rows. N is the hierarchy level of SDH. N may be equal to 1, 4, 16 or 64, as shown in figure 3.17

Figure 3.17 STM-N Frame

12 nos. of A1 bytes		12 nos. of A2 bytes		4 Nos. of J0 bytes		8 Nos. of X bytes
B1		E1		F1	11 Nos. of X bytes	
D1	Bytes not used	D2	Bytes not used	D3	Bytes not used	
AU Pointer						
12 nos. of B2 bytes		K1		K2		
D4		D5	Bytes not used	D6	Bytes not used	
D7	Bytes not used	D8		D9		
D10		D11		D12		
S1	11 Z1 bytes	11 Z2 bytes	M1	E2	11 Nos. of X bytes	

◄─────────── 36 Columns ───────────►

9
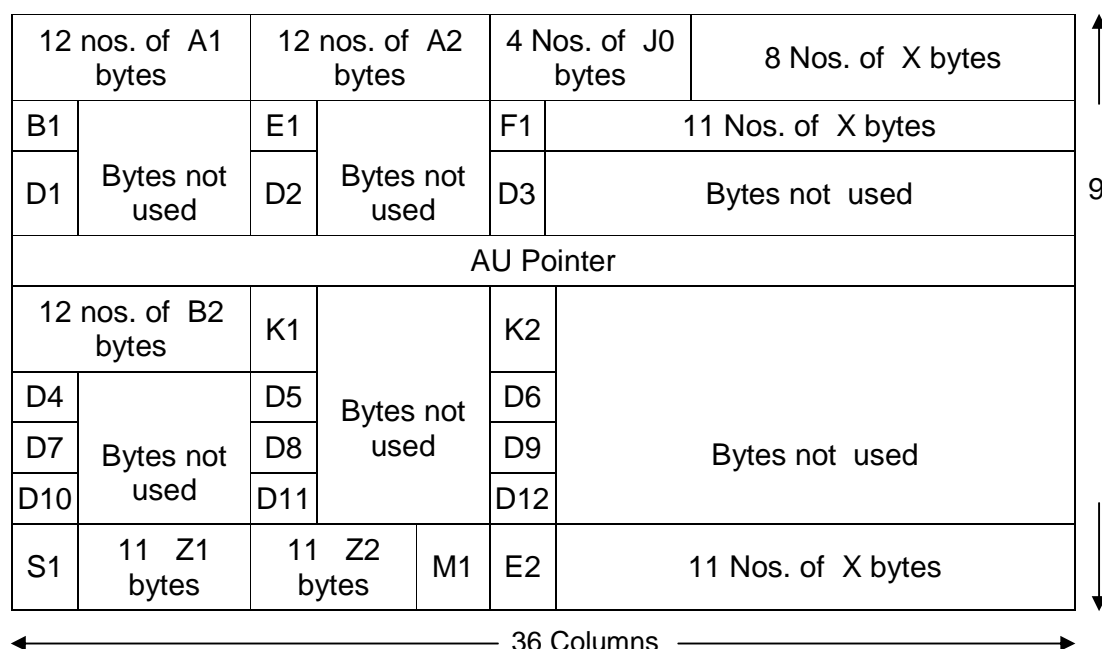
Figure 3.18 SOH OF STM-4 Frame

The SOH of STM-4 is shown in figure 3.18.

The A1 Bytes are 3 of STM-1 X4 = 12   The A2 Bytes are 3 of STM-1 X4 = 12
The B2 Bytes are 3 of STM-1 X4 = 12   The J0 Bytes are 1 of STM-1 X4 = 4
The Z1 Bytes are 3 of STM-1 X4 -1= 11   The Z2 Bytes are 3 of STM-1 X4-1=11
AU Pointer 9 of STM-1 X 4 = 36 Bytes

The X bytes are reserved for National use (NU). All other bytes are presently not in use.

Review Questions:

1. Explain what do you understand by the basic frame structure of STM-1
2. What are the functions performed by RSOH?
3. What are the functions performed by MSOH?
4. What are the functions of AU pointer and POH added to VC-4 payload?
5. Explain the make up of 155.520 mbps from the independent components of STM frame
6. What are the functions of BIP-8 and BIP-24 in SOH?
7. Explain the functions of Embedded Communication Channel.
8. Explain the make up of C4
9. Explain the make up of C3
10. Explain the mapping of C4
11. Explain the generation of VC-4 from C-3s
12. Explain the generation of VC-4 from C-12s

Objective:

1. The basic frame of STM-1 contains 270 columns and 9 rows in duration of 125µs.   **T**/F
2. The numbers of STM- 1 frames are transmitted in one second is 8000.   **T**/F
3. The section overhead of a STM-1 frame contains 9 columns and 9 rows.   **T**/F
4. D4 to D12 bytes of MSOH of an STM 1 frame are allotted for communication of data between two multiplexing sections.
    T/F
5. K1 & K2 bytes of MSOH are allocated to 1+1 or 1 for n Automatic protection switching commend.   **T**/F
6. The bit rate of data communication channel of MSOH is 576Kbps.   **T**/F
7. The number of pointer actions is in relation with the difference of bit rate between VC4 and STM1.   **T**/F
8. The justification is accompanied by incrimination or de-crimination of pointer bits.   **T**/F
9. Positive justification is related to the rate of the VC4 that is lower than the payload of STM1.
    T/F
10. Each row of C4 container in STM –1 frame of 125µ consists of 20 blocks.   **T**/F
11. VC3 frame of125µs consists of 85 columns and 9 rows.   **T**/F
12. In asynchronous projection the bits are put into the C12 as and when they arrive without taking into account of frame structure.   **T**/F
13. The frame duration of C12 is 500µs.   **T**/F

Choose the correct answer-

1. The basic frame of STM-1 contains-   (a)
    a) 270 columns and 9 rows in duration of 125µs.
    b) 261 columns and 9 rows in duration of 125µs.

2. The numbers of bytes in regenerative section over head of STM- 1 frame are-   (b)
    a) 45   b) 27

3. The pointer in overhead section of an STM-1 frame of 125µs consists-   (a)
    a) of one row and 9 columns   b) of 9rows and 1column.

4. 1+1 or 1 for n Automatic protection switching commends of STM system-   (a)
    a) E1 & E2 bytes of MSOH are allocated   b) K1& K2 bytes of MSOH are allocated

5. The bit rate of data communication channel of MSOH is-   (a)
    a) 576Kbps   b) 195Kbps

6. Negative justification is done when the bit rate of VC4-   (a)
    a) Is higher in respect to the payload of STM1 frame
    b) Is lower in respect to the payload of STM1 frame

7. The VC4 of an STM- 1 frame consists of-   (a)
    a) 260columns and 9 rows   b) 261columns and 9 rows.

8. The frame duration of C12 is
    a) 500µs   b) 125µs

*****

CHAPTER-4

Pointers

**Objectives:** By going through this chapter, the trainee must be in a position to understand

1. The meaning, purpose and functioning of pointer

4.1 AU-n Pointer:

The AU-n pointer provides a method of allowing flexible and dynamic alignment of the VC-n within the AU-n frame. Dynamic alignment means that the VC-n is allowed to "float" within the AU-n frame. Thus, the pointer is able to accommodate differences, not only in the phases of the VC-n and the SOH, but also in the frame rates.

4.2 AU-n Pointer Location:

The AU-4 pointer is contained in bytes H1, H2 and H3 as shown in Fig.T.13D.4.1. The three individual AU-3 pointers are contained in three separate H1, H2 and H3 bytes as shown in figure 4.2.
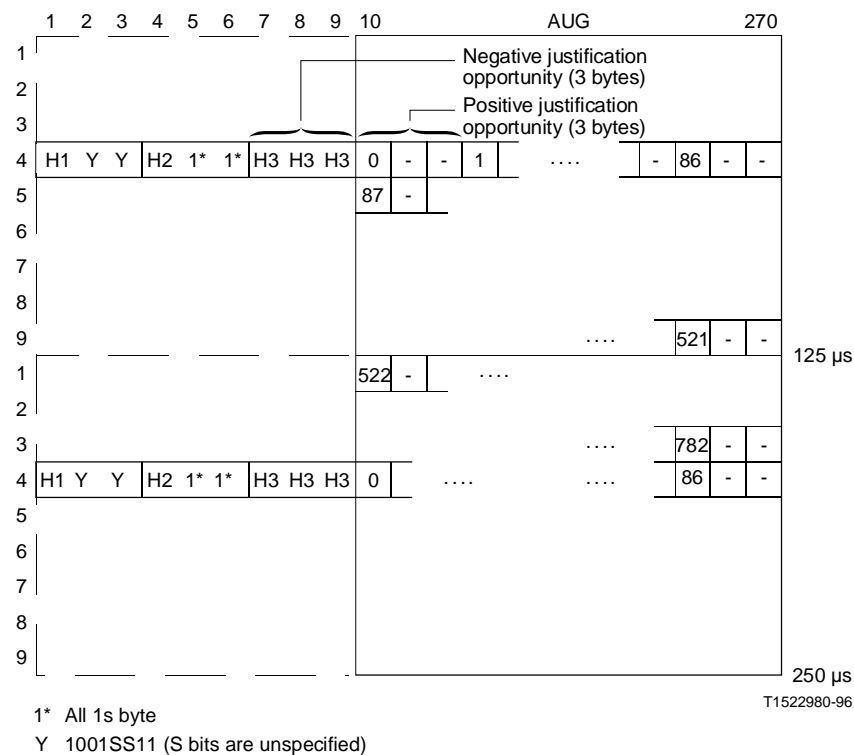
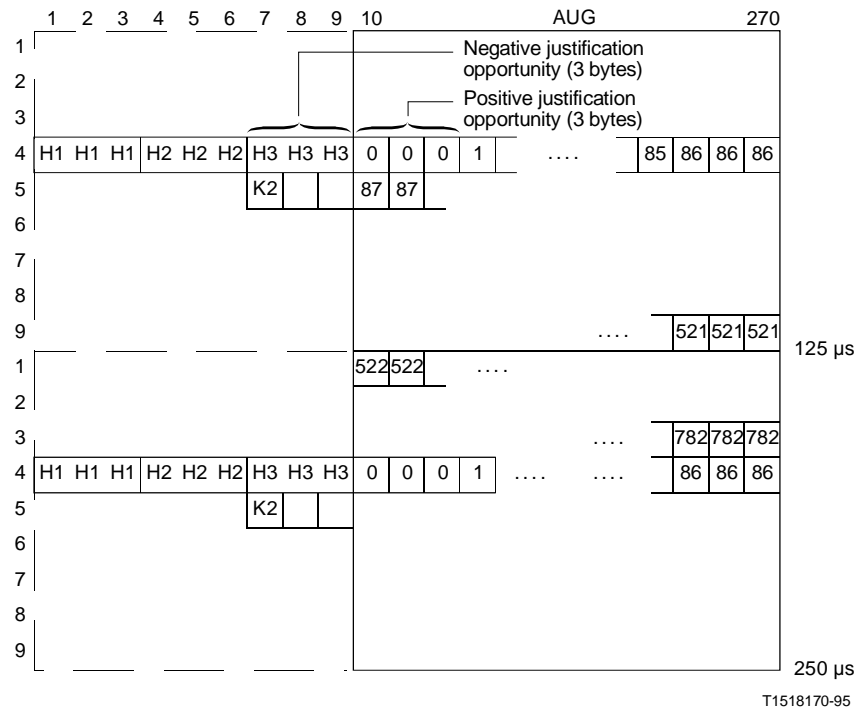**Figure 4.1 AU-4 Pointer Offset Numbering**

Figure 4.2 AU-3 Pointer Offset Numbering

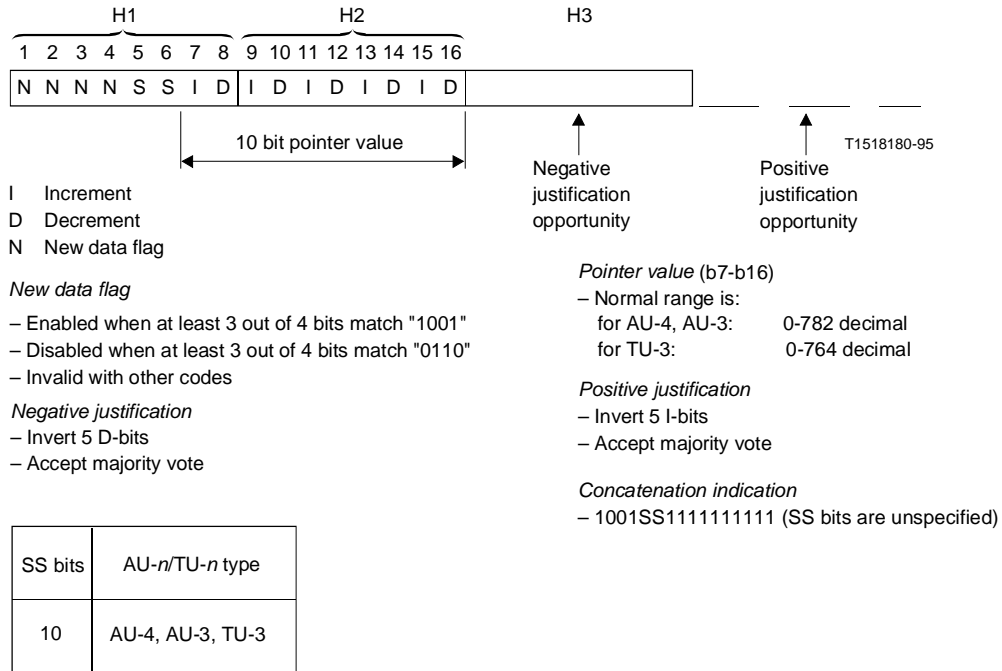NOTE – The pointer is set to all "1"s when AIS occurs.

Figure 4.3 AU-n/TU-3 Pointer (H1, H2, H3) Coding

4.3 AU-n Pointer Value:

The pointer contained in H1 and H2 designates the location of the byte where the VC-n begins.

The two bytes allocated to the pointer function can be viewed as one word as shown in fig. 4.3.

The last ten bits (bits 7-16) of the pointer word carry the pointer value. As illustrated in fig. 4.3,

the AU-4 pointer value is a binary number with a range of 0 to 782 which indicates the offset, in three byte increments, between the pointer and the first byte of the VC-4 (fig. 4.1). Fig. 4.3 also indicates one additional valid pointer, the concatenation Indication. The Concatenation Indication is indicated by "1001" in bits 1-4, bits 5-6 unspecified, and ten "1"s in bits 7-16. The AU-4 pointer is set to Concatenation Indication for AU-4 concatenation (see fig. 4.8).

As in Fig. 4.3, the AU-3 pointer value is also a binary number with a range of 0 to 782. Since there are three AU-3s in the AUG, each AU-3 has its own associated H1, H2 and H3 bytes. As shown in figure 4.2, the H bytes are shown in sequence. The first H1, H2, H3 set refers to the first AU-3, and the second set to the second AU-3, and so on. For the AU-3s, each pointer operates independently.

1* All 1s byte
Y 1001SS11 (S bits are unspecified)
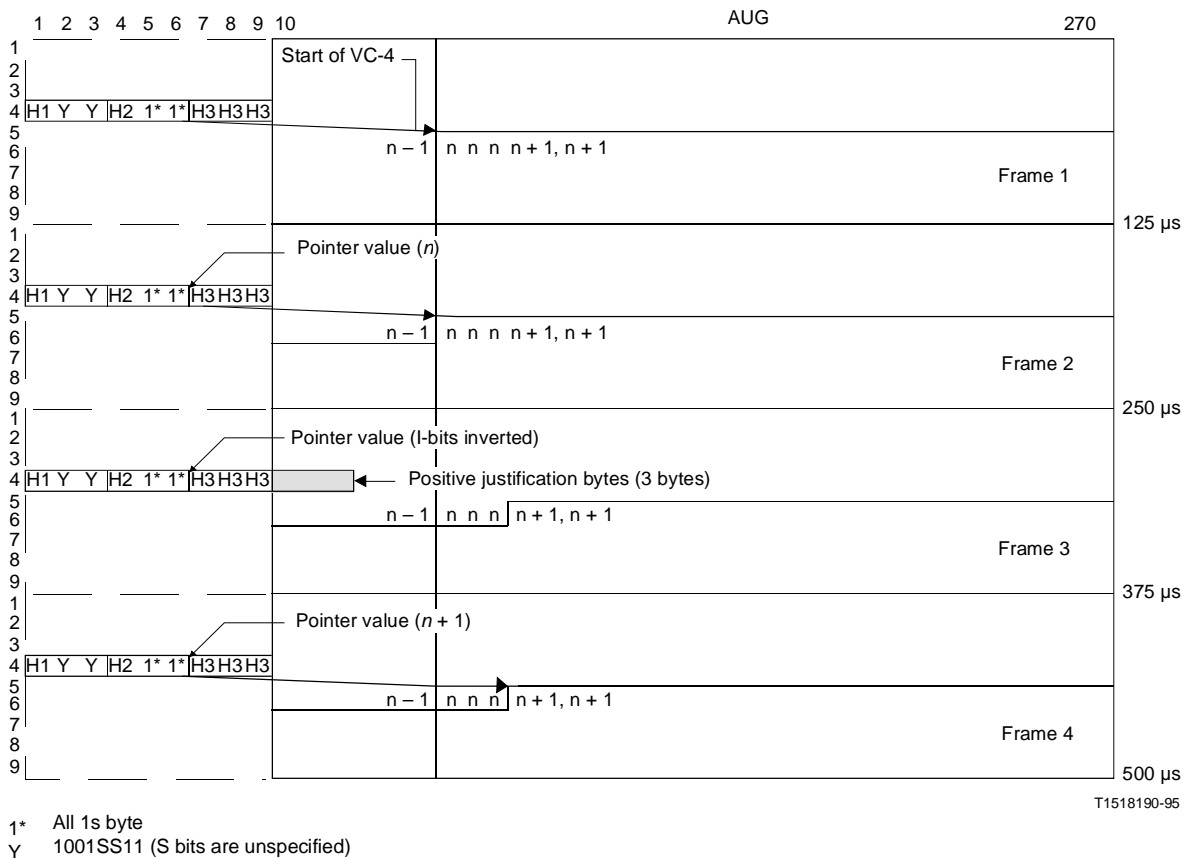
Figure 4.4 AU-4 Pointer Adjustment Operation – Positive Justification

In all cases, the AU-n pointer bytes are not counted in the offset. For example, in an AU-4, the pointer value of 0 indicates that the VC-4 starts in the byte location that immediately follows the last H3 byte, whereas an offset of 87 indicates that the VC-4 starts three bytes after the K2 byte.

4.4 Frequency Justification: If there is a frequency offset between the frame rate of the AUG and that of the VC-n, then the pointer value will be incremented or decremented as

needed, accompanied by a corresponding positive or negative justification byte or bytes. Consecutive pointer operations must be separated by at least three frames (i.e. every fourth frame) in which the pointer value remains constant. If the frame rate of the VC-n is too slow with respect to that of the AUG, then the alignment of the VC-n must periodically slip back in time and the pointer value must be incremented by one. This operation is indicated by inverting bits 7, 9, 11, 13 and 15 (I-bits) of the pointer word to allow 5-bit majority voting at the receiver. Three positive justification bytes appear immediately after the last H3 byte in the AU-4 frame containing inverted I-bits. Subsequent pointers will contain the new offset. This is illustrated in figure 4.4.

For AU-3 frames, a positive justification byte appears immediately after the individual H3 byte of the AU-3 frame containing inverted I-bits. Subsequent pointers will contain the new offset. This is illustrated in figure 4.5.
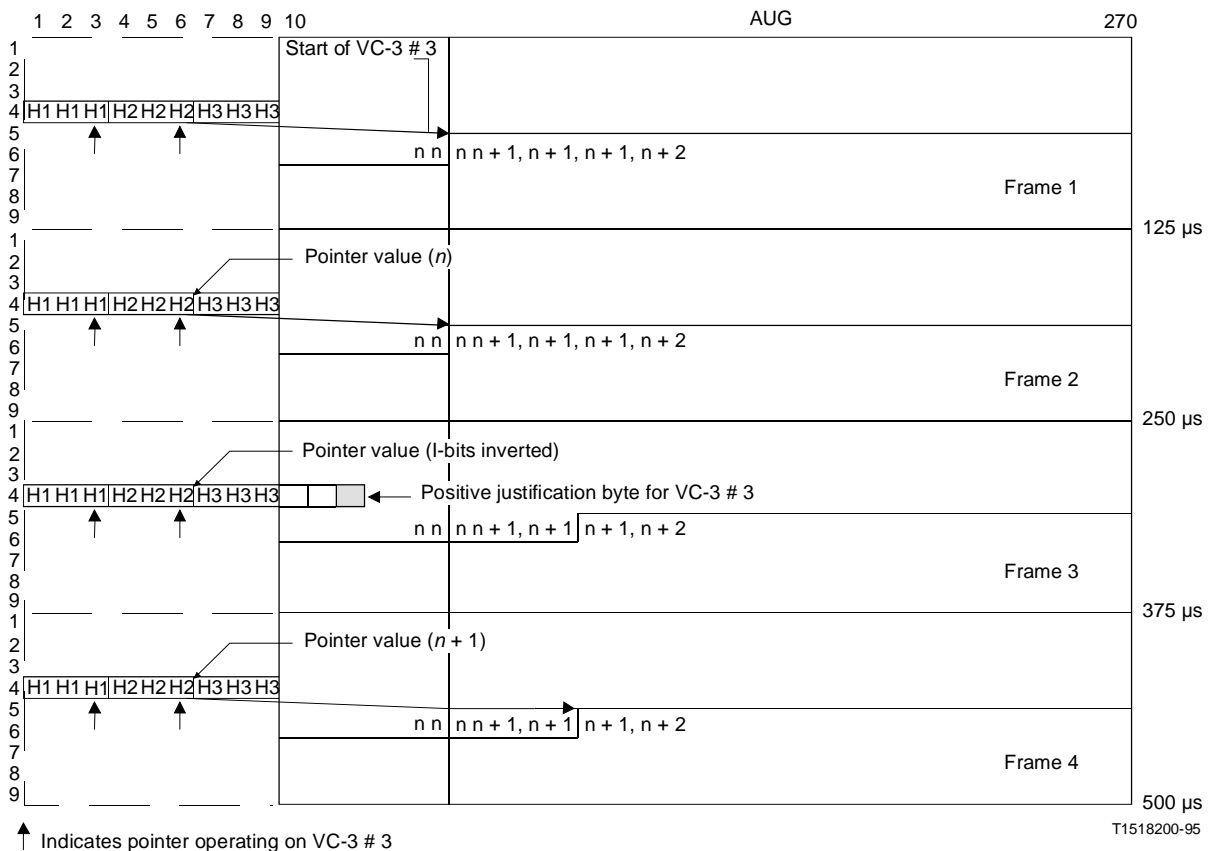
Figure 4.5 AU-3 Pointer Adjustment Operation – Positive Justification

If the frame rate of the VC-n is too fast with respect to that of the AUG, then the alignment of the VC-n must periodically be advanced in time and the pointer value must be decremented by one. This operation is indicated by inverting bits 8, 10, 12, 14 and 16 (D-bits) of the pointer word to allow 5-bit majority voting at the receiver. Three negative justification bytes appear in the H3 bytes in the AU-4 frame containing inverted D-bits. Subsequent pointers will contain the new offset. This is illustrated in figure 4.6.

For AU-3 frames, a negative justification byte appears in the individual H3 byte of the AU-3 frame containing inverted D-bits. Subsequent pointers will contain the new offset. This is illustrated in figure 4.7.

1*   All 1s byte
Y   1001SS11 (S bits are unspecified)
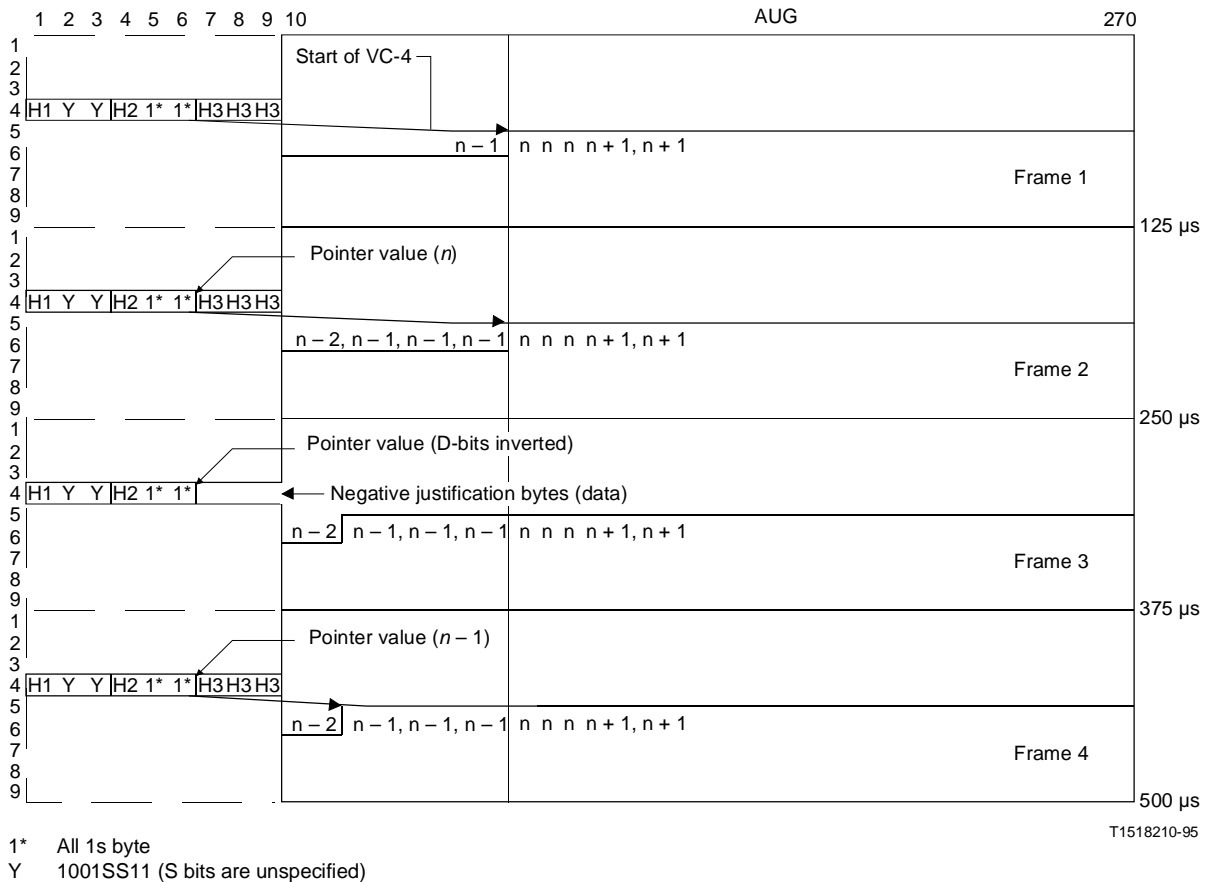
Figure 4.6 AU-4 Pointer Adjustment Operation – Negative Justification

4.5 New Data Flag (NDF):

Bits 1-4 (N-bits) of the pointer word carry an NDF, which allows an arbitrary change of the pointer value if that change is due to a change in the payload. Four bits are allocated to the flag to allow error correction. Normal operation is indicated by a "0110" code in the N-bits. NDF is indicated by inversion of the N-bits to "1001". An NDF should be interpreted as enabled when three or more of the four bits match the pattern "1001". An NDF should be interpreted as disabled when three or more of the four bits match the pattern "0110". The remaining values (i.e. "0000", "0011", "0101", "1010", "1100" and "1111") should be interpreted as invalid. The new alignment is indicated by the pointer value accompanying the NDF and takes effect at the offset indicated.

4.6 Pointer Generation:

The following summarizes the rules for generating the AU-n pointers.

During normal operation, the pointer locates the start of the VC-n within the AU-n frame. The NDF is set to "0110".

The pointer value can only be changed by operation 3, 4 or 5.

If a positive justification is required, the current pointer value is sent with the I-bits inverted and the subsequent positive justification opportunity is filled with dummy information. Subsequent pointers contain the previous pointer value incremented by one. If the previous pointer is at its maximum value, the subsequent pointer is set to zero. No subsequent increment or decrement operation is allowed for at least three frames following this operation.
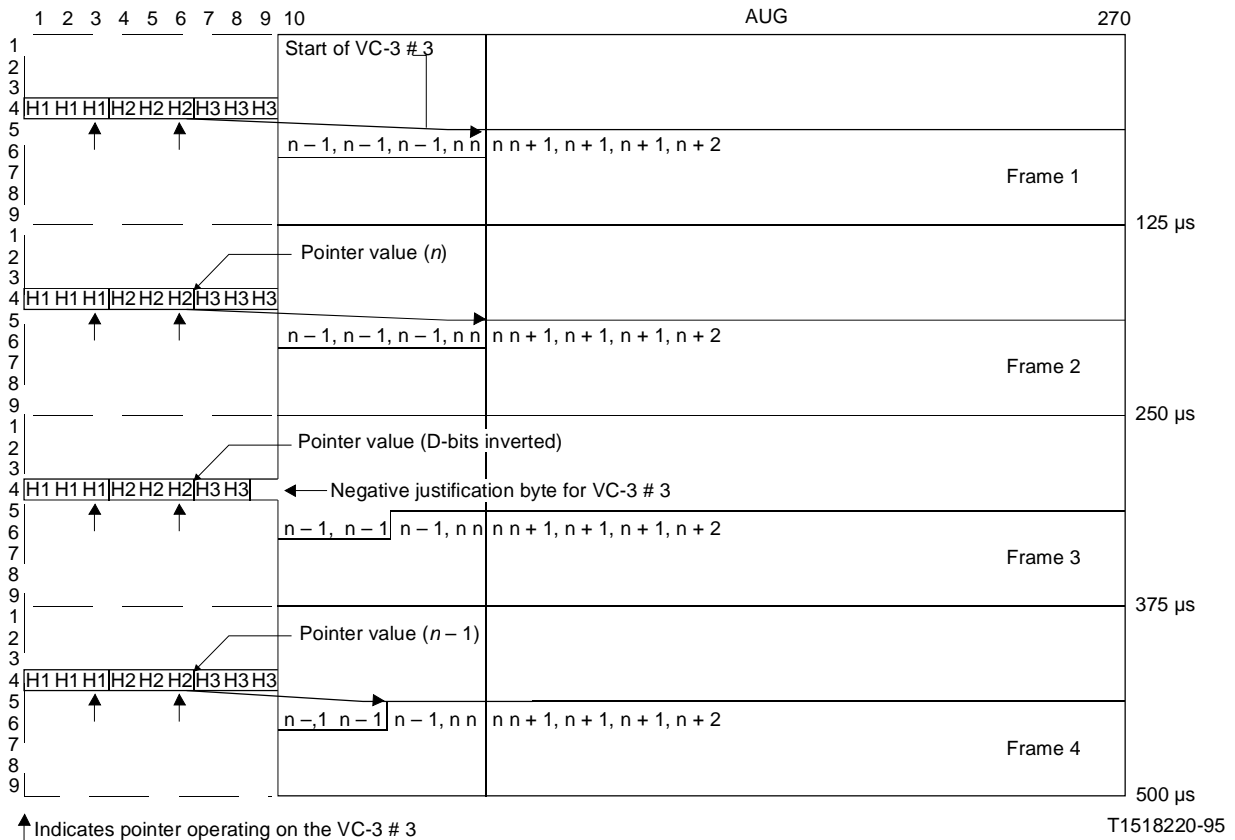
Figure 4.7 AU-3 Pointer adjustment Operation – Negative Justification

If a negative justification is required, the current pointer value is sent with the D-bits inverted and the subsequent negative justification opportunity is overwritten with actual data. Subsequent pointers contain the previous pointer value decremented by one. If the previous pointer value is zero, the subsequent pointer is set to its maximum value. No subsequent increment or decrement operation is allowed for at least three frames following this operation.

If the alignment of the VC-n changes for any reason other than rules 3 or 4, the new pointer value shall be sent accompanied by NDF set to "1001". The NDF only appears in the first frame that contains the new values. The new location of the VC-n begins at the first occurrence of the offset indicated by the new pointer. No subsequent increment or decrement operation is allowed for at least three frames following this operation.

4.7 Pointer Interpretation:

The following summarizes the rules for interpreting the AU-n pointers.

- During normal operation, the pointer locates the start of the VC-n within the AU-n frame.

- Any variation from the current pointer value is ignored unless a consistent new value is received three times consecutively or it is preceded by one of the rules 3, 4 or 5. Any consistent new value received three times consecutively overrides (i.e. takes priority over) rules 3 or 4.

- If the majority of the I-bits of the pointer word are inverted, a positive justification operation is indicated. Subsequent pointer values shall be incremented by one.

- If the majority of the D-bits of the pointer word are inverted, a negative justification operation is indicated. Subsequent pointer values shall be decremented by one.

- If the NDF is interpreted as enabled, then the coincident pointer value shall replace the current one at the offset indicated by the new pointer value unless the receiver is in a state that corresponds to a loss of pointer.
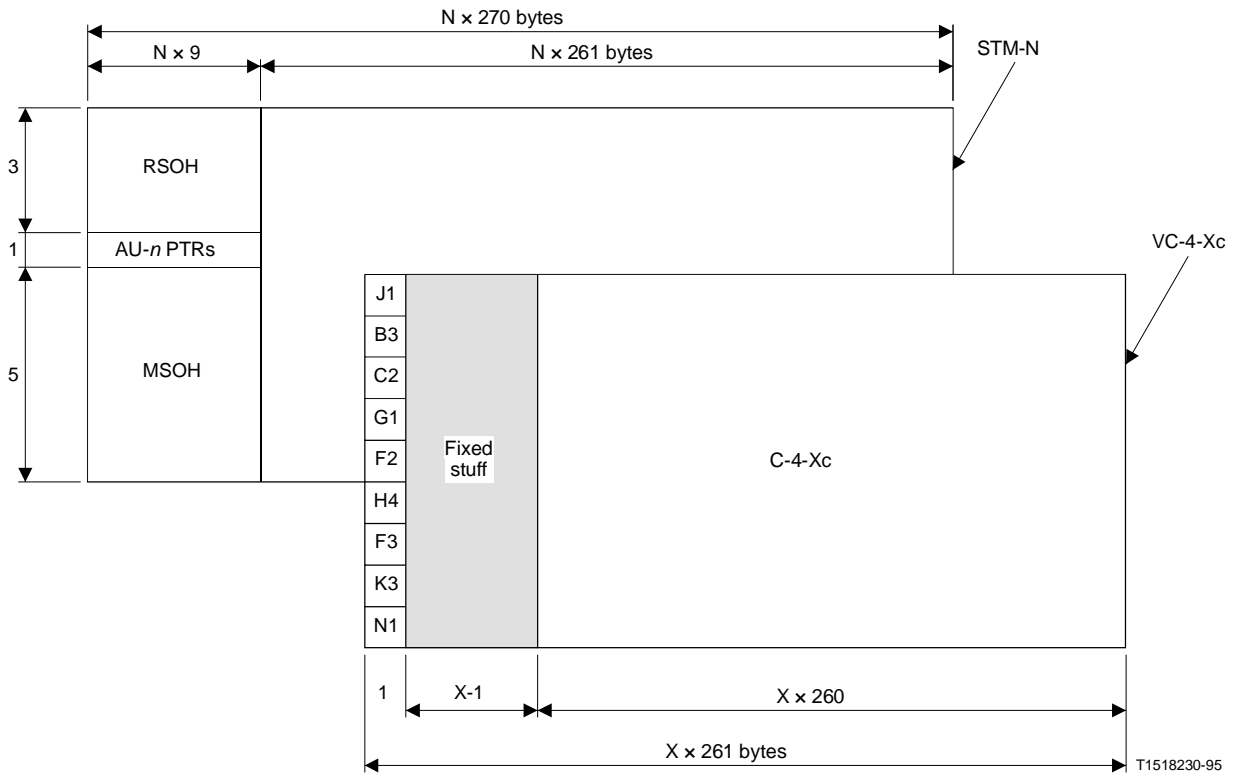
4.8 AU-4 Concatenation:

AU-4s can be concatenated together to form an AU-4-Xc (X concatenated AU-4s) which can transport payloads requiring greater capacity than one Container-4 capacity.

4.9 Concatenation Of Contiguous AU-4s:

A concatenation indication, used to show that the multi Container-4 payload carried in a single VC-4-Xc should be kept together, is contained in the AU-4 pointer. The capacity available for the mapping, the multi Container-4, is X times the capacity of the Container-4 (e.g. 599 040 Mbit/s for X = 4 and 2 396 160 kbit/s for X = 16). Columns 2 to X of the VC-4-Xc are specified as fixed stuff. The first column of the VC-4-Xc is used for the POH. The POH is assigned to the VC-4-Xc (e.g. the BIP-8 covers 261 X columns of the VC-4-Xc). The VC-4-Xc is shown in figure 4.8.

The first AU-4 of an AU-4-Xc shall have a normal range of pointer values. All subsequent AU-4s within the AU-4-Xc shall have their pointer set to Concatenation Indication "1001" in bits 1-4, bits 5-6 unspecified, and ten "1"s in bits 7-16. The Concatenation Indication indicates that the pointer processors shall perform the same operations as performed on the first AU-4 of the AU-4-Xc.

PTR   Pointer

Figure 4.8 VC-4-XC Structure

4.10 Virtual Concatenation Of AU-4s:

The virtual concatenation method for TU-2s is defined in 4.26. The details and the extensibility of the virtual concatenation method to the AU-4s are under study.

4.11 TU-3 Pointer:

The TU-3 pointer provides a method of allowing flexible and dynamic alignment of VC-3 within the TU-3 frame, independent of the actual content of the VC-3.

4.12 TU-3 Pointer Location:

Three individual TU-3 pointers are contained in three separate H1, H2 and H3 bytes as shown in figure 4.9.

4.13 TU-3 Pointer Value:

The TU-3 pointer value contained in H1 and H2 designates the location of the byte where the VC-3 begins. The two bytes allocated to the pointer function can be viewed as one word as shown in figure 4.3. The last ten bits (bits 7-16) of the pointer word carry the pointer value. The TU-3 pointer value is a binary number with a range of 0-764 which indicates the offset between the pointer and the first byte of the VC-3 as shown in figure 4.9.

T1518240-95
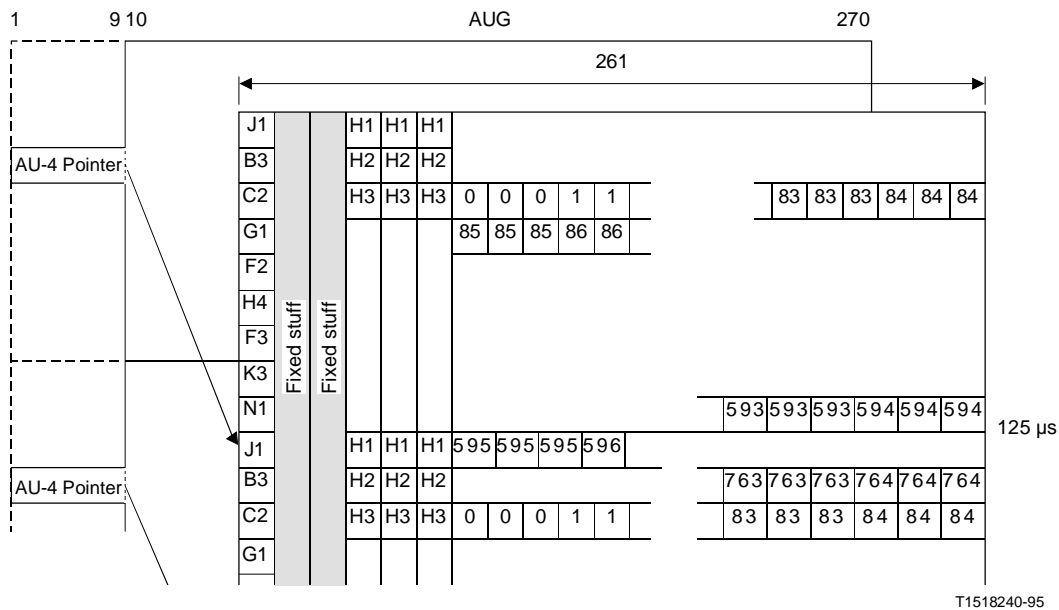
Figure 4.9 TU-3 Pointer Offset Numbering

4.14 Frequency Justification:

If there is a frequency offset between the TU-3 frame rate and that of the VC-3, then the pointer value will be incremented or decremented as needed accompanied by a corresponding positive or negative justification 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 VC-3 is too slow with respect to that of the TU-3 frame rate, then the alignment of the VC-3 must periodically slip back in time and the pointer must be incremented by one. This operation is indicated by inverting bits 7, 9, 11, 13 and 15 (I-bits) of the pointer word to allow 5-bit majority voting at the receiver. A positive justification byte appears immediately after the individual H3 byte in the TU-3 frame containing inverted I-bits. Subsequent TU-3 pointers will contain the new offset.

If the frame rate of the VC-3 is too fast with respect to that of the TU-3 frame rate, then the alignment of the VC-3 must be periodically advanced in time and the pointer must be decremented by one. This operation is indicated by inverting bits 8, 10, 12, 14 and 16 (D-bits) of the pointer word to allow 5-bit majority voting at the receiver. A negative justification byte appears in the individual H3 byte in the TU-3 frame containing inverted D-bits. Subsequent TU-3 pointers will contain the new offset.

4.15 New Data Flag (NDF):

Bits 1-4 (N-bits) of the pointer word carry an NDF, which allows an arbitrary change of the value of the pointer if that change is due to a change in the VC-3. Four bits are allocated to the flag to allow error correction. Normal operation is indicated by a "0110" code in the N-bits. NDF is indicated by inversion of the N-bits to "1001". An NDF should be interpreted as enabled when three or more of the four bits match the pattern "1001". An NDF should be interpreted as disabled when three or more of the four bits match the pattern "0110". The remaining values (i.e. "0000", "0011", "0101", "1010", "1100" and "1111") should be interpreted as invalid. The new alignment is indicated by the pointer value accompanying the NDF and takes effect at the offset indicated.

4.16 Pointer Generation:

The following summarizes the rules for generating the TU-3 pointers:

- During normal operation, the pointer locates the start of the VC-3 within the TU-3 frame. The NDF is set to "0110".
- The pointer value can only be changed by operation 3, 4 or 5.
- If a positive justification is required, the current pointer value is sent with the I-bits inverted and the subsequent positive justification opportunity is filled with dummy information. Subsequent pointers contain the previous pointer value incremented by one. If the previous pointer is at its maximum value, the subsequent pointer is set to zero. No subsequent increment or decrement operation is allowed for at least three frames following this operation.
- If a negative justification is required, the current pointer value is sent with the D-bits inverted and the subsequent negative justification opportunity is overwritten with actual data. Subsequent pointers contain the previous pointer value decremented by one. If the previous pointer value is zero, the subsequent pointer is set to its maximum value. No subsequent increment or decrement operation is allowed for at least three frames following this operation.
- If the alignment of the VC-3 changes for any reason other than rules 3 or 4, the new pointer value shall be sent accompanied by the NDF set to "1001". The NDF only appears in the first frame that contains the new value. The new VC-3 location begins at the first occurrence of the offset indicated by the new pointer. No subsequent increment or decrement operation is allowed for at least three frames following this operation.

4.17 Pointer Interpretation:

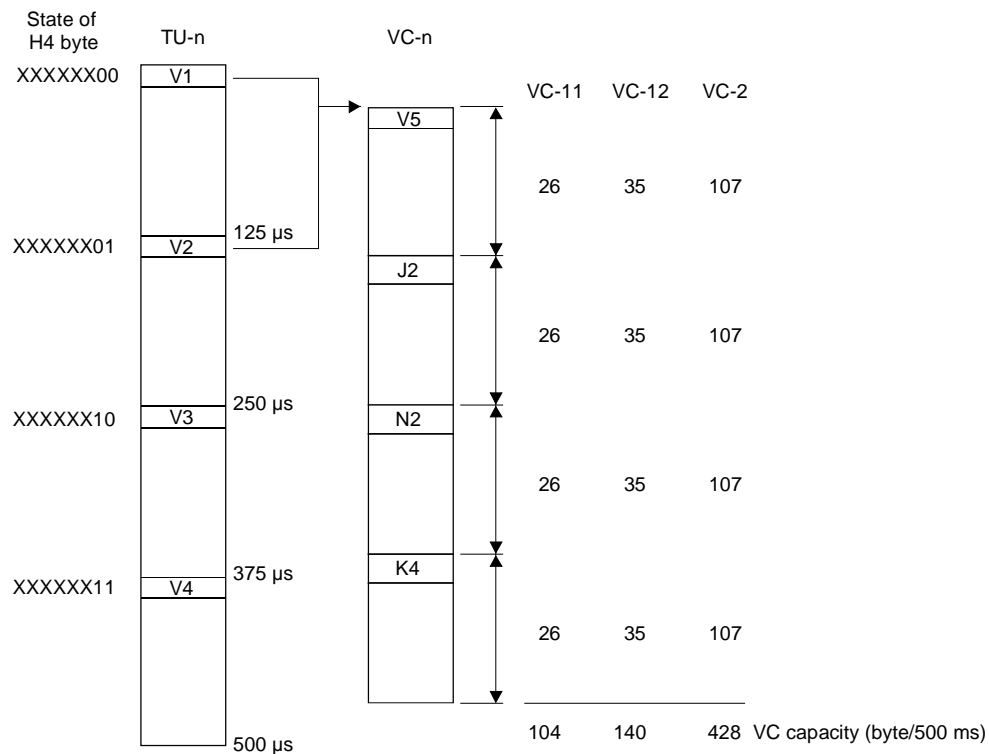The following summarizes the rules for interpreting the TU-3 pointers:

- During normal operation the pointer locates the start of the VC-3 within the TU-3 frame.
- Any variation from the current pointer value is ignored unless a consistent new value is received three times consecutively or it is preceded by one of rules 3, 4 or 5. Any consistent new value received three times consecutively overrides (i.e. takes priority over) rules 3 or 4.
- If the majority of the I-bits of the pointer word are inverted, a positive justification is indicated. Subsequent pointer values shall be incremented by one.
- If the majority of the D-bits of the pointer word are inverted, a negative justification is indicated. Subsequent pointer values shall be decremented by one.
- If the NDF is interpreted as enabled, then the coincident pointer value shall replace the current one at the offset indicated by the new pointer value unless the receiver is in a state that corresponds to a loss of pointer.

4.18 TU-2/TU-1 Pointer: The TU-1 and TU-2 pointers provide a method of allowing flexible and dynamic alignment of the VC-2/VC-1 within the TU-1 and TU-2 multi-frames independent of the actual contents of the VC-2/VC-1.

4.19 TU-2/TU-1 Pointer Location: The TU-2/TU-1 pointers are contained in the V1 and V2 bytes as illustrated in figure 4.10.

4.20 TU-2/TU-1 Pointer Value:

The Tributary Unit pointer word is shown in figure 4.11. The two S bits (bits 5 and 6) indicate the Tributary Unit type. The pointer value (bits 7-16) is a binary number, which indicates the offset from V2 to the first byte of the VC-2/VC-1. The range of the offset is different for each of the Tributary Unit sizes as illustrated in figure 4.12. The pointer bytes are not counted in the offset calculation.

|					VC-11	VC-12	VC-2
State of H4 byte	TU-n		VC-n				
XXXXXX00	V1						
			V5		26	35	107
XXXXXX01	V2	125 µs					
			J2		26	35	107
XXXXXX10	V3	250 µs					
			N2		26	35	107
XXXXXX11	V4	375 µs	K4				
					26	35	107
		500 µs			104	140	428 VC capacity (byte/500 ms)

TU   Tributary unit
VC   Virtual container
V1   VC Pointer 1
V2   VC Pointer 2
V3   VC Pointer 3 (action)
V4   Reserved

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NOTE – V1, V2, V3 and V4 bytes are part of the TU-n and are terminated at the pointer processor.

Figure 4.10 Virtual Container Mapping In Multi-framed Tributary Unit
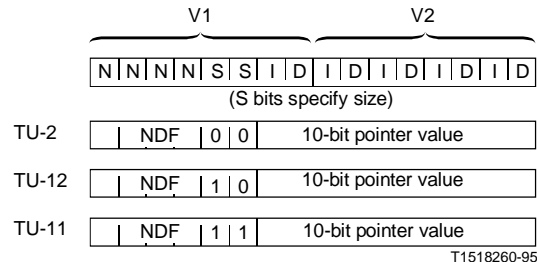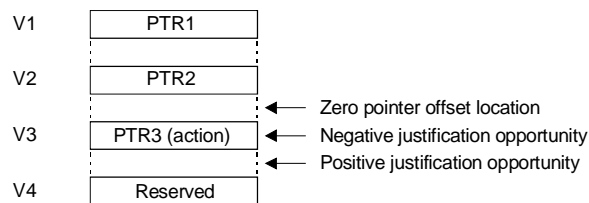
I Increment
D Decrement
N New Data Flag

New Data Flag
– Enabled when at least 3 out of 4 bits match "1001"
– Disabled when at least 3 out of 4 bits match "0110"
– Invalid with other codes

Negative justification
– Invert 5 D-bits
– Accept majority vote

Positive justification
– Invert 5 I-bits
– Accept majority vote

Pointer value
Normal range is:
  – for TU-2:   0-427 decimal
  – for TU-12: 0-139 decimal
  – for TU-11: 0-103 decimal

Concatenation indication
– 1001SS11111111 (SS bits are unspecified)
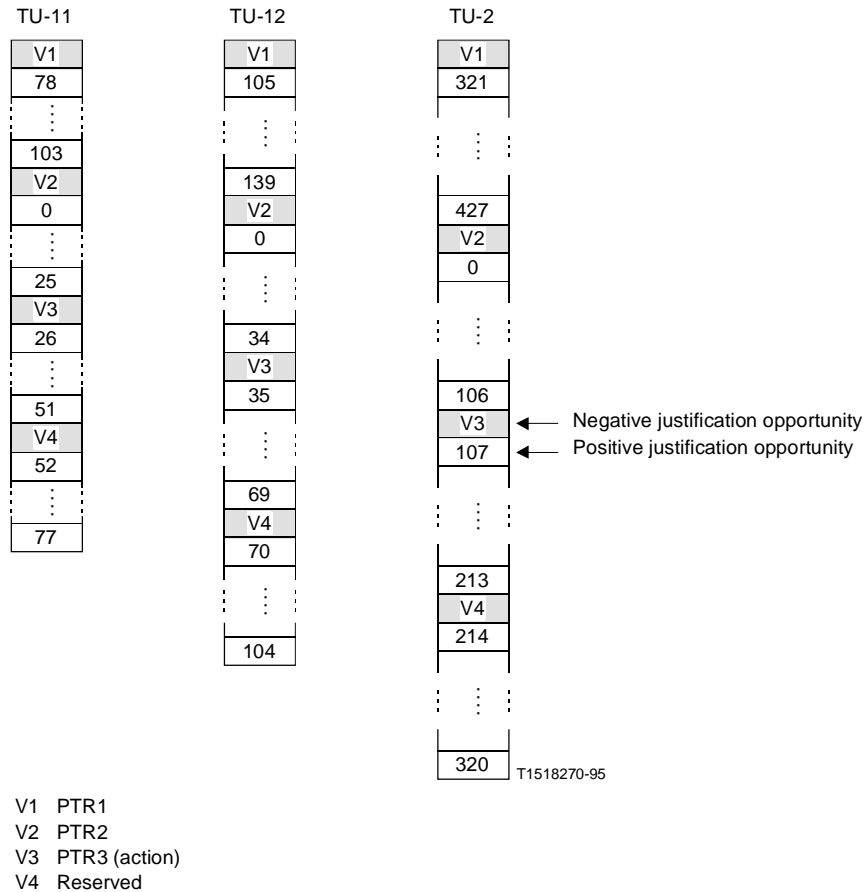
Figure 4.11 TU-2/TU-1 Pointer Coding

4.21 TU-2/TU-1 Frequency Justification:

The TU-2/TU-1 pointer is used to frequency justify the VC-2/VC-1 exactly in the same way that the TU-3 pointer is used to frequency justify the VC-3. A positive justification opportunity immediately follows the V3 byte. Additionally, V3 serves as the negative justification opportunity such that when the opportunity is taken, V3 is overwritten by data. This is also shown in Fig.4.12. The indication of whether or not a justification opportunity has been taken is provided by the I- and D-bits of the pointer in the current Tributary Unit multi-frame. The value contained in V3 when not being used for a negative justification is not defined. The receiver is required to ignore the value contained in V3 whenever it is not used for negative justification.

4.22 New Data Flag (NDF):

Bits 1-4 (N-bits) of the pointer word carry an NDF. It is the mechanism, which allows an arbitrary change of the value of a pointer. As with the TU-3 pointer NDF, the normal value is "0110", and the value "1001" indicates a new alignment for the VC-n, and possibly new size. An NDF should be interpreted as enabled when three or more of the four bits match the pattern "1001". An NDF should be interpreted as disabled when three or more of the four bits match the pattern "0110". The remaining values (i.e. "0000", "0011", "0101", "1010", "1100" and "1111") should be interpreted as invalid. The new alignment is indicated by the pointer value and size value accompanying the NDF and takes effect at the offset indicated.

4.23 TU-2/TU-1 Pointer Generation And Interpretation:

V1   PTR1
V2   PTR2
V3   PTR3 (action)
V4   Reserved

Figure 4.12 TU-2/TU-1 Pointer Offsets

The rules for generating and interpreting the TU-2/TU-1 pointer for the VC-2/VC-1 are an extension to the rules provided in Fig. 4.16 and Fig. 4.17 for the TU-3 pointer with the following modifications:

The term TU-3 is replaced with TU-2/TU-1 and the term VC-3 is replaced with VC-2/VC-1.

4.24 TU-2 Concatenation:

TU-2s may be concatenated to form a TU-2-mc (m concatenated TU-2s) when a payload requires more than a Container-2. This forms a multi Container-2 payload, which is carried in a single VC-2-mc. The rules by which TU-2s can be concatenated are separated into two categories:

- Concatenation of contiguous TU-2s in the higher order VC-3;
- Virtual concatenation of TU-2s in the higher order VC-4.

4.25 Concatenation Of Contiguous TU-2s In The Higher Order VC-3:

TU-2s are contiguous in time in the higher order VC-3. The first TU-2 of an TU-2-mc shall have a normal range of pointer values. All subsequent TU-2s within the TU-2-mc shall have their pointer set to the Concatenation Indication ("1001" in bits 1-4, bits 5-6 unspecified, and all ones in bits 7-16 of the TU-2 pointer). The Concatenation Indication indicates that the TU-2 pointer

---

processor performs all the operations as indicated by the first TU-2 pointer in the TU-2-mc. With this type of concatenation the VC-2-mc contains a single Virtual Container POH which appears in VC-2 #1 of the VC-2-mc.

With virtual concatenation (see 8.3.6.2), the available capacity of the VC-2-mc is lower than that with contiguous concatenation due to the fact that with the virtual concatenation each VC-2 carries its own POH contrary to contiguous concatenation where only the VC-2 # 1 of the VC-2-mc carries its own POH. In order to be able to interconnect VC-2-mcs using different types of concatenation, the mapping of signals in VC-2-mcs should be based on the lower available capacity, namely the capacity of VC-2-mc based on virtual concatenation. Stuffing bytes should be inserted in the VC-2-mc payload based upon contiguous concatenation to accommodate the difference in capacity.

4.26 Virtual Concatenation Of TU-2s In The Higher Order VC-4:

This method of concatenation allows for the transport of a single VC-2-mc in $m \times$ TU-2 without the use of Concatenation Indication in the pointer bytes. The method only requires the path termination equipment to provide concatenation functionality.

Virtual concatenation requires the concatenated Tributary Unit signals at the origin of the path to be launched with the same pointer value. The so formed Tributary Units at each interface shall be kept in a single higher order VC-4.

When the higher order VC-4 is terminated, the restrictions that apply in passing the concatenated Tributary Units from one interface to another is that all of the concatenated Tributary Units are connected to a single higher order VC-4 and that the time sequencing of the concatenated Tributary Units is not altered.

Differences in delay of the individual concatenated VC-2 signals may occur due to pointer processing at intermediate equipment. The maximum difference in pointer value within a concatenated group at any interface is for further study. At the path termination the VC-2-mc can be reconstructed by using the pointer values for alignment. Each concatenated VC-2 signal will carry its own POH. At the VC-2-mc path termination, the individual BIP-2s are aggregated to give a single BIP error monitor.

4.27 TU-2/TU-1 Sizes: Bits 5 and 6 of TU-2/TU-1 pointer indicate the size of the TU-n. Three sizes are currently provided; they are defined in Table 4.1.

Size	Designation	TU-n pointer range (in 500 µs)
00	TU-2	0-427
10	TU-12	0-139
11	TU-11	0-103
NOTE – This technique is only used at the TU-2/TU-1 levels.		

Table 4.1 TU-2/TU-1 Sizes

VC-3/VC-4 POH
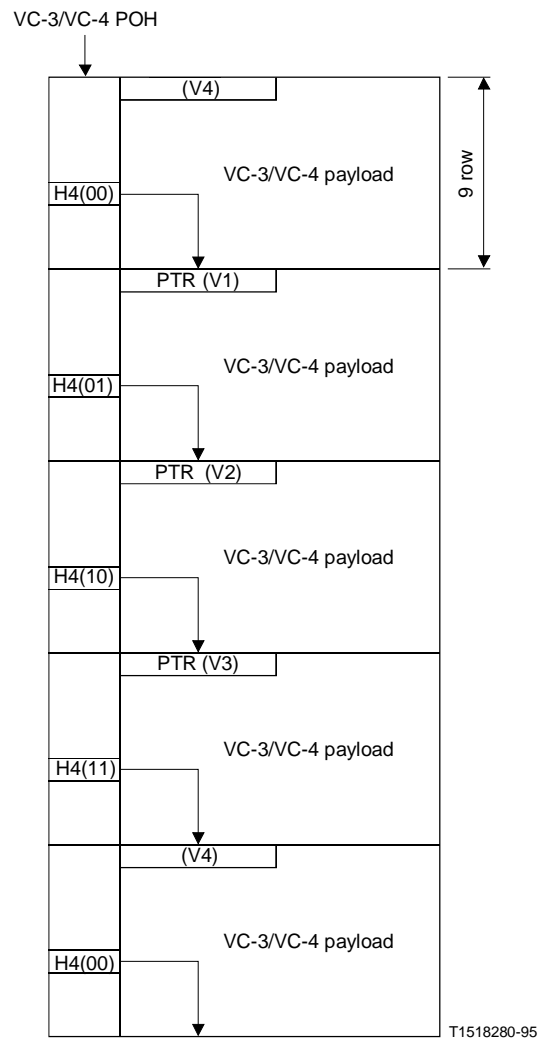
In H4 (XY), XY represent bits 7 and 8 of H4

Figure 4.13 TU-1/2 500 µs Multi-frame Indication Using H4 Byte

4.28 TU-2/TU-1 Multi-frame Indication Byte:

```
    H4 bits
1 2 3 4 5 6 7 8 Frame N°  Time
---------------------------------
X X X X X X 0 0   0        0        X – Undefined contact
X X X X X X 0 1   1
X X X X X X 1 0   2
X X X X X X 1 1   3      500 µs   TU-n multi-frame
```

Figure 4.14 Tributary Unit Multi-frame Indicator Byte (H4) Coding Sequence

The value of the H4 byte, read from the VC-4/VC-3 POH, identifies the frame phase of the next VC-4/VC-3 payload as shown in Fig. 4.13. The coding of the H4 byte is illustrated in Fig. 4.14.

Objective:

1. In an STM –1 frame three bytes together generates one address.   T/F
2. A line of VC4 in an STM –1 frame generates 86 addresses.   T/F
3. All the 9 lines of VC4 in an STM –1 frame generates 783 addresses.   T/F
4. The first H1 and the first H2 bytes of AU4 are used to generate pointer address. T/F
5. All the H3 bytes of AU4 are used for negative justification.   T/F
6. NDF OF an AU4 allows arbitrary modification of the value of the pointer.   T/F
7. In normal operation the value of NDF of an AU4 is 1001.   T/F
8. In positive justification the AU4 pointer is incremented one address from the position of the previous address.   T/F
9. In negative justification the AU4 pointer is decremented one address from the position of the previous address.   T/F
10. According to G709 standard, the value of the pointer remains constant for at least three consecutive frames.   T/F
11. The TU3 pointer value contained in H1 and H2 designates the location of the byte where the VC3 begins.   T/F
12. V1, V2, V3 and V4 bytes of TU12 of 500µs are used as the pointer bytes.   T/F

Choose the correct answer-

1. A row of VC4 in an STM –1 frame generates-   (a)
   a) 87 addresses   b) 86 addresses

2. The number of bytes to generates an address in VC4 frames-   (a)
   a) 3 bytes   b) 4bytes

4. To generate a pointer address for negative and positive justification-   (a)
   a) The first H1 and the first H2 bytes of AU4 are used.
   b) All H3 bytes of AU4 are used

6. In positive justification, the AU4 pointer value is-   (a)
   a) Incremented one address from the position of the previous address.
   b) Decremented one address from the position of the previous address.

7. The V3 byte of TU12 of 500µs is used for-   (a)
   a) Negative justification   b) Positive justification

Subjective:

1. Explain the purpose and meaning of pointer.
2. What do you understand by positive and negative justification?
3. By using H1, H2 and H3 bytes in AU-4 pointer and AU-3 pointer, explain how pointer is useful for offset numbering?
4. Pointer is 16 bits with increment and decrement bits. How these bits are used for pointer indication?
5. What are the rules for generation and interpretation of TU-3 pointer?
6. Explain TU-2,TU12 pointer

*****

CHAPTER-5

Network Topologies

Objectives: By going through this chapter, the trainee must be in a position to understand

1. Different types of networks used for SDH
2. Network Node Interface

5.1 TOPOLOGY

The word topology basically means shape, and the term network topology refers to the shape of a network—how all of the nodes (points) of a network are wired or connected together. Networks may be wired in several different topologies, and the choice of a topology is often as important decision when you plan a network. The topologies have different costs (both to install and maintain), levels of performance, and levels of reliability.

5.2 TYPES

Network topologies can be divided into four main types as under,

- String or Bus
- Ring or Loop
- Star
- Mesh

5.2.1 String Network:

In a String network, the traffic is transported by a succession of interconnection nodes. The services (Voice, Data, Video) can be added or dropped at any node in the chain. The two end nodes are called terminal nodes and can be formed by either terminal multiplexers or line terminals. The intermediate nodes can by either add and drop nodes, containing ADMs (Add/Drop Multiplexers) or regenerating nodes, containing regenerators. String networks are often called linear networks for applications such as railway, highway and pipe line networks.


TE : Terminal Multiplexer   ADM : Add & Drop Multiplexer
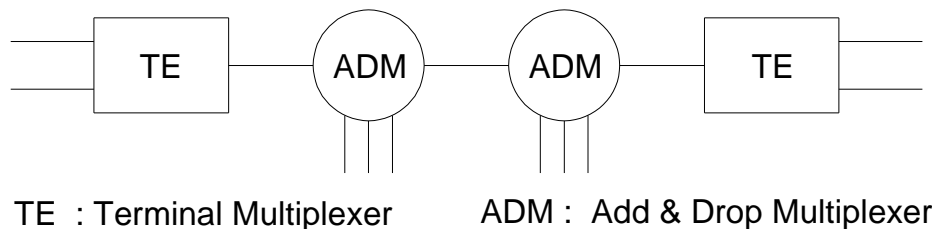
**Figure 5.1 String Network**

5.2.2 Ring Network:

A Ring network is a string looped back on itself, formed only of ADM nodes, with no terminal nodes. This type network plays an important role because of the network's self healing mechanisms that operate at very high speed (<50 milliseconds), when the network fails due to faults like cable breakage, power failure, fire in a node etc. Ring networks have a wide range of applications from access networks to LAN (Local Area Network), WAN (Wide Area Network) and national networks.

5.2.3 Star Network:

In a Star network, all the traffic passes through a central node, called the hub, which is generally a cross connect equipment. The main disadvantage of the star topology is the weakness of the network. If the hub fails, no traffic can be transported among the various branches (or links) of the star. This type of topology is commonly used in subscriber access networks.
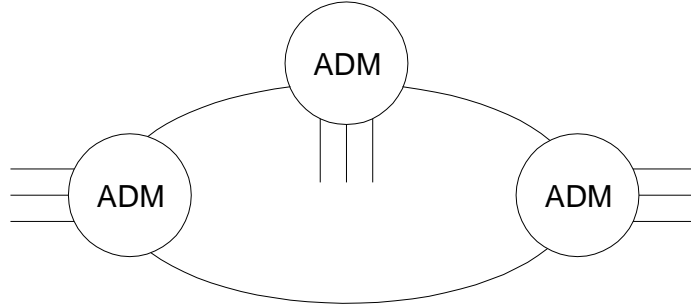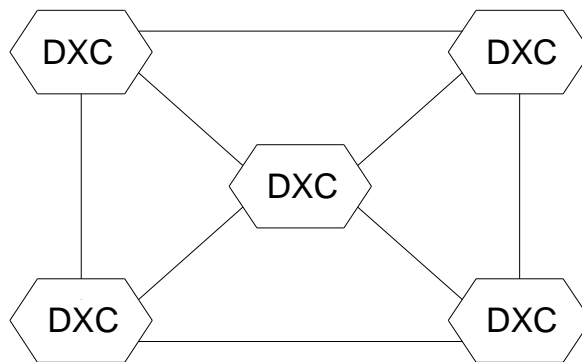

Figure 5.2 Ring Network
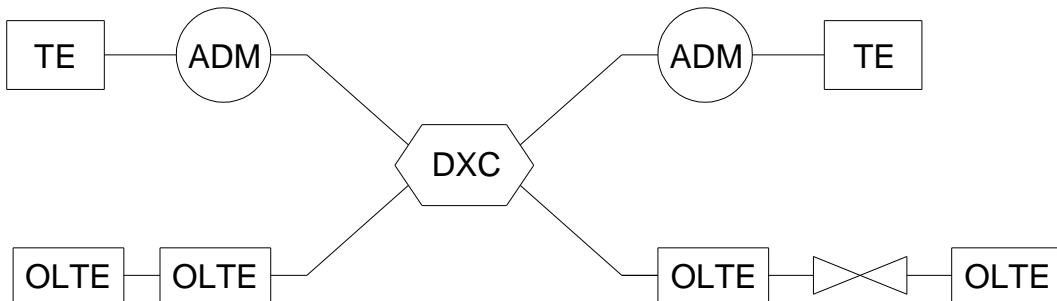
Figure 5.3 Star Net Work

5.2.4 Mesh Network:

Figure 5.4 Mesh Network

In a meshed network each node is interconnected to at least two others by one or more links. The nodes of meshed network mainly contain cross-connect equipment. Meshed networks are very useful in SDH, because of their reflex type self heading mechanisms (<200 milliseconds) with the cross connect equipment or network restoration through re-routing (assisted by network manager). Meshed networks are mainly used for national networks.

5.3 Network Node Interface (NNI): It is the interface at a network node, which is used to interconnect another network node. The NNI is the most important interface. This interface is defined in ITU(T)'s Rec.G.708 and allows interconnection of network components (e.g., network nodes and multiplex systems) via cable or radio links.

Recommendation G.708 describes the logical characteristics of the interface (i.e., structure and meaning of the bit stream at the NNI). The physical characteristics will be specified in other recommendations. Both electrical and optical interfaces are specified for the STM-1 level (155.52 Mbps). The electrical interface uses CMI coding similar to the 139.264 mbps interface described in ITU (T) Rec. G.703.

For the higher levels of SDH (e.g., 622.080 and 2488.320 mbps) only optical interfaces are specified. The line termination (LT) equipment will be integrated into the multiplexer in the future. Therefore, no standardized electrical interface between the multiplexer and the LT is specified.

Other interfaces important in the test and measurement field are the plesiochronous interfaces found in ITU-T Recommendation G.703. These interfaces will be used as long as the plesiochronous and synchronous systems coexist.

Objective:

1. Voice, data and video can be dropped or added at any node of the bus network.   **T**/F
2. The intermediate nodes of bus topology are called add and dropped nodes.   **T**/F
3. The intermediate nodes of bus topology can be either a regenerative node or a multiplexer.

    T/F
4. A ring network is a string of nodes that are looped back.   **T**/F
5. A ring network has only ADM nodes.   **T**/F
6. With the property of self-healing ability, a ring network can restore the failed circuit in less than 50ms.   **T**/F
7. Ring network cannot restore the failed circuit in less than 50ms.   **T**/F
8. In a star network the central node is called HUB.   **T**/F
9. The star topology is commonly used in subscriber access network.   **T**/F
10. Meshed network is mainly used for national network.   **T**/F

Choose the correct answer-

1. The end nodes of bus topology are called-   (a)
    a) Terminal nodes   b) Add /drop nodes
2. A ring network consists of-   (a)
    a) ADM nodes   b) Both the ADM and Terminal nodes
3. In star network if the HUB fails-   (a)
    a) No traffic can flow in the links   b) Traffic can flows through the alternative link
4. The nodes of meshed network contain –
    a) Cross-connected equipments   b) No need of cross-connected equipment

Subjective:

1. Explain the different types of network topologies used in SDH.

2. Write briefly about NNI.

*****

CHAPTER-6

Availability and Survivability

Objectives: By going through this chapter, the trainee must be in a position to understand

1. Protection categories as defined in ITU-T Rec. G.803.
2. Types of protections and applications
3. Self healing mechanism
4. Ring network protection- self healing ring protection
5. Multiple ring networks

Introduction: The deployment of optical fiber throughout the network and the adoption of the SDH network elements make end to end monitoring and maintenance possible. The management capability of the synchronous network will enable the failure of links or even nodes to be identified immediately. Using self-healing ring architectures, the network will be automatically reconfigured with traffic instantly re-routed until such a time as the faulty section has been repaired. As a result failures will not disrupt services, and guarantee high levels of network performance.

6.1 Network Availability Enhancement Techniques:

The ITU-T Recommendation G.803 describes the architectural features of the main strategies, which may by used to enhance the availability of a transport network. This availability enhancement can be performed through the following two main mechanisms.

- Protection including network protection and sub network protection
- Network restoration through traffic re routing.

6.2 Protection Categories Defined In ITU-T Recommendation G.803:

- SDH multiplex section 1 + 1 protection.
- SDH multiplex section N + 1 protection
- SDH multiplex section shared protection rings.
- SDH multiplex section dedicated protection rings.

6.3 SDH Sub Network Connection Protection (SNCP):

SDH Higher order
SDH Lower order

6.4 Types Of Protection And Applications:

Several types of failures may occur in a network (Table.6.1), each with a different probability of occurrence. For example, equipment failures are more common than link or station failures.

Equipment Protection Switching (EPS): Fig.6.1 (b). For non strategic networks with light traffic, equipment can be adequately protected by circuit board duplication 1+1 or N+1.

Automatic Protection Switching (APS): Fig.6.1 (a) Some systems also duplicate the cable 1+1, N+1and in the event of a circuit board failure, there is not only a change over to the protection board, but also to the protection link.

Path Protection Switching (PPS): Fig.6.1 (c) If the network carries heavy traffic or is of strategic importance, equipment protection is not considered sufficient. The user also needs protection against link breakage, caused by human error, such as damage by mechanical shovels, or sabotage. Such protection is provided by duplicating the link on two different routes (1+1 APS) or by setting up a ring or meshed network. If one of the inter node links fails, the traffic is not interrupted.

6.5 Types Of Protection And Applications:

Failure		Protection	
	Redundancy	Name	Type
Component	Board	*EPS (Equipment Protection Switching) Fig.6.1(b)	EPS N+1 EPS 1+1
	Board & Cable	*APS (Automatic Protection Switching – Cable in the same duct) Fig.6.1(a)	APS N+1 APS 1+1 APS N:1 APS 1:1
Link Cause: Excavation Sabotage	Route	Cable Protection with two different routes Ring, Mesh Fig.6.1(c)	APS 1+1 APS 1:1
Node Cause: Fire, Energy Interrupt	Station	Node Protection Fig. 6.1(d)	Ring & Mesh

Table.6.1 Automatic Protective systems

(a) Automatic Protective Switching

(b) Equipment Protection System

(c) Cable Protection

○   Single Node
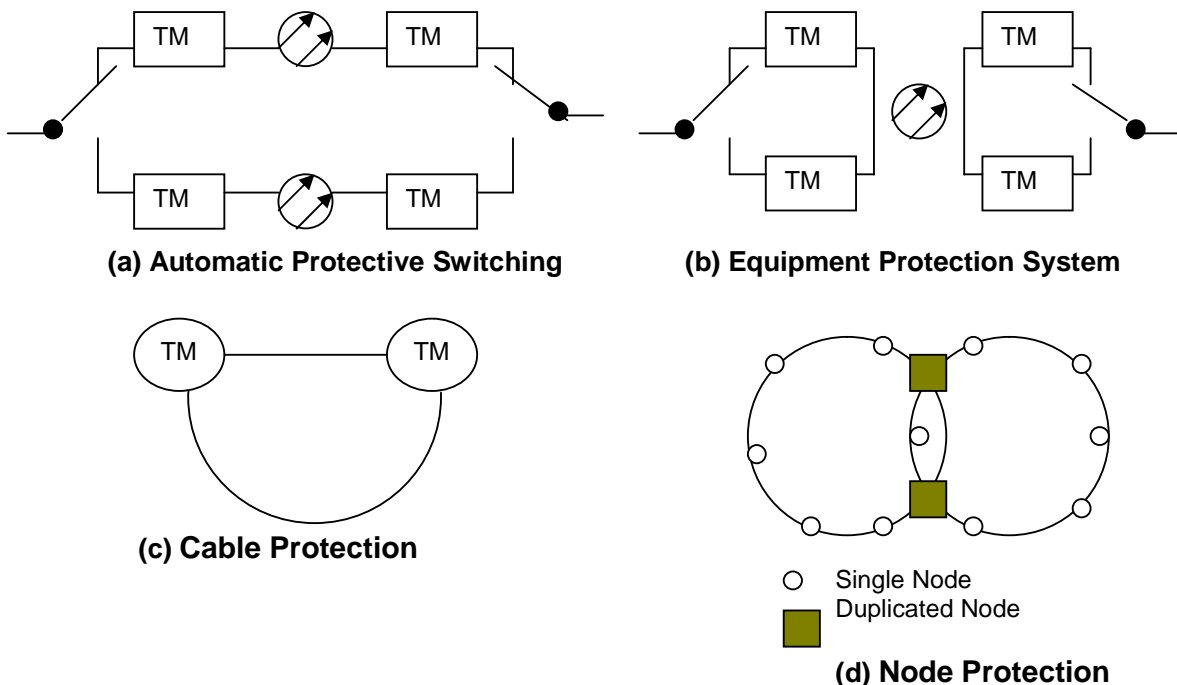■   Duplicated Node

(d) Node Protection

Fig.6.1 Protection Systems

Node Protection: Fig. 6.1 (d) If heavy traffic is carried (national networks), operators require not only link protection but also protection of some strategic nodes against station failures, such as fires and power failures. In that event, important network nodes are duplicated.

## 6.6 SDH Self Healing Mechanism:

SDH provides a higher availability and faster restoration of the long distance media because of the availability of a fully matured system of network protection and restoration. In the event of a failure, protection switches operate on both sides of the failure to route the traffic through the spare capacity. While looking at the self healing mechanism, there are the following three parameters where a trade off has to be reached.

- "Complexity" determined in terms of the information and processing required.
- "Cost" determined by the amount of redundant facility, which must be planned.
- "Response time" measured in milliseconds for a network re optimization after a major breakdown.

For network restoration strategy, we can either go in for section restoration or path restoration type of mechanisms. Where as path restoration surpasses section restoration as far as efficiency of capacity utilization is concerned, at the same time, it losses some ground as far as speed of restoration is concerned. There are a host of other attributes to be carefully evaluated while deciding on any of these mechanisms and alternatives. Needless to say that greater the flexibility higher the complexity in algorithms and network optimization.

a) Multiplexing Section Protection:

K1 and K2 bytes, as shown in MSOH of SOH, are dedicated for protection of multiplexing section. These are as recommended by ITU-T in Appendix A of G.783. They are used to co-ordinate switching at both the ends of section.
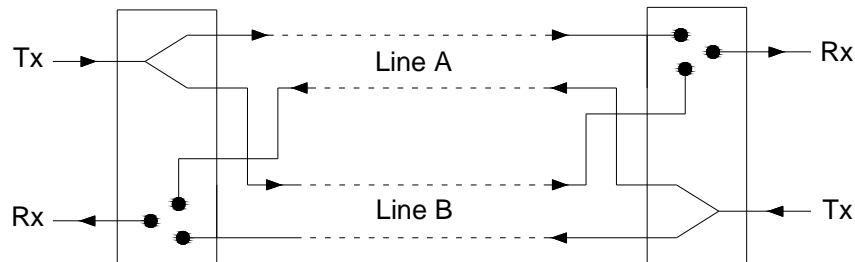
**Fig. 6.2 Multiplexing Section Protection (1+1)**
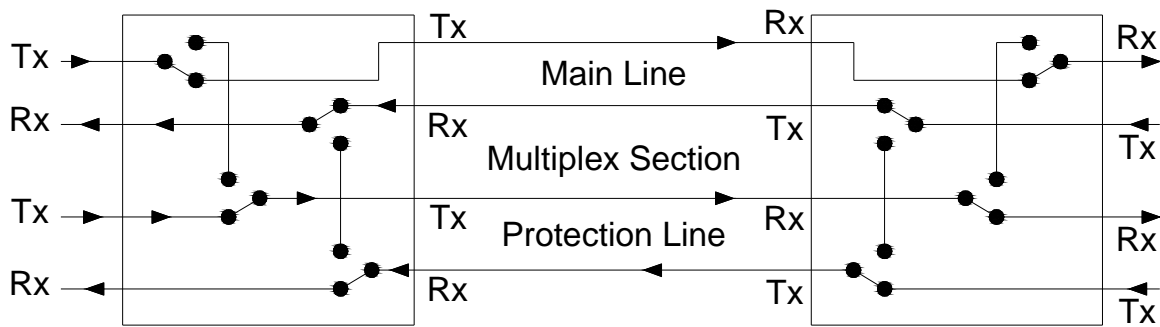
**Fig. 6.3 Multiplexing Section Protection (1:1)**

b) Path Protection:

The basic reliability of a path in SDH network is high. This is a direct result of higher functional integration, which means fewer independent, fault prone elements in series. In case of failure, path can be rearranged using cross connections, which provides high availability of transmission network based on SDH and incorporating automatic service protection.

The highest availability is achieved when the whole end to end path is duplicated. Benefits of path protection can be obtained by a simple, robust path set up protocol, which replaces a failed path within a very short time. Duplication or 1+1 protection is shown in Fig.6.4 and 1:1 protection scheme is shown in Fig. 6.5.
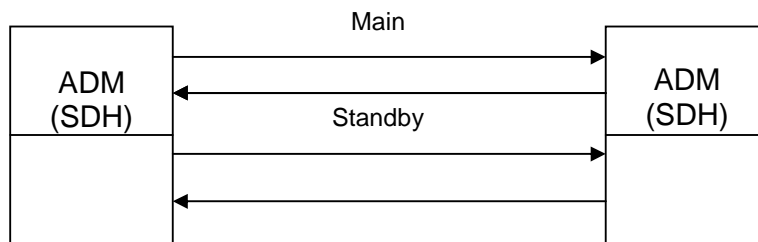
Fig. 6.4 1 + 1 Path Protection
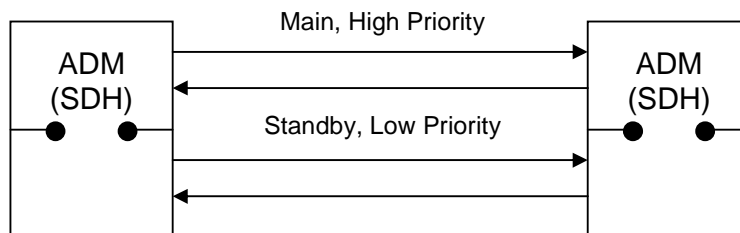
Fig. 6.5 1 : 1 Path Protection

In case of 1+1 configuration, the standby route is idle when main is in working condition. When main fails the standby takes over the load. In case of 1:1 configuration, the main route transports traffic of higher importance where as the standby carries the traffic of lesser importance. When main fails, standby transports the traffic of higher importance and traffic of lesser importance is kept under suspension. Even if standby fails the traffic of lesser importance suspended.

6.7 Ring Network Protection:

Depending upon whether it is a BSHR (Bi directional self healing ring) or USHR (unidirectional self healing ring), even double faults on a ring can be tolerated. With the help of self healing ring (SHR) architecture, the network will be automatically reconfigured with traffic instantly re routed until the faulty equipment gets repaired.
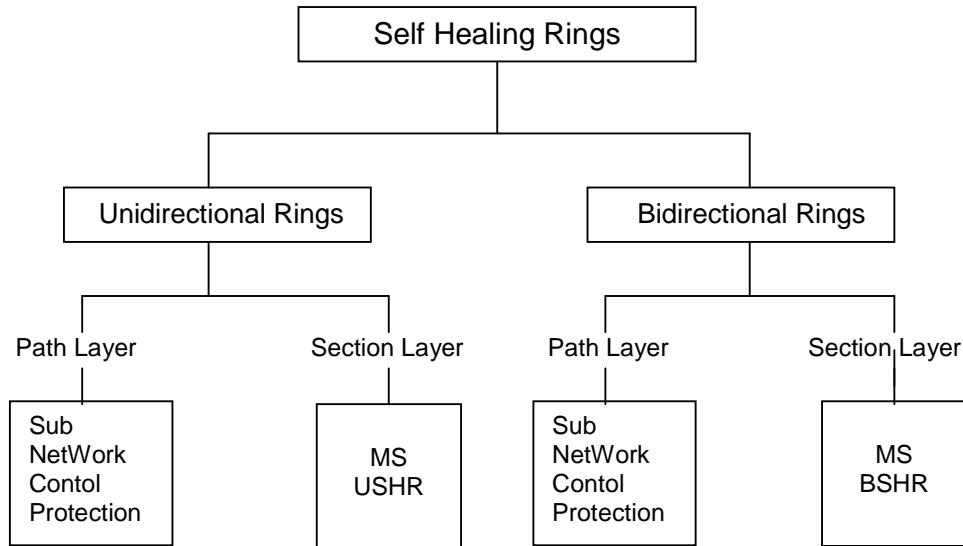
Fig. 6.6 Self Healing Ring Protection

The SDH rings can be used to provide end to end path protection and multiplex section (MS) protection at the transmission media level against link and node failures.

6.7.1 Dedicated Protection Rings (DPRINGS): Uses the path protection option where protection fibres are used but the route may not be different.

6.7.2 Diverse Route Protection (DRP): A separate protection route is followed and this technique is used where the traffic demand is very high, say STM-16, and the distances are comparatively shorter.

6.7.3 MS Switched Protection Ring (SPRING): The protection capacity, which is reserved all the way round the ring is shared. In the event of a failure, protection switches operate on both sides of the failure to route the traffic through the spare capacity.

6.8 Single Ring Network:

Ring networks combine network reliability with economic competitiveness. There are two categories of self healing rings.

6.8.1 Unidirectional rings: Consists of two fibres and can provide section protection or path protection. Transmission and reception traffic travels in the same direction around the ring, on the working fibre. The protection fibre can either be used for duplication of traffic or for carrying an empty STM – N or low priority traffic. Fig.6.7
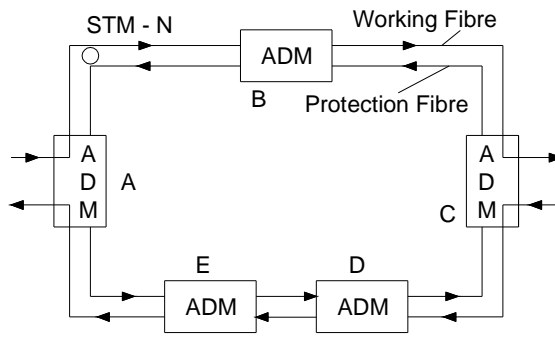
6.7 Unidirectional rings   **6.8 Bidirectional rings**
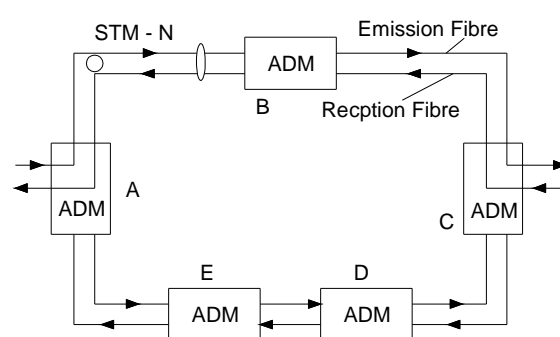
6.8.2 Bidirectional rings: Supports only section protection. Transmission and reception traffic travel in opposite directions around the ring and therefore uses both fibres of the pair. Consequently, half of the bandwidth must be reserved for protection, to allow for re routing the traffic in the event of failure in another part of the ring. Such is the case with two fibre bidirectional rings. Fig. 6.8

There are also four fibre bidirectional rings, in which one pair of fibres is reserved for protection. That pair of fibres may be used for low priority traffic and (1:1 APS protection) between adjacent nodes.

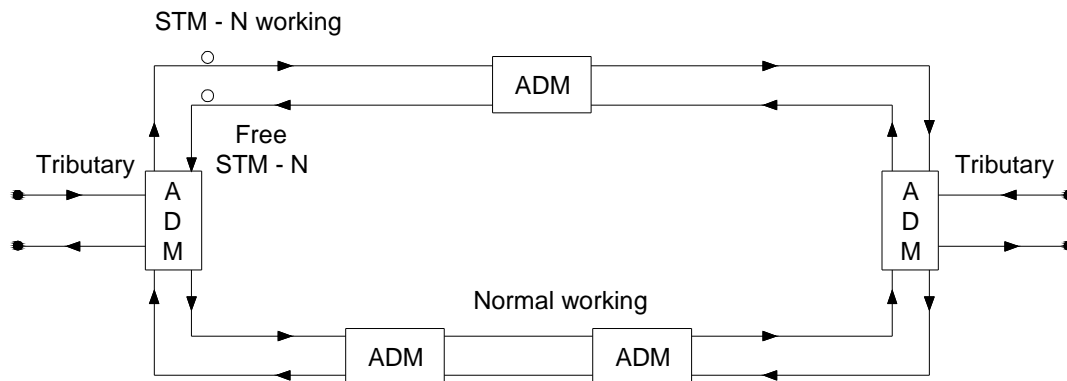**6.9 Ring Protection Mechanisms:** There are two types of ring protection mechanism.

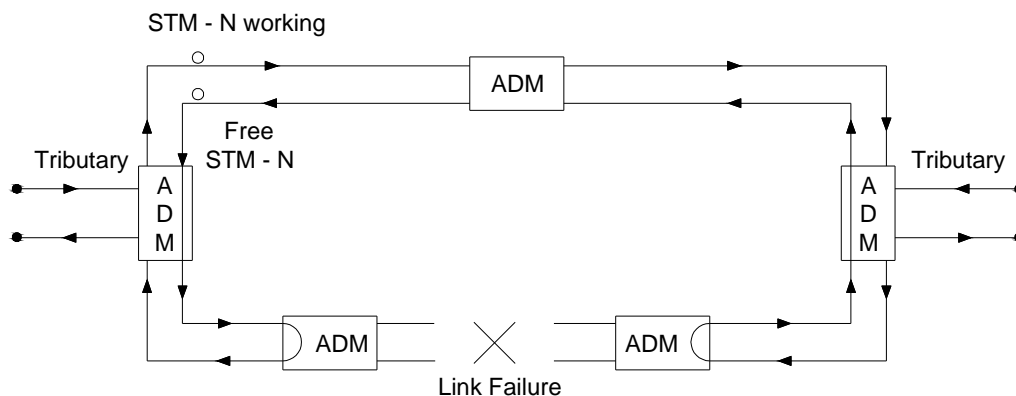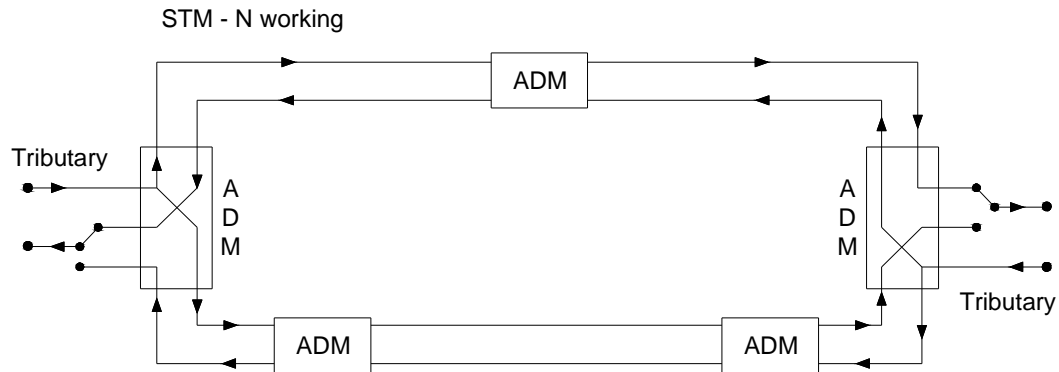**Fig. 6.9(a) USHR With Section Protection – Normal Operation**

Fig. 6.9 (b) USHR With Section Protection – Failed Condition

STM - N working

Fig. 6.10 USHR With Path Protection.

6.9.1   Multiplex section protection: Multiplex section protection is based on failure detection at the multiplex section level, by both ADMs located on both sides of the failure. If a failure occurs in one section, the STM-N signal is completely re routed by switching over to the protection fibre, even if the failure is due to only one of the containers in the frame.

This type of protection is usually a little slower than path protection, as some communication between neighboring ADMs is required in order to initiate the protection switching. Fig. 6.9 (a) shows multiplex section protection in normal operation and Fig. 6.9 (b) shows the protection during failure condition.

6.9.2 Path protection: Path protection consist in duplicating the traffic simultaneously on fibre 1 (the working fibre) and fibre 2 (the protection fibre). The highest quality signal is selected in reception in each virtual container VC-n of the STM-N frame. Path protection is therefore an end-to-end protection mechanism performed on the tributary level after failure detection on the path level. In other words, if a failure occurs on path 1, the signal of path 2 will be selected.

6.10 Sub-network connection Protection (SNCP)

Sub-Network Connection Protection (SNCP) is a per path protection and is a mechanism for SDH networks providing path protection (end-to-end). The data signal is transmitted in a ring structure via two different paths and can be implemented in line or ring structures. A protection protocol is not required. SNCP is a 1+1 protection scheme (one working and one protection transport entity). Input traffic is broadcasted in two routes (one being the normal working route and the second one being the protection route).

SNCP is path protection switching that is initiated in the path terminating equipment. In SNCP, protection is initiated on a failure in the path. It is required to create two paths for each circuit ,one working and one protection. Traffic in the source network element is bridged on both the working and the protection paths while the destination network element selects the best of the signals from the working or protection paths. SNCP is a dedicated protection mechanism. SNCP operates in a unidirectional protection manner. SNCP is a protection scheme, which can be applied on an individual basis to VC-n (both high order VC or low order VC) signals. The entry and the exit nodes are designated at connection provisioning time. A node can be both entry and exit node in case of bidirectional SNCP ring connection .SNCP ring groups are formed from unprotected facilities when SNCP ring connections are provisioned on these facilities all intermediate nodes have pass-through connections.

The advantage of the SNCP architecture is the simplicity of operation. No extra signalling protocol is needed to perform protection switching in case of failure. The protection switching mechanism is working autonomously in each node, always selecting the signal with the better quality. In the case of a failure, SNCP provides fast switchover, independent of the rest of the network. The main disadvantage of this system is that the bandwidth needed for the protection traffic cannot be used for anything else, and therefore increases the costs of the network infrastructure.

6.11 Multiple Ring Networks:

Since one link breakage is self healed per ring, network reliability increases with the number of rings. The choice of the number of rings and their corresponding nodes is based on several criteria such as topology, traffic matrix etc.

Forming a multiple ring network requires a ring connecting node to exchange traffic between rings. The configuration of the node effects the number of interface and thus the cost of the network. The node may be a cross connect equipment or ADM set up as a small cross connect equipment for a small network (a few STM-1s)

6.12 Microwave Link Systems For SDH:

Present telecommunication infrastructure tends to be dominated by optical fibre, satellite and new types of mobile systems. At the same time the microwave link with highly advantageous modulation technique in combining amplitude and phase modulation by offering several different amplitudes and phases is also used for SDH transportation. Using VLSI, the bandwidth required for a digital signal band can be considerably reduced. Some new systems use 256 QAM, 513 QAM and even 1024 QAM. 3 x STM-4 sin the 4 or 5 GHz frequency band can work 1.8 gbps. 22 STM-1s (using 512 QAM technique i.e. 3.4 gbps using combined 4 & 5 GHz frequency band) can be transmitted in a microwave system. SDH Radio can be complementary to fibre system.

Review Questions:

1. Equipment of the SDH can be adequately protected by circuit board duplication 1+1 or N + 1 **T/**F
2. Duplicating the link on different routes provides the automatic path protection of a SDH network. **T/**F
3. If one of the inter node links of a APS network fails, the traffic is interrupted. T/**F**
4. In the event of a failure of a SDH network, protection switches operate on both sides of the failure to route the traffic through spare capacity. **T/**F
5. The multiplexing section of a SDH network is protected by 16 bits of MSOH. **T/**F
6. In case of 1+1 configuration of a SDH network the stand by route is idle when main is working condition. **T/**F
7. In case of 1:1 configuration of the SDH network the main route transports traffic of higher importance where as the stand by carries the traffic of lesser importance. **T/**F
8. Bi-directional SDH ring supports only section protection. **T/**F
9. In bi-directional ring of SDH, half the bandwidth must be reserved for protection to allow for rerouting the traffic in the event of failure in another part of the ring. **T/**F
10. Network reliability in SDH increases with the number of rings. **T/**F

Choose correct answer:

1. If one of the inter node links of a APS network fails- (b)
   a) The traffic is interrupted   b) The traffic is not interrupted

2. The multiplexing section of a SDH network is protected by- (a)
   a) 16 bits of MSOH   b) 8bits of MSOH

3. In case of 1+1 configuration of a SDH network- (a)
   a) The stand by route is idle when main is working condition.
   b) The stand by route and main route are in working condition.

4. Bi-directional SDH ring supports- (b)
   a) Only section protection   b) Both the path and section

Subjective:

1. What are the protection categories as defined by ITU-T's Rec. G.803?

2. Explain the types of protections and their applications.

3. What is the difference between N + 1 and N : 1 systems?

4. What do you understand by self healing mechanism?

5. Explain the multi section protection and path protection.

6. Explain the ring protection

7. Explain what you understand about USHR and BSHR.

8. Explain what do you understand by DPRING, DRP, SPRING.

9. Explain what is SNCP ? Discuss its applications and advantages.

CHAPTER-7

Network Management

Objectives: By going through this chapter, the trainee must be in a position to understand

Network management system of SDH
Different network protocols and interfaces
Internal management
NMs applications

7.1 Network Management System (NMS) is required to manage diversely located SDH network multiplexers and elements to ensure proper network operations and monitoring from a remote location. NMS is a combination of hardware and software . An NMS managed network elements is called managed devices.

The functions performed by a network management system can be divided into five broad categories.

- Fault management, which includes fault detection and location.
- Performance management, which includes conversion of alarms, error data etc into information.
- Configuration management, which includes conversion of information data.
- Resource management
- Network security.

Management tasks include discovering network inventory, monitoring device health and status, providing alerts to conditions that impact system performance, and identification of problems, their source(s) and possible solutions. An NMS employs various protocols to accomplish these tasks. For example, SNMP protocol can be used to gather the information from devices in the network hierarchy. Functions provided by the NMS should comply with the International Telecommunication Management Networks (TMN) standards of the ITU-T and be expanded to meet future expansions.
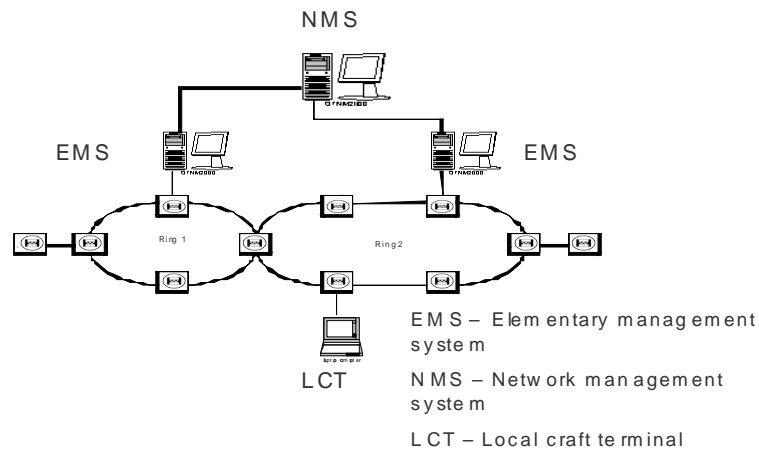
Fig. 7.1 Network Management system

7.1.1 Craft Terminal (CT) is an element-management application that provides network operators with facilities for local or remote setup for continuous field maintenance of transmission network elements for SDH/Optical Networks. It is basically a dumb terminal or terminal emulation program running on a laptop to access a SDH network element to issue commands for logging and management purposes. Craft terminal has OAM&P software downloaded into the management card of an network element through a serial interface. CT when used by crafts persons on "craft port" locally is called Local Craft Terminal and Remote Craft Terminal when used from a remote location. This interface can also be attached to a centralized database (console) server, allowing for remote management. It is then called the Extended Craft Terminal and a part of the network management solution for the operation of SDH transmission networks to supports necessary distributed operations and maintenance functionality.

7.1.2 Element Management System (EMS): EMS is a comprehensive sub-network management system for managing multi-domain network consisting of SDH products and network elements. EMS facilitates management of multi-region networks by supporting partitioning of network and flexible role based access control. It is loaded with a host of sophisticated features including auto-discovery of networks, advanced circuit management; alarm monitoring, node augmentation and hot-standby support.

EMS is supported with a dedicated server to meet the minimum management capabilities of sophisticated transmission and avoid the operational complexity of managing multiple network element. Configuration management is mandatory for EMS and other NMS process are optional hence EMS is told to be a mini NMS that costs less.

7.2 External Interfaces:

The SDH management system can be accessed through 4 types of interfaces.

- **F – Interface:** A craft terminal, which is a PC, loaded with the Proprietary Application Software of a company. F interface is a serial interface. At a time only one station or network element can be accessed.

- **Ethernet:** (Local Area Network – LAN). This is a parallel interface. At a time many stations or network elements can be accessed.

| Layers	QB2	QB3	QECC
Application	Info Model CMSE ISO9595, ISO 9596, ROSE X.219, X.229 ACSE X.217,X.227	Info Model CMSE ISO9595, ISO 9596, ROSE X.219, X.229, ACSE X.217,X.227	Info Model CMSE ISO9595, ISO 9596, ROSE X.219, X.229, ACSE X.217,X.227
Presentation	X.216, X.226, ASN 1,X 209	X.216, X.226, ASN 1, X 209	X.216, X.226, ASN 1, X 209
Presentation	X.215, X.225	X.215, X.225	X.215, X.225
Transport	ISO 8073-8073 AD2	ISO 8073-8073 AD2	ISO 8073-8073 AD2
Network	ISO 8473 - X.25 L3	ISO 8473	ISO 8473
Data Link	ISO 8802.3, ISO 8802.2	LLCMAC, LAP D – Q.921	LAP D – Q.921
Physical	ITU (T) V.11/V.35 Or V.28/V.24 X.21,X.21bis,X.27	ISO 8802.3 / IEEE 802.3	D1 - D3 or D4 - D12 SDH - DCC

Table 7.1 ITU (T)'s Network Management Protocols

- **Embedded Communication Channels (ECC):** DCCR – The data bytes D1, D2, D3 of RSOH and DCCM – the data bytes D4 to D12 of MSOH.
- **QD2 interface:** Data exchange through QD2 interface according to Supervisory and Information System for local and remote Access (SISA).

ITU(T) has recommended different protocols for different areas of working of SDH system. The Q interfaces used for network and transmission management are as per ITU(T)'s G.773.

- **QB2:** The NMS is extended to different remote SDH islands using X.25 lines through QB2 interface.

- **QB3**: Ethernet (Local Area Network – LAN)

- **QECC:** The NMS is extended to remote elements by using bridge network and embedded communication channel. The SDH network management protocols as applied to ISU's OS1 7 layered model are given in Table 7.1

Fig 7.1 shows the different interfaces of SDH Management Protocols.
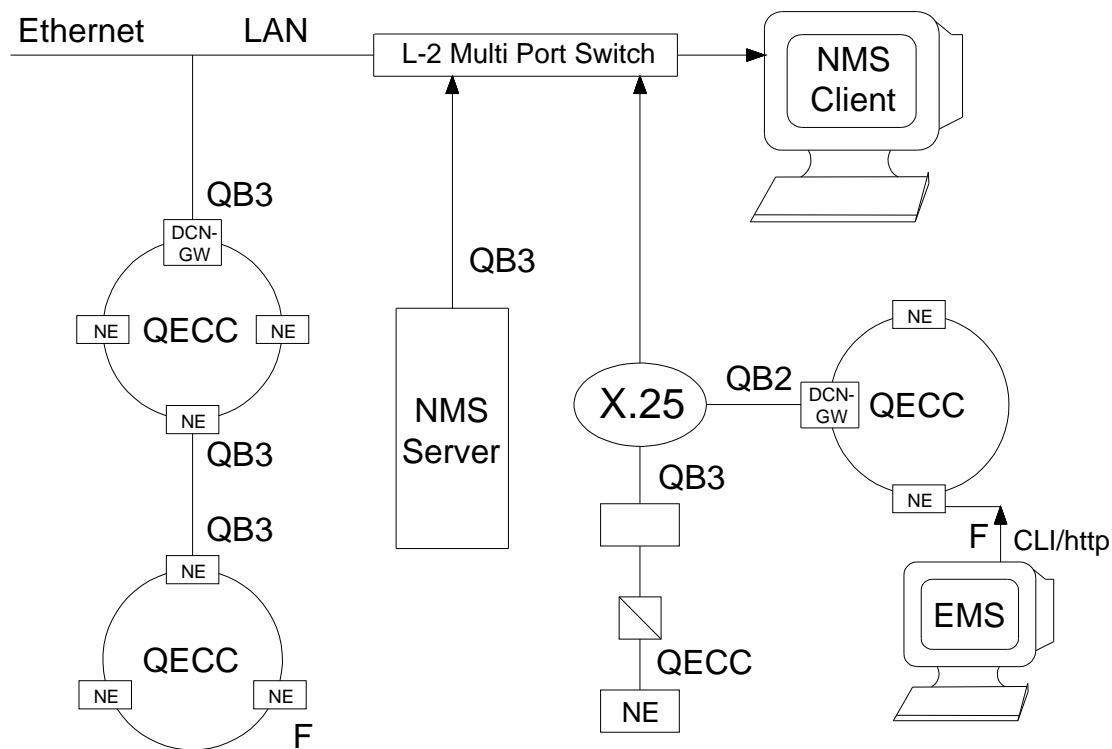
**Fig. 7.1 Network Management Protocols**

7.3 Internal Interfaces:

STM1/STM4 system is managed through a master controller on the ADM/TM module and slave controllers on TRIB modules. The master controller contains a non volatile memory for the application software of the network element. This memory can contain two complete versions of the software and download new software while in service.

Internal Management Communications between modules takes places through C-Bus. An exception is the power supply module which is either controlled via Qecb channel or via the PS – fault interface. Fig. 7.2 Shows the internal management system.
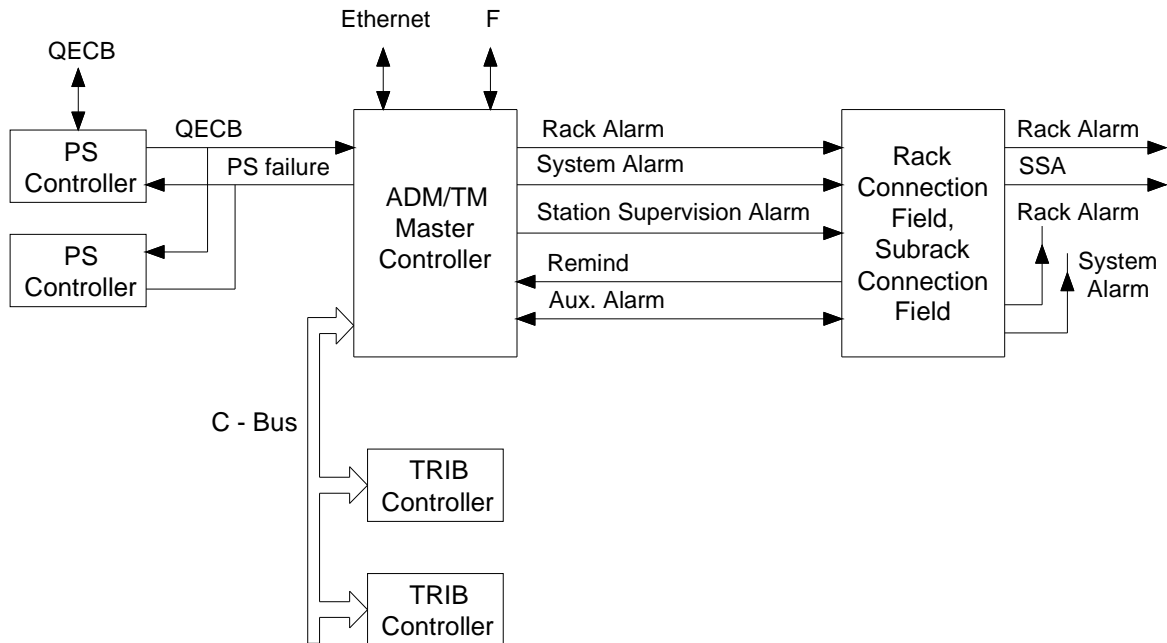
Fig. 7.2 Internal Management

7.4 Functions:

- Provides technical management support
- Supplies operator with the information of network status
- Alters the multiplexer and line configuration to manage signal switches

7.5 Applications:

a) Failure Management:

Equipment – Testing, diagnostics, alarm supervision: The NMS supports detection, identification and rectification of faults.

Network – Locates a failed unit

b) Performance Management: Evaluation of resource behavior and efficiency of communication activities.

Equipment – Failure rates

Network – Quality rating for data network availability

c) Security Management: Controlling access to unauthorized operators

Equipment – Controlling access (using a password)

Network – Controlling access

d) **Configuration Management:** Modification of operating parameters.

Equipment – Usage of hardware as per the software program and expandability

Network – Configure the system as per the existing network and equipment, provide for modification, restoration in case of failure.

7.6 Telecommunications Management Network (TMN):

Telecommunications Management Network with the use of the ISO protocols CMISE and ROSE at the level of application layer is an additional feature of SDH to specify the interfaces between the equipment units and the management network for open system interface. TMN uses embedded control channels that are in the frame D1 to D3 in RSOH and D4 to D12 in MSOH.

Review Questions:

Objective:

1. F – interface is a serial interface through which the craft terminal can be connected to the ADD/DROP nodes SDH.   **T**/F
2. Through F- inter face only one node of SDH can be accessed at a time.   **T**/F
3. Through F- inter face many nodes of SDH can be accessed at a time.   T/**F**
4. NMS is connected to Ethernet port of SDH network and many network elements can be accessed.   **T**/F
5. The NMS Is extended to remote SDH through QB2 interface.   **T**/F
6. QB3 is an Ethernet port of a network element of SDH.   **T**/F
7. The internal management communication between ADM and tributary modules of SDH takes place through C – bus cable.   **T**/F
8. The power supply module of SDH nodes controlled through Qecb.   **T**/F

Choose the correct answer

1. F – interface on ADM of SDH is a –   (a)
   a) Serial inter face   b) Parallel inter face.

2. QECB port of SDH element controls-   (a)
   a) Power supply module   b) ADM module of SDH

3. The Ethernet port of a network element of SDH is –   (a)
   a) QB3   b) Qb2   c) QECC

Subjective:

1. Explain F- Interface, Ethernet, Embedded communication channel.

2. What do you know about different network management protocols?

3. Explain the internal management of NMS

4. Explain the functions and applications of NMS

5. What is the use of D1 to D12 bytes in SOH?

CHAPTER-8

Synchronization

Objectives: By going through this chapter, the trainee must be in a position to understand

1. The synchronization System of SDH, meaning of PRC,SSU,SEC, modes of synchronization & synchronization redundancy

8.1 Introduction: SDH is designed as a synchronized network. The inputs to SDH are PDH tributaries. The PDH asynchronous traffic signals can be directly dropped/inserted at any level of the SDH system. These asynchronous traffic inputs can cause data errors, normally known as Slips. The effect of slips is as below.
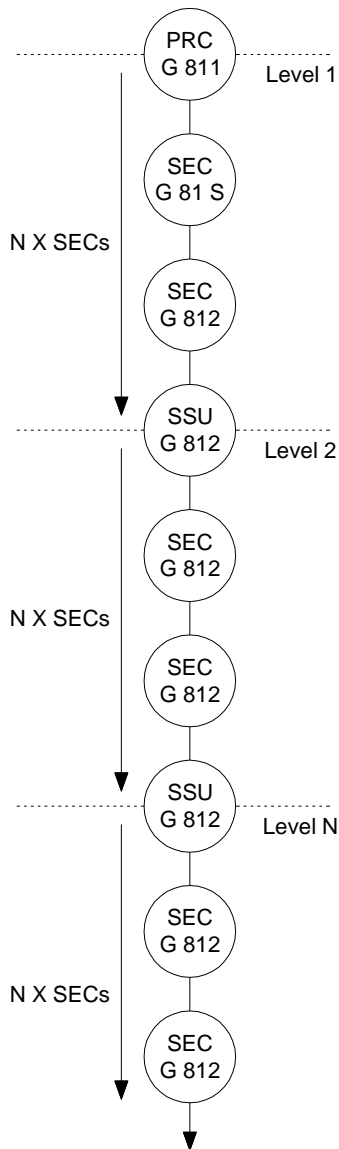
- Voice : Less input, occasional click sound
- Fax : Loss of Scan lines
- Analog Data: Several seconds of drop out
- Digital Data : Full of errors
- Digital Video: Frame freeze for several seconds.

Due to the above effects of slips it is necessary that the asynchronous inputs are synchronized at SDH input level. To compensate the phase and frequency differences between the PDH input signals to SDH equipment, a pointer adjustment mechanism is used. Such adjustments of pointers bring low frequency Jitter and therefore must be limited. To minimize such adjustments of pointers, it is necessary that all the clocks in the SDH system are synchronized with a master clock or number of master clocks. Such systems of synchronization is shown in Fig. 8.1

The system is defined as per ITU(T)'s recommendations G.811, G.812, G.813. Primary Reference Clock (PRC) is the master clock as per G.811. To filter the systematically accumulated noise in the synchronization, chains, a G.812 clock or Stand alone Synchronization Unit (SSU) is to be provided in the trail. The SSU should be provided after 20 or less than 20 consecutive network elements (NEs) or SDH equipment clocks (SSUs). The SSU is also used as Secondary Master Clock when PRC or connection to PRC fails.

N=20 Maximum N=10 With maximum restriction
That total SECs in a Trail = Maximum 60

Fig. 8.1 Synchronization Network Trail

As per ITU (T)'s G.803, there should not be more than 10 SSU's in a trail to PRC and in between to SSU's there should not be more than 20 NEs. One NE means 1 terminal equipment or 1 Add and Drop MUX or 4 regenerators. In total there should not be more than 60 NEs connected to one PRC in a trail.

It is also necessary that one SSU is connected with two or more synchronization trails and Global Positioning System (GPS) timing receivers or other timing sources meeting the ITU(T)'s G.811. This is to increase the availability of the synchronization even though the connection to PRC or to other SSU fails as shown in fig. 8.2.
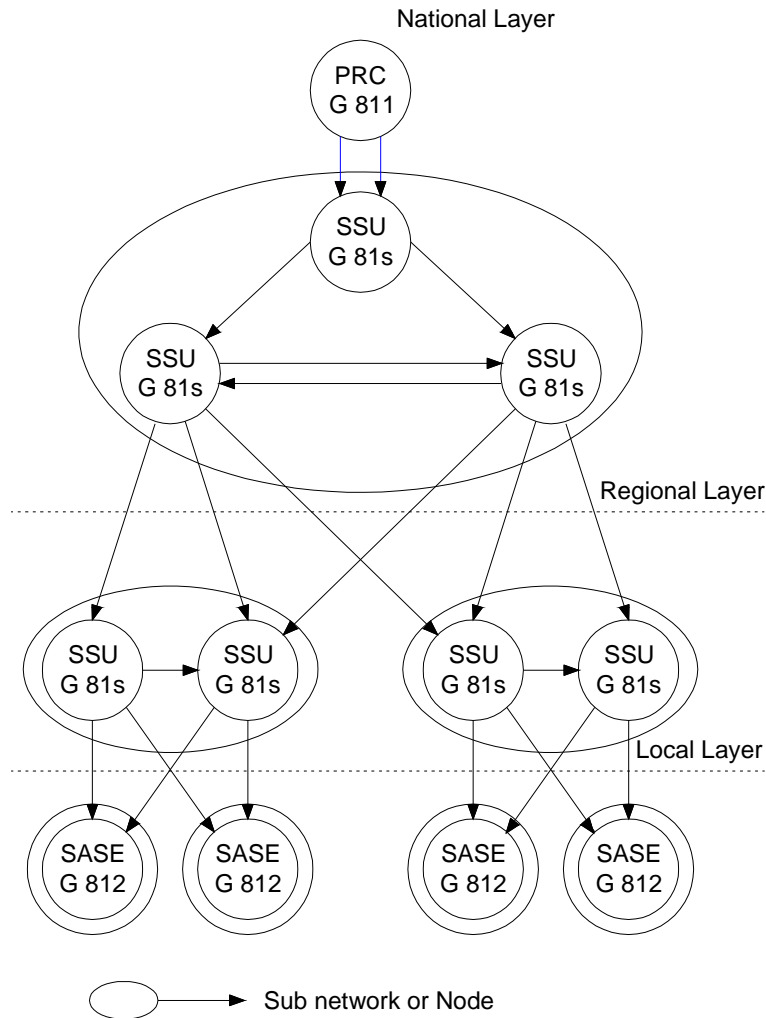
Fig. 8.2 Synchronization Network Architecture

8.2 Synchronization: ITU(T)'s recommendation G.782 provides different possibilities of synchronization at any NE. All the possibilities offered for the synchronization along with synchronous quality marker (S1 byte of MSOH) minimize the pointer movements. The synchronization function operates in one of the three modes depending on the availability, quality and priority of the reference sources.

8.3 Modes Of Synchronization:

1. Tracking Mode (Locked Mode): T0 is phased locked to the selected external timing source.

T1: Clock from SDH Interface. The synchronous clock (T0) is derived from SDH tributaries/aggregate inputs. The clock is directly derived from two STM-N without going through the equipment clock function. In this case, the S1 Byte of MSOH that is, the synchronization status message (SSM) received on the input STM-N aggregate/tributary is outputted on all STM-N outputs in the S1 byte except in the return direction of this input. In which case a separate message is inserted in S1 byte " Do not use for synchronization ". This is to avoid timing loops at the same synchronizing station or SEC.

T4

Clock directly derived from a
STM-N without going through
Equipment clock function
(SDH SynchronizationOutput)

T3 ————

Time of Day
Clock (T0)

———— T1

Piesiochrounous Interface
External (PDH Clocks)

SDH interface
STM Input Clock

Piesiochrounous Interface
External (PDH Clocks)

T2
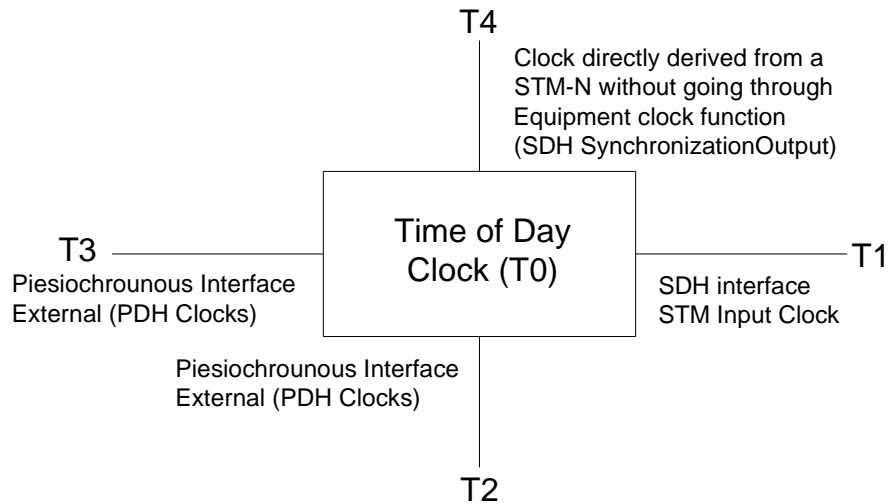
Fig : 8.3 Clock Synchronization Possibilities

SSM is the quality level transmitted in the S1 byte of MSOH. Different quality level values of SSM are shown in the Table 8.1

Quality level (User Programmable)		5 – 8 bits of S1 (MSOH)	Description
High	1	0010	G.811
	2	0000	Unknown (PDH synchronization)
	3	0100	G.812 Transit
	4	1000	G.812 Local
	5	1011	Internal G.812 clock
Low	6	1111	Do not use for synchronization(AIS)

Table 8.1 SSM Quality Levels

For other sources **T2** and **T3** user defined quality level is used.

T2 :Clock From PDH Interface – Internal.   Synchronization clock is derived from any two freely selectable PDH tributary inputs.

T3:Clock From PDH Interface – External. The synchronization clock is derived from any two external PDH timing sources or tributaries.

2. Hold Over Mode:

While operating in locked mode as described above, a holdover value is calculated basing on the difference between the system frequency and the internal reference and stored in the memory. When all synchronization inputs **T1, T2** and **T3** are lost, the system enters into hold over mode. The hold over value stored in memory described as above is used to retain the frequency as it was in locked mode.

A configurable quality level for holdover is inserted in the S1 byte on STM outputs.

4. Free Running Mode:

When all synchronization inputs **T1, T2** and **T3** are lost and even a hold over value could not be stored in memory, the clock synchronization function enters into the free running mode and adopts local clock as system clock.

A configurable quality level for free running is inserted in the S1 byte on STM output.

8.4 Modes of T4 Synchronization:

The synchronization of **T4** operates in 2 modes

- **Locked Mode:** Phase locked to selected source.

- **Unlocked Mode:** All the selected levels of T0 are lost or have a quality level below the configured squelching threshold. If T0 of not selected as source the output is squelched.

8.5 Synchronization Clock Selection - Priority:

The priority of clock synchronization selection is defined as,

- **Locking mode(Tracking):**

❖ High priority (PH)
❖ Medium priority (PM)
❖ Bottom priority (PB)

- **Holdover Mode**

- **Free Running Mode**

Any loss of synchronization clock brings an immediate shift to next priority below as shown in fig. 8.4 When the system finds a synchronization clock of higher priority again, it returns back approximately within 60 seconds, the time required for analysis and satisfaction.
t1 = immediate   t2 = 60 seconds (approx)
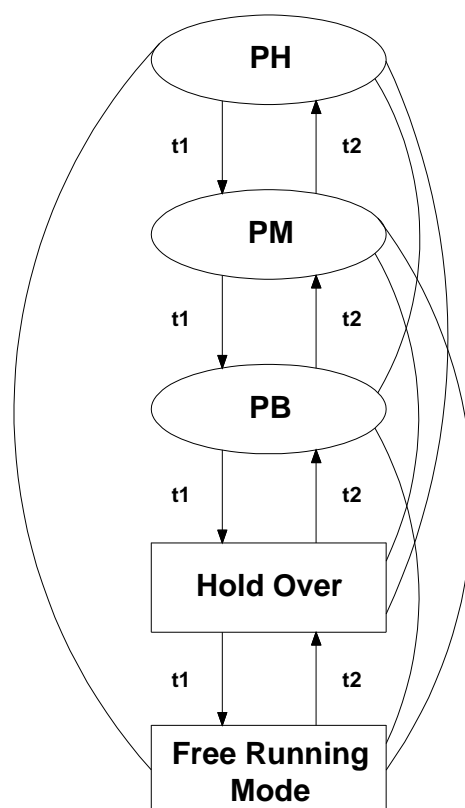
Fig. 8.4 Selection Priorities Of Synchronization Clock

8.6 Synchronization Redundancy :
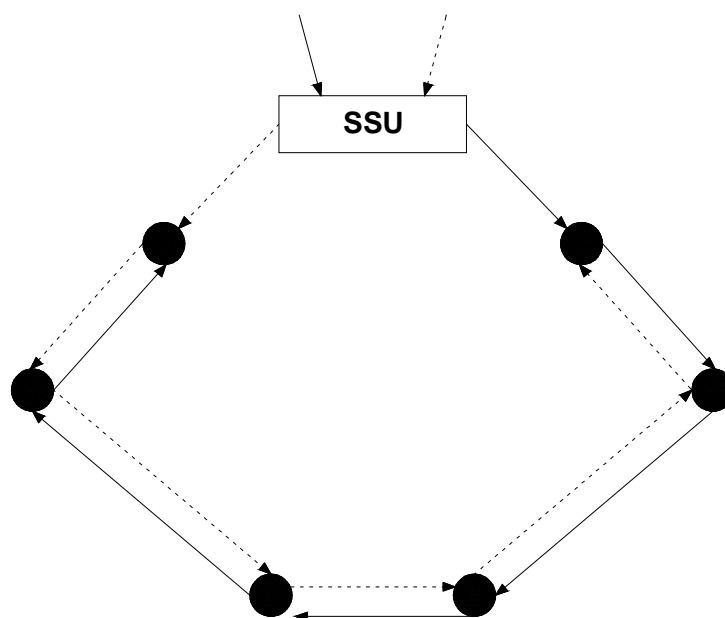
Fig. 8.5(a) Synchronization Redundancy

The synchronization is provided with redundancy to avoid interruptions in case there is a path disconnection or any other failure. Fig. 8.5 shows the synchronization redundancy. The line indicates the dark path and light line indicates the redundant path.

a: All reference sources lost
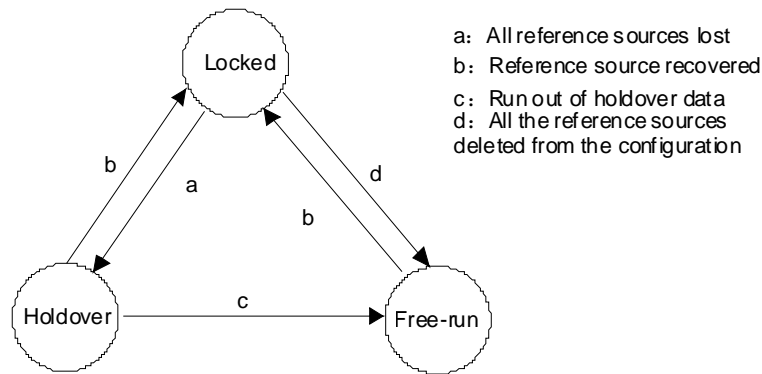b: Reference source recovered
c: Run out of holdover data
d: All the reference sources
deleted from the configuration

Fig. 8.5(b) Synchronization Redundancy

8.7 ITU(T)'s Recommendation for Synchronization :

G.803: As per Fig. 8.1, the total number of network elements in chain after SSU shall be less than 20. And number of SSUs be limited to 10 with a overall limit of number of NEs from PRC and last NE shall be less than 60.

G.811: The minimum frequency accuracy for a PRC is 10^{-11}. Therefore maximum slip rate between two PRC synchronized (sub) networks is 1 slip in 2.4 months for 8K frames per second signals. Eg. 64 kbps and 2 mbps signals.

G.812: For transit node clocks, the maximum frequency offset when entering holdover mode is 5×10^{-10} and the maximum frequency drift whilst in holdover mode is 10^{-9} per 24 hours.

G.822: For traffic performance, the maximum slip rate allowed is 5 slips per day in 24 hours for greater than 98.9% of time. The overall maximum frequency difference along a pseudo-synchronous tandem traffic connection is 7.2×10^{-9} and only for less than 1.1% of time. To meet the above performance availability of each PRC node clock and link must be>0.989.

G.823: The jitter and wander of the network shall be limited as per ITU-T Recommendation G.823. A relative wander level shall be limited in a network less than 18 micro sec to avoid slips.

8.8 Network Design Requirements:

To protect the synchronization network against single failures, the following redundancies are necessary.

- The PRC shall be internally or externally duplicated i.e 1+1 or 1+2 protected.

- The node clocks shall be internally 1+1 protected.

- The node clocks (SSU) shall have two or more diverse connections to a PRC. GPS PRC also may be deployed as one of the input clock to ensure the reliability of the clock output from SSU during failures of input PRC clock.

- The telecommunication systems shall have two or more connections from their node clock.

- Protection switching in the synchronization network must not cause further network synchronization problems, especially timing loops (slave clock synchronizing back to the master) which would seriously degraded the quality of services. Unknowingly created, it may

be very difficult to find and break such loops. Care is to be taken in the planning and using S1 byte etc.

- It shall be preferable that the synchronization signals should be transported over SDH connections as aggregate signals and over pure PDH connections as tributary signals.

- If the level of wander in a centralized master clock synchronization network exceeds 18 micro sec, then it would be necessary to partition it into several centralized master clock synchronization sub networks.

- It shall be ensured that lower stratum timing shall not be fed to higher stratum timings.

- To limit the noise/wander accumulation in the long chains of SDH NEs, and to avoid the number of NEs going on holdover during the interruption in the network, SSUs may be suitably deployed.

- The cascading of the clocks (NEs) should be minimized. Fig.T.13D.8.1 shows that there can be 20 (N=20). SDH clock NEs between the two SSUs and there can be 10 SSUs (M=10) in the chain subject to total of 60 SDH clock NEs in cascade. In order to maintain the Transient and local clock standards, the NES shall be restricted to 10 to 15 in a chain between SSUs and cascaded. SECs should be 50 to 60. However before fixing the number of NEs in the chain, the quality of internal clock shall be verified. This determines the number of NEs in a chain that can be deployed.

- A SDH section with 5 to 6 Regenerators in continuous chain should be treated as one SDH clock NE for the purpose of NEs in cascade.

- The SSUs have the multiple outputs of 2048 kbps/2048 MHz, which can be used for different rings, SDH chains, PDH networks, Access networks or other networks emerging from same station.

- The SSUs could possibly be deployed at intersecting points of SDH rings.

- To ensure the clock availability, GRPS (Global Positioning Receiver System) may be deployed at every SSU location.

- The Jitter and wander in the network and a trail shall be limited as per ITU-T Recommendation G.823. SSUs shall be deployed before Jitter and Wander limits are crossed in a trail.

The major centers should have highest quality SSUs (Transit node clock level as per G.812). Local Nodes can have lower quality SSUs,i.e. local clock level as per G.813.

Objective:

1. Frequent adjustment of pointer produces low frequency jitter.

2. To minimize the number of pointer adjustments, all the clocks in the SDH system are synchronized with a master clock. **T**/F

3. To filter the systematically accumulated noise in the synchronization chains, stand-alone synchronization unit (SSU) is provided in the trail. **T**/F

4. The SSU should be provided after 20 or less than 20 consecutive network elements. **T**/F

5. The SSU is also used as secondary master clock when PRC or connection to PRC fails. **T/F**

6. Maximum 60 NEs can be connected to PRC in a trail. **T**/F

7. SEC generates the system clock (T_0), which is used for synchronization of internal processing and for all out going SDH. **T**/F

8. The timing loop is avoided by sending do not use massage on S byte of SOH. **T**/F

9. When the bits from 5 - 8 of S1 take value 1111, it gives the massage do not carry for clock synchronization. **T**/F

10. The minimum frequency accuracy for a PRC is 10^{-11}. **T**/F

11. For traffic performance, the maximum slip rate allowed is 5 slips per day in 24 hours for greater than 98.9%. **T**/F

12. One ADM/TM Supports 21 numbers of 2MB Tributaries for Electrical termination. **T**/F

Choose the correct answer-

1. Frequent adjustment of pointer produces- (a)

   a) Low frequency jitter   b) High frequency jitter.

2. The SSU should be provided – (a)

   a) After 20 or less than 20 consecutive network elements.

   b) More than 20 consecutive network elements.

3. As per the ITU-T's standard G 803 the number of SSU –

   a) Should not be more than 10 in a trail to PRC.

   b) Should be more than 10 in a trail to PRC.

4. To a PRC in a trail- (a)

   a) Maximum 60 NEs can be connected   b) More than 60 NEs can be connected

5. In hold over mode the system synchronization of SDH ring can work for- (a)

   a) 24 hours.   b) Less than 24 hours

5. The T_0 clock is kept locked to the selected reference – (a)

   a) In Lock mode   b) In Holdover mode

6. T1 clock is a reference clock of – (a)

   a) STM-N.   b) Any 2Mbps

7. For traffic performance, the maximum slip rate allowed- (a)

   a) Are 5 slips per day in 24 hours for greater than 98.9%.

   b) Are 4 slips per day in 24 hours for greater than 98.9%.

Subjective:

1. Explain the synchronous network trail.
2. Distinguish between PRC,SSU and SEC.
3. What do you understand by Time of day clock and how it is derived?
4. What do you understand about ITU-T's Rec.G.81s?
5. Explain the synchronous network architecture.
6. What do you understand by SSM. How it is related with the clock synchronization?
7. Explain the different modes of clock synchronization.
8. What do you understand by Locking mode of **T0?**
9. What do you understand by Holdover mode**?**
10. What do you understand by Free running mode**?**
11. What do you understand by T4 synchronization?
12. Explain the clock selection priorities
13. What do you understand about Synchronization redundancy?

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CHAPTER-9

ITU (T)'s SDH Recommendations

Objectives: By going through this chapter, the trainee must be in a position to know

ITU-T's Recommendations of SDH

9.1 Introduction:

SDH Hierarchy was adopted by ITU – T in 1988. The recommendations of ITU - T at the time of adoption and subsequent additions time to time are shown in Table 9.1

9.2 ITU (T)'s Recommendations For SDH:

G.702	-	PDH bit rates
G.703	-	Plesiochronous interfaces
G.707	-	SDH flow rates
G.708	-	Network node interface for SDH
G.709	-	SDH multiplexing structure
G.773	-	Q interfaces for network and transmission management
G.781	-	Structure of recommendations concerning SDH multiplexing equipment
G.782	-	General characteristics of SDH multiplexing equipment
G.783	-	Characteristics of functional blocks of SDH multiplexing equipment
G.784	-	SDH management
G.sdxc1	-	Structure of recommendations concerning SDH cross-connect panels
G.sdxc2	-	General characteristics of SDH cross-connect panels
G.sdxc3	-	Characteristics of functional blocks of SDH cross-connect panels
G.802	-	Inter working between networks, based on different asynchronous digital Hierarchies and speech encoding laws.
G.803	-	Architectures of transport networks based on the SDH
G.821	-	Performance evolutions in the pay load
G.825	-	Control of jitter and wander within SDH digital networks .
G.957	-	Optical interfaces for SDH systems and equipment
G.958	-	SDH digital line systems on optical fibre cables
G.tna1	-	SDH network
G.sna1	-	Architecture of SDH networks
G.sna2	-	Performance data of SDH networks
G.81s	-	SDH synchronization and clocks
G.652,	-	Classification of Optical interfaces
G.653,	-	"
G.654	-	"
M.30	-	Transmission Management Network (TMN)

Table 9.1 ITU (T)'s Recommendations For SDH

- **G.702 & G.703:** Mainly PDH recommendations covering the number of PDH digital hierarchy bit rates 1544 & 2048 kbps, and PDH based digital networks.

- **G.70x:** G.707, G.708 & G.709 form a coherent set of specifications for SDH & NNI.

1. The first level of SDH shall be 155.520 mbps.

2. Higher SDH bit rates shall be obtained as integer multiples.

3. Higher rate levels should be denoted by the corresponding multiplication factor of the first level.

G.707: Covers the advantages offered by synchronous digital multiplexing method, defines the standardized levels of SDH bit rates, specifies the SDH bit rates. The bit rates of SDH as specified by G.707 are shown in Table 9.2

SDH Bit Rates:

| SDH Level	Bit Rates
1	155.520 mbps
4	622.080 mbps
16	2488.320 mbps
64	9953.280 mbps

Table 9.2 SDH Bit Rates As Per ITU (T)'s G.707

- **G.708:** Specifies signal structure of NNI for SDH, specifies the general principles and basic frame structure of the network node interface(NNI) for SDH and covers the principles of SDH working. The SDH is the key to flexible broadband networks that features efficient operation, administration and maintenance. The SDH standards exploit one common characteristic of all PDH networks, i.e. 125 micro seconds duration, the sampling rate of audio signal. The frame structure contains 9 rows and number of columns depending upon STM level. In STM-1 there are 9 rows and 270 columns. In 1.544 mbps 24 channel PDH signal, there are 25 bytes (time slots) in 125 microseconds and two additional bytes for supervisory etc i.e. 9 rows x 3 columns. Similarly in 2.048 mbps (30 Chl), there are 32 bytes in one frame. Adding 4 bytes more, it becomes 36 bytes i.e. 9 rows x 4 columns. STM-1 contains 9 rows and 270 columns. The first 9 rows and 9 columns accommodate Section Overhead (SOH) and 9 rows and 261 columns accommodate the information payload. So the speed is 270 x 9 x 8 x 8000 bits / sec, i.e. equal to 155.520 mbps.

Basic Frame Structure of SDH:

1. The overall frame size of 9 rows x 270 columns.

2. Section Over Head definition and its byte allocation.

3. Arrangement for international synchronous inter connection of STM-1s

4. Enables inter connection of synchronous digital network elements for transport of payloads including digital signals of SDH.

- **G.709:** Specifies the multiplexing structure within the basic frame and multiplexing of basic frames with one another. Formats for mapping of multiplexing elements into the STM-1 at the NNI and the method of multiplexing to STM-1 shall be as described as in this Recommendation. It is a Synchronous Basic Multiplexing Structure.

- **G.773:** Covers mainly the network and transmission management systems and defines the Q interfaces for management.

- **G.781, G.782, G.783 & G.784:** Covers the characteristics of SDH multiplexing equipment. G.781 presents the structure of recommendations concerning synchronous multiplexing equipment and gives information on the different options to be found there. G.782 specifies the general characteristics of synchronous multiplexing equipment. G.783 specifies the characteristics of the functional blocks of the multiplexing equipment. G.784 covers the management functions.

- **G.802 & G.803:** G.802 Specifies the inter working between networks, based on different asynchronous digital hierarchies and speech encoding laws and G.803 Specifies the architectural features of the main strategies which may be used to enhance the availability of a transport network & protection category.

- **G.957 & G.958:** Specifications with regard to optical interfaces and cables. G.957 covers the characteristics of optical interfaces to be used within the context of SDH (details of attenuation values required in accordance with the scope of the application selected, maximum permissible chromatic dispersion according to the light source). G.958 covers on line digital systems based on SDH to be used on optical fibre cables.

- **G.sdxc1, G.sdxc2, G.sdxc3:** Covers the cross connect panels, equipment designed for information switching like virtual containers.

- **G.sna1 & G.Sna2:** Covers the description of performance and architecture of transmission networks, principles and applications of SDH. G.sna1 covers architecture like access points, network nodes etc., G.sna2 concerns network performance data. G.sna1 also describes the layered model of transport network.
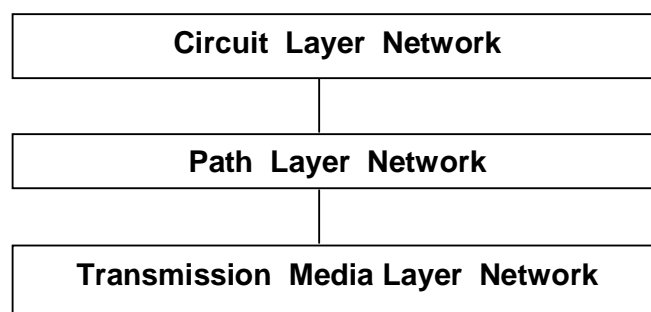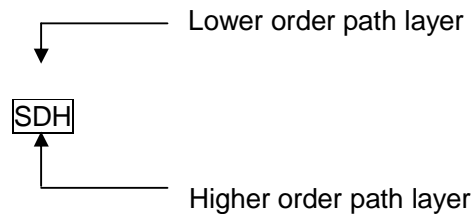

Fig. 9.1 Layerd Model Of SDH Transport Network

Circuit Layer Networks:

Provides users with circuit switched and leased line services. Identifies different circuit layer networks.

Path Layer Networks:

Supports different types of circuit layer networks.

Lower order path layer

SDH

Higher order path layer

Transmission Media Layer Network:

Identifies different physical interfaces.

- **G. tna1:** General functional architecture to transport networks.

- **G.81s:** Specify the clocks & methods of synchronization of clocks used at various stages of SDH system. G.811 specifies the primary reference clock (PRC), one or two such clocks are only provided in a country. G.812 specifies the SSU, the stand alone synchronization unit, which shall be synchronized by PRC or another SSU. G.812 specifies network element clock, which is a clock located in SDH system equipment.

- **G.821:** Covers pay load performance evolutions.

- **G.825:** Specifies the method of control of jitter and wander in SDH networks.

- **M.30:** Specifies the transmission management network(TMN) principles.

- **G.65s:** Classify the optical interfaces based on application and show the application codes.

ITU-T recognizes Three Application Categories:

Intra Office (I): Distances less > 2 km

Inter Office Short Haul (S): 15 km approximately

Inter Office Long Haul (L): 40 km approximately with 1310 nm window and 60 km with 1550 nm window.

Application	Intra	Inter – Office				
	Office	Short – haul		Long – haul		
Source nominal wavelength (nm)	1310	1310	1550	1310	1550	
Type of fibre	Rec. G.652	Rec. G.652	Rec. G.652	Rec. G.652	Rec. G.652 Rec. G.654	Rec. G.653
Distance (Km)	< 2	15		40	60	
STM Level — STM-1	1-1	S-1.1	S-1.2	L-1.1	L-1.2	L-1.3
STM Level — STM-4	1-4	S-4.1	S-4.2	L-4.1	L-4.2	L-4.3
STM Level — STM-16	1-16	S-16.1	S-16.2	L-16.1	L-16.2	L-16.3

Table 9.3 Classification Of Optical Interfaces

The G.65s are described in Table 9.3.

The details of some SDH related recommendations are given in Table .9.4.

9.3 ITU (T)'s SDH Related Recommendations:

Item	Recommendation	Year
Network Architecture	G.tna, G.sna1,G.sna2,	1992
Network Node Interface (functions)	G.707,G.708,G.709	1990
Physical	G.957,G.703	1990
Multiplex Equipment	G.781.G.782,G.783.	1990
Line Equipment	G.958.	1990
Cross connect equipment	G.sdc x1,G.sdc x2,G.sdc x3	1992
Element management	G.784	1990
Equipment clock	G.81s	1992

Table 9.4 ITU (T)'s SDH Related Recommendations

Objective:

1. ITUT's recommendation for SDH - the G708 defines the SDH multiplexing structure.
   T/F
2. ITUT's recommendation for SDH - the G709defines the SDH multiplexing structure. **T**/F
3. ITUT's recommendation for SDH - the G708 defines the network node interface for SDH.
   T/F
4. ITUT's recommendation for SDH - the G781 defines structure of recommendations concerning SDH multiplexing structure. **T**/F
5. ITUT's recommendation for SDH - the Gsdxc1 defines structure of recommendations concerning SDH cross connect panels. **T**/F
6. ITUT's recommendation for SDH - the G 802 defines inter working between networks based on different synchronous digital hierarchies and speech encoding laws. **T**/F
7. ITUT's recommendation for SDH - the G.957 defines optical interfaces for SDH systems and equipment. **T**/F
8. ITUT's recommendation for SDH - the G.958 defines SDH digital line systems on optical fiber cables. **T**/F
9. ITUT's recommendation for SDH - the G. 81s defines SDH synchronization and clocks.
   T/F
10. ITUT's recommendation for SDH - the G784 defines the SDH management. **T**/F

Choose the correct answer-

1. ITUT's recommendation for SDH –   (a)
   a) The G709 defines the SDH multiplexing structure.
   b) The G708 defines the SDH multiplexing structure.

2. ITUT's recommendation for SDH –   (a)
   a) The G781 defines structure of recommendations concerning SDH multiplexing structure.
   b) The G708 defines structure of recommendations concerning SDH multiplexing structure

3. ITUT's recommendation for SDH –   (a)
   a) The G.957 defines optical interfaces for SDH systems and equipment.
   b) The G.958 defines optical interfaces for SDH systems and equipment.

Subjective:

1. What are the SDH bit rates as per ITU-T's Rec. G.707?

2. What do you understand about NNI as per ITU-T Rec.G.708?

3. Explain basic frame structure of SDH

4. What is the purpose of ITU-T Rec. G.709?

5. Explain the layered model of transport network

6. Explain what do you understand regarding the classification of Optical interfaces

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CHAPTER-10

Jitter and Wander In SDH Systems &
Testing of SDH Network

Objectives: By going through this chapter, the trainee must be in a position to understand

1. Jitter and Wander in SDH systems

2. Different types of tests to be conducted on SDH systems

3. Different alarms

10.1 Introduction:

Jitter and Wander are defined respectively as the short term and long term variations of the significant instants of a digital signal from their ideal positions. They are relative terms and always mentioned with respect to a reference clock and can be represented as varying their positions with respect to time by moving backward or forward in reference to an ideal clock source. In any transmission network Jitter and Wander accumulate according to their generation and transfer characteristics of each equipment connected, can effect the signals and might cause bit errors, uncontrollable slips etc. It is necessary that the amount of jitter and wander are controlled for SDH network interface. The jitter, which is specified as maximum phase amplitude and is quantified as a peak to peak value as it is the peak jitter that causes the bit error. Jitter is measured in Unit Intervals (UIs). One UI is of one data bit width.

The measurement of wander needs any Primary Reference Clock (PRC) or any other reference clock, which is free from wander. It involves low frequencies with long duration and can consist of hours of phase information. High temporal resolution is needed to measure phase transients.

10.2 Parameters To Measure Synchronization Quality And to Specify Performance Limits:

- **Time Interval Error (TIE):** It is the phase difference between the signal and reference clock, measured in nano seconds. It is set to zero at the start of total measurement period and provides the information of phase changes since the beginning of the measurement.

- **Maximum Time Interval Error (MTIE):** It is defined as the largest peak to peak TIE within a specified interval and characterizes frequency off set and phase transients. A time window of specified interval is moved across the entire measurement time of TIE and the peak value is the MTIE.

- **Time Deviation (T Dev):** It is defined as the rms value of the filtered TIE and characterizes its spectral contents. The band pass filter is centered on a frequency of $0.42/t$, where t is the observation interval. As rms part of T Dev calculation requires sufficient time to get a good statistical average, at least 12 t is required for accurate value of T Dev. Normal practice is to observe for 3t for calculation of T Dev for an interval of t.

10.3 Network Synchronization:

The cross connect as shown in Fig. 10.1 receives various tributaries as inputs and generates a new aggregate output signal. The timing of the output signal is determined by the synchronous clock function and the input signal might be at slower phase when compared with the output signal. The two signals are originated from the same clock function but varying at the input and output of the network element. The causes are as given below.

- Changes in cable delays due to temperature changes.
- Frequency drift due to DC off set in the PLL synchronous clock.
- Random phase transients in the synchronous distribution chain due to protection switching.

Synchronization Clock Function

Regenerator   Cross Connect

TE — ADM — ▷ — X — ADM — TE
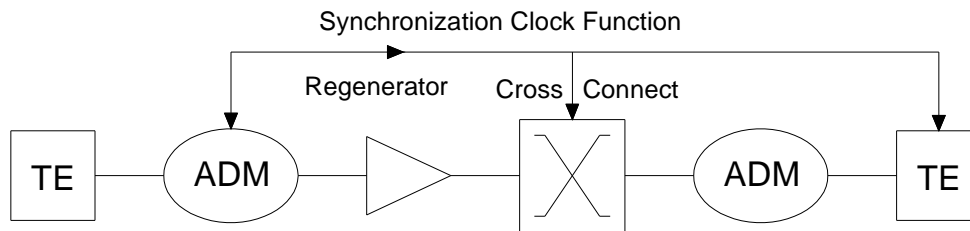
Fig. 10.1 SDH Path Synchronization

The input and output phase variations are to be removed to maintain the integrity of data. This is achieved by the pointer justification process, which shifts the pay load by advancing or retarding within the STM-N signal. At receiving end where the pay load is demapped, these adjustments might result in pay load jitter which should be smoothened to ensure that jitter remains within limit. Especially the low frequency wander in the SDH systems is gradually stored up by the pointer processing mechanism and released as a higher frequency phase transient in the pay load causing adverse effects on data integration. To avoid this, the jitter and wander should be kept within the permissible limits.

10.4 Testing Of Transmission Network: The testing activities are related to

- Design verification and field trial
- Installation and commissioning
- Operation and maintenance

SDH network contains the capability to support the in service testing by network management system for operation and maintenance. However, the insufficiency of this capability and necessity of comprehensive testing make it essential to use external SDH Test Set to ensure that the SDH network elements provide the promised operational benefits to the network operators and their customers as per ITU-T standards.

10.5 Objectives Of Testing: The SDH functionality is dependent more on software. The testing objective covers four broad categories.

- Transport Capability Tests
- Payload Pointer Tests
- Line Interface Tests
- Embedded Overhead Tests

10.5.1 Transport Capability Tests:

Transport Capability tests include BER and Mapping/De-Mapping tests, which confirm that an SDH network carries a payload of 2 mbps, 34 mbps or 140 mbps tributary signals and delivers it correctly to the destination.

10.5.2 Payload Pointer Tests:

Payload Pointer tests include timing offset and tributary output jitter tests, which confirm that SDH network equipment is operable with other non-SDH network elements already in use in networks.

10.5.3 Line Interface Tests:

Line Interface tests include the parametric tests that confirm the electrical and optical functional capabilities of an SDH interface.

10.5.4 Embedded Overhead Tests:

Embedded overhead tests include alarm stressing and performance monitoring, network management protocol tests and other special tests, which confirm that SDH network elements respond in a predictable manner under stress condition.

10.6 General Aspects Of Testing:

The general aspects that should be considered while testing SDH network, are as below.

10.6.1 Completion Of Basic Installation:

Completion of basic installation before the testing is necessary to ensure the following.

* Each Network Element (NE) is fully assembled with its cards installed
* Cabling is done between Digital Distribution Frame (DDF) and NE tributary ports
* Computer control of the NE is established
* Configuring of NE operating characteristics is completed

10.6.2 Avoiding Optical Receive Overload:

Care should be taken to avoid overload of receiver using attenuator while testing NE.

10.6.3 Synchronization:

It is essential to synchronize the set up to ensure that no uncontrolled pointer adjustments occur during testing.

10.7 Functional Tests:

The test set up is as shown in Fig.10.2 for the following functional verification tests.


10.7.1 Verifying Correct Mechanical Installation:

This test is for checking correct mechanical installation of an SDH network element that may be Add/Drop Multiplexer (ADM), Line Terminal Multiplexer (LTM) or Digital Cross Connect (DXC). In Fig. 10.2, it is assumed that the NE is an ADM.

Performing a BER test on each Virtual Container path (VC-n) processed by the NE, checks the NE for the following.

- Correct cabling between DDF and tributary ports.
- The basic performance of the network element's electronics including optics.

Installation is correct if no error or alarm is observed.
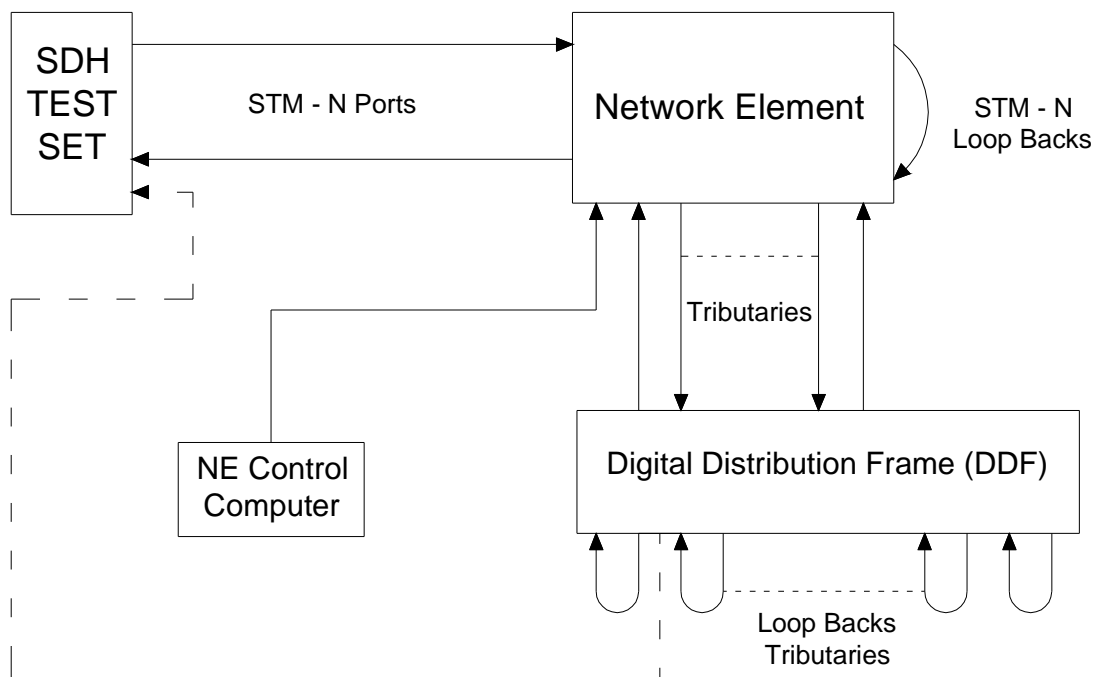
Fig. 10.2 SDH Functional Tests

10.7.2 Verifying Path Routing To PDH Tributary Ports:

This test verifies path routing through an ADM or DXC. It identifies, which VC-n paths are terminated by the NE, with the mapped payload being dropped to a PDH tributary port.

10.7.3 Verifying Path Routing To SDH Tributary Ports:

This test verifies the VC-4 path routing to the SDH tributary ports. The test set up is as in Fig. 10.2 with the receive input shown in dotted line.

10.7.4 Verifying Trail Trace Identifier Configuration: This test verifies correct NE configuration of the trail trace identifier for a terminated path. In addition, it verifies automatic reporting of the associated trace identifier mismatch alarm to the management system.

10.7.5 Verifying Clock Synchronization:

SDH network synchronization is very important issue in view of its serious impact on the network performance. Following are the two key elements for precise and reliable SDH network synchronization.

- An accurate PRC (Primary Reference Clock)

- Accurately routed timing information from PRC to all nodes in the network.

The above can be checked by the following three distinct tests.

- Line frequency measurement

- Monitoring the pointer activity

- Observing the indication of Sync status byte (S1)

If the PRC is poorly distributed to NEs it causes increase in pointer activity, resulting in increased tributary jitter and in worst case, this activity leads to corruption or even loss of payload data.

The Lock Sync. test verifies correct configuration of the clock synchronization hierarchy in the NE. Three alternative clock sources are mentioned below.

- **Primary:** External 2 MHz clock (also used for Sync of SDH test set),

- **Secondary:** Received STM-N line signal

- **Tertiary:** NE's own internal clock.

10.8 Mapping And De-Mapping Tests:
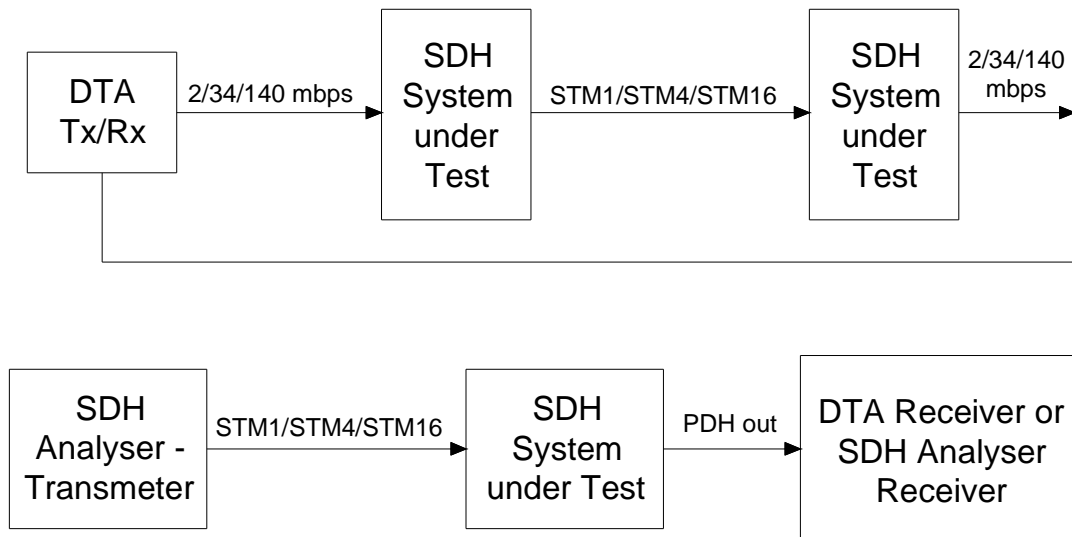
Fig. 10.3 Mapping And De-Mapping Test

The test set up for Mapping and De-mapping tests is as shown in Fig.10.3 .

10.8.1 Mapping Test:

Mapping is the process of assembling the payload from the container into virtual container. This test verifies the performance of the payload mapping process in a device under test by off-setting the bit rate of tributary test signal to stress the synchronization capabilities of the mapping process. There should be no error in the bit rate of 2 mbps, 34 mbps, 140 mbps or 55 mbps with the off setting by $\pm$ 50 ppm, $\pm$ 20 ppm, $\pm$ 15 ppm and $\pm$20 ppm respectively.

10.8.2 De-Mapping Test:

De-Mapping is the reverse process of mapping. It is the process of recovering the tributary signal from the virtual container. This test, by off setting the frequency of mapped PDH signal with reference to the virtual container, verifies that de-mapping of payload from the SDH signal takes place without any error.

10.9 Jitter Testing:

Jitter testing of SDH network includes measurement of the following.

- STM-N optical jitter tolerance
- STM-N optical output jitter
- PDH tributary jitter
- Pointer adjustment jitter (combined jitter)
- De-mapping jitter

Jitter is the short term variation of the significant instants of the digital signal with respect to the position in time, which they should otherwise occupy. It can also be considered as spurious phase modulation of digital signal clock. Jitter measurements are always made on clock signal and expressed in Unit Intervals (UIs), which are independent of bit rate and can be calculated as below.

The jitter frequency is rarely a sinusoidal, although sinusoidal jitter frequency is often used in testing. For example,

$$M = \text{Modulation Index} = \frac{\text{Peak deviation of bit rate}}{\text{Jitter frequency}} = \pi \times jpp \quad (Jpp = \text{Jitter Peak to Peak})$$

For a 2.048 kbps data, UI = 0.488 ns, if the Jitter function (amplitude) is 2.44,the peak to peak jitter will be = 2.44/0.488 = 5 UI
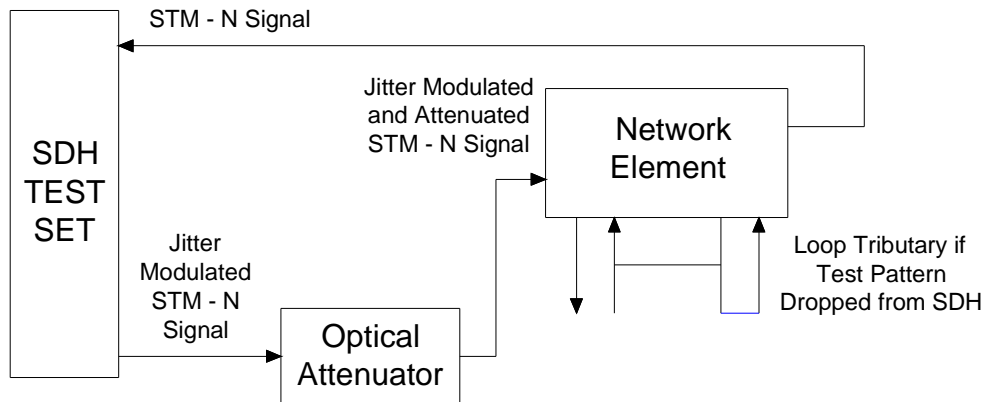
Therefore, M = 3.14 x 5 = 15.70

If jitter frequency is 100 Hz, peak deviation of bit rate = 100 x 15.70 = 1570 Hz

Therefore, the bit stream varies as 2048000 $\pm$ 1570 Hz at a rate of 100 times per second.
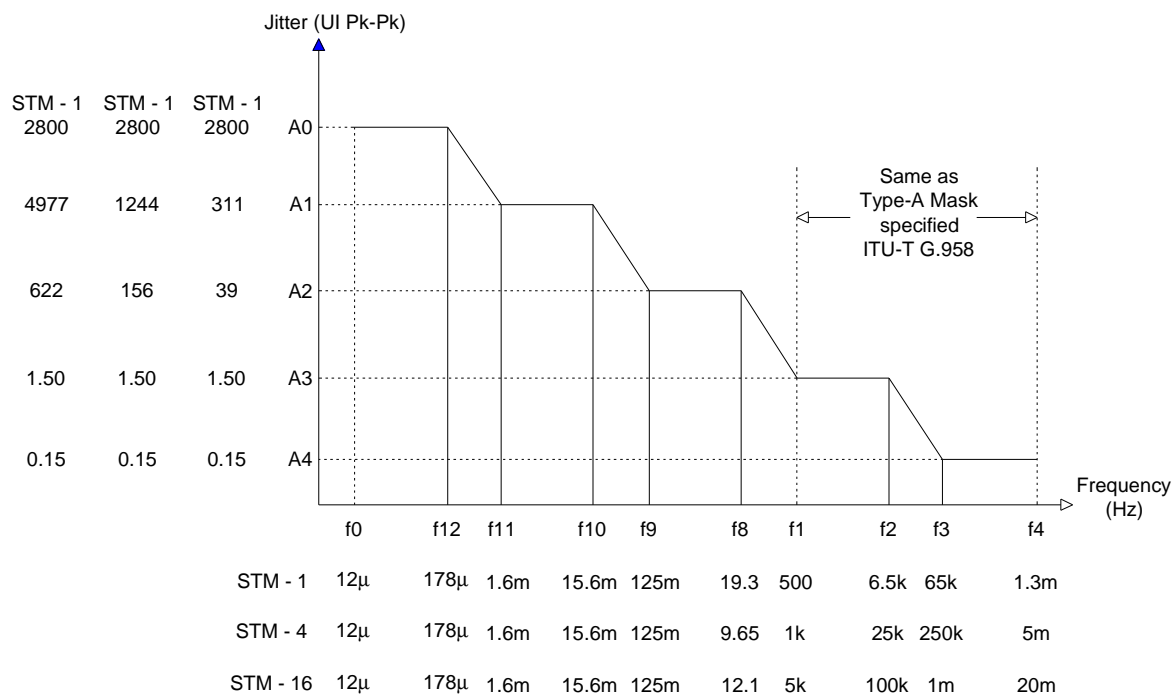
The primary sources of jitter are the network elements themselves. The types of jitter and the possible causes are as given below.

- **Mapping/De-Mapping Jitter:** Mapping and De-Mapping jitter are caused by the phase smoothing associated with the read/write clock of elastic stores and the bit stuffing/de-stuffing used to compensate for frequency variation of the mapped tributary signal.

- **Pointer Jitter:** Pointer jitter is caused by excessive pointer movements as a result of the effects of clock noise, frequency off-sets.

Fig. 10.4 STM-N Optical Output Jitter Tolerance

Jitter (UI Pk-Pk)

	STM - 1	STM - 1	STM - 1	
A0	2800	2800	2800	
A1	4977	1244	311	
A2	622	156	39	
A3	1.50	1.50	1.50	
A4	0.15	0.15	0.15	

Same as Type-A Mask specified ITU-T G.958

Frequency (Hz)

	f0	f12	f11	f10	f9	f8	f1	f2	f3	f4
STM - 1	12μ	178μ	1.6m	15.6m	125m	19.3	500	6.5k	65k	1.3m
STM - 4	12μ	178μ	1.6m	15.6m	125m	9.65	1k	25k	250k	5m
STM - 16	12μ	178μ	1.6m	15.6m	125m	12.1	5k	100k	1m	20m

Fig. 10.5 SDH Jitter Tolerance Mask (ITU-T G.825)

- **Systematic Jitter:** Systematic jitter is caused by mis aligned timing recovery circuits, finite pulse width and clock threshold off-sets.

10.9.1 Measuring SDH Jitter Tolerance:

This test as shown in Fig. 10.4 verifies that NE complies with the ITU-T Jitter Specification and requires evaluating the results against the defined mask as shown in Fig. 10.5.

10.9.2 Measuring SDH Optical Output Jitter:

This test verifies maximum acceptable jitter as per ITU-T Recommendation G.958 at NE's optical output. The test set up is as shown in Fig. 10.6.
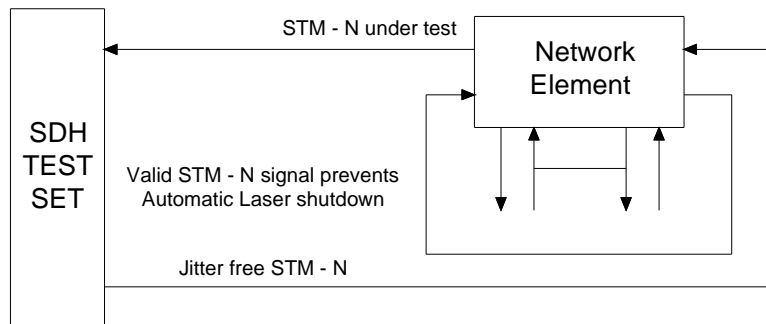
Fig. 10.6 STM-N Optical Output Jitter

10.9.3 Measuring PDH Tributary Jitter:

The jitter present on a PDH signal output from an SDH network, results from following two primary sources.
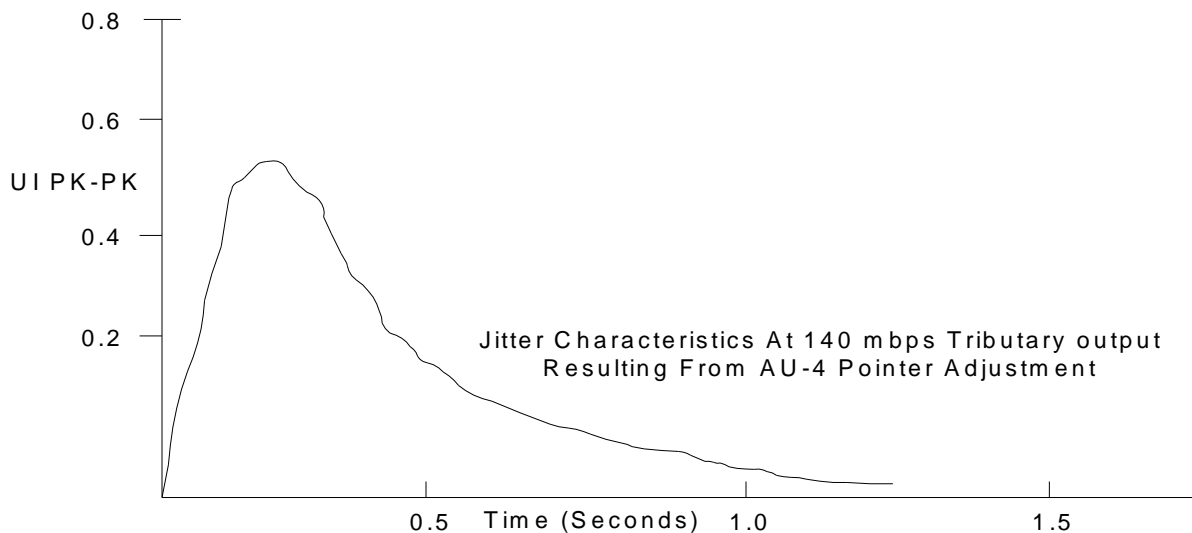
- Pointer adjustment
- Bit stuff justification process performed when mapping an asynchronous signal into the synchronous transport signal.

Therefore, both pointer adjustment jitter and de-mapping jitter are to be tested to verify the compliance with the ITU-T standard G.783, which limits the maximum acceptable level of jitter.

10.9.4 Pointer Jitter (Combined Jitter):

The pointer movements occur often in SDH network causing the output of large amount of jitter spikes at the tributary ports and into the PDH network, which is not designed to withstand with such large amount of transient jitter. Therefore, testing of this jitter is very much essential to ensure that this effect is minimized and that errors and loss of data do not occur.

Jitter resulting from pointer adjustment is totally different in character from jitter previously experienced in PDH network. It is transient in nature, relatively high in amplitude and most of the energy is contained in low frequency components as shown in Fig. 10.7

**Fig. 10.7 PDH Pointer Adjustment Jitter**

For this testing, the set up is as shown in Fig. 10.8. The SDH test set is capable to generate combined impairment by providing independent control over PDH off set and pointer sequence.

This set is to be done according to ITU-T standard G.783 given in Table. 10.1

Pay Load	Pointer	Sequence	Measurement Bandwidth	Max. Jitter (UI PK-Pk)
2 mbps	TU-12	A,B,C,	0.02 – 100 KHz *	0.4
		A,B,C	18 - 100 KHz **	0.075
34mbps	TU-3	A,B,C,	0.1 - 800 KHz *	0.4
		D,	0.1 - 800 KHz **	0.75
		A,B,C,D	10 - 800 KHz **	0.075
140mbps	TU-4	A,B,C,	0.02 - 3500 KHz *	0.4
		D,	0.02 -3500 KHz *	0.75
		A,B,C,D	10 - 3500 KHz **	0.075
* = Equivalent to Measurement Filter " LP + HP1"				
** = Equivalent to Measurement Filter " LP + HP2"				

Table 10.1 Pointer Adjustment Jitter
(ITU-T G.783 Pointer Jitter Specification)

Current ITU-T/ETSI standards define four pointer sequences for use during this testing of NE. Pointer jitter test involves measuring the tributary jitter while the network element is stressed with pointer sequence shown in Fig. 10.9 defined in ITU-T standard G.783 for 34 mbps (TU-3 pointer) and for 140 mbps (AU-4 pointer).
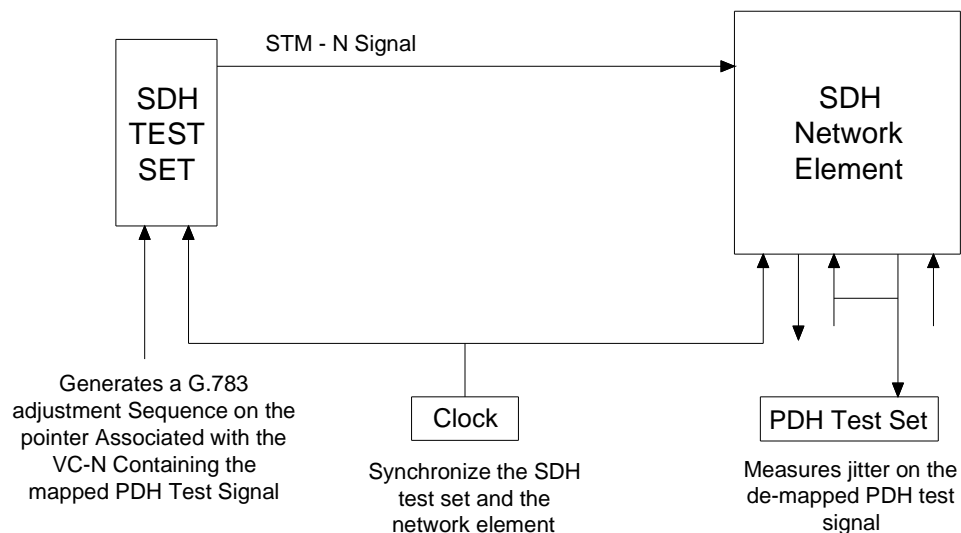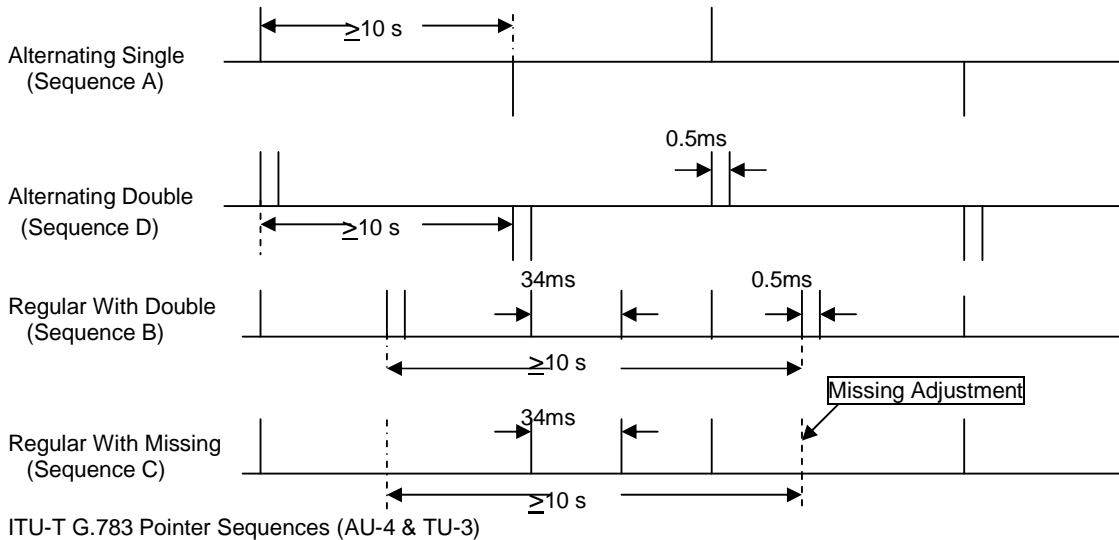

Fig. 10.8 Pointer Jitter Test

When testing 2 mbps, similar pointer sequences are generated on the TU-12 pointer associated with the 2 mbps tributary under test with the following differences.

- Sequence D is not valid.
- The time separating regular adjustments in sequence B & C is greater than 750 ms (not 34 ms)
- The time separating the double pointer adjustment in sequence B is 2 ms (not 0.5 ms).

The maximum acceptable level of pointer adjustment jitter at PDH output tributaries on SDH NEs as per ITU-T standard G.783 is given in Table. 10. 2.

ITU-T G.783 Pointer Sequences (AU-4 & TU-3)

Fig. 10.9 Pointer Jitter Sequences

	SDH Tx	**Settings**	**PDH Rx**	**Settings**	
Pay Load	**Pointer Sequence**	**PDH Service Off Set**	**Measurement Filters**	**Measurement Period (Second)**	**Max. Jitter (UI PK-PK)**
2 mbps	A	±50 ppm.	LP+HP1	20 S	0.4
	BC		LP+HP1	30 S	0.4
	A	Any value in range.	LP+HP2	20 S	0.075
	BC		LP+HP2	30 S	0.075
34 mbps	AD	±20 ppm.	LP+HP1	20 S	0.4(A) 0.75(D)
	BC		LP+HP1	30 S	0.4
	AD	Any value in range.	LP+HP2	20 S	0.075
	BC		LP+HP2	30 S	0.075
140 mbps	AD	±15 ppm.	LP+HP1	20 S	0.4(A) 0.75(D)
	BC		LP+HP1	30 S	0.4
	AD	Any value in range.	LP+HP2	20 S	0.075
	BC		LP+HP2	30 S	0.075

Table 10. 2 Pointer Jitter Measurements Settings

The maximum jitter variation depends on the following.

- Pointer sequence used to stress the NE's de-synchronization
- The jitter measurement bandwidth.
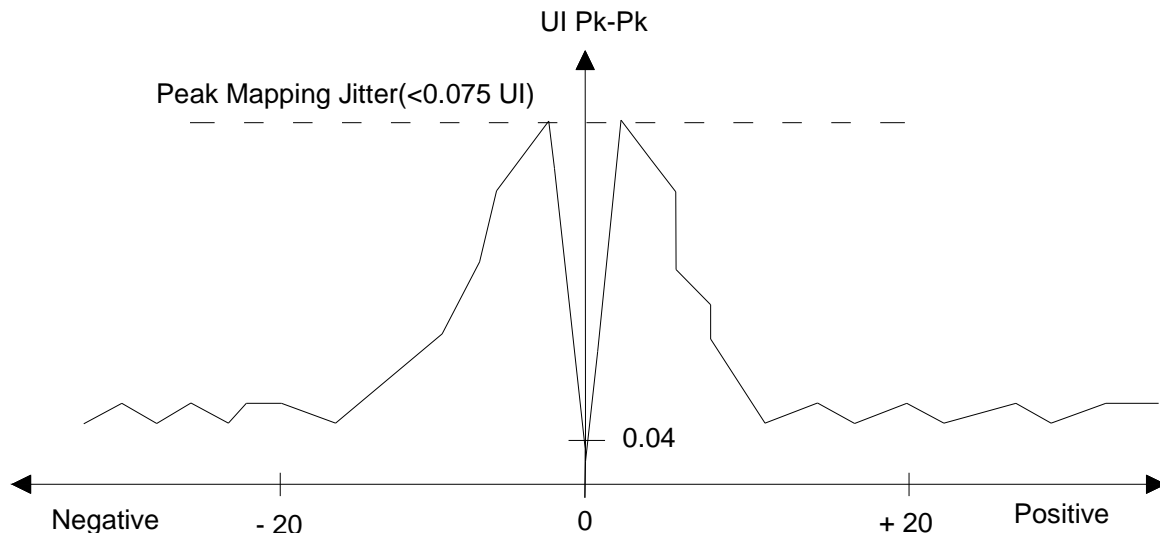
10.9.5 De-Mapping Jitter:

Typical de-mapping jitter characteristic is shown in Fig. 10.10 and it is less serious than pointer jitter. The characteristics of de-mapping jitter are as given below.

- Low amplitude
- Relatively high frequency and can therefore be suppressed by the de-synchronizer in SDH-NE
- Its amplitude varies as the PDH tributary frequency is off set relative to VC-n. This is due to changes in the mapping's bit stuff justification ratio to compensate such off set.

The peak de-mapping jitter occurs at a small off set from OPPM (PDH tributary relative to VC-n). The limits as per ITU-T G.783 Rec. are given below in Table 10.3.

Pay Load	Off-Set Range (ppm)	Measurement Bandwidth	Max. Jitter (UI PK-PK)
2 mbps	$\pm$ 50	18 – 100 KHz*	0.075
34 mbps	$\pm$ 20	10 – 800 KHz*	0.075
140mbps	$\pm$ 15	10 – 3500 KHz*	0.075
* = Equivalent to measurement Filter "LP + HP2"			

Table 10.3 De-Mapping Jitter Test

Fig. 10. 10 De-Mapping Jitter Characteristic

The objective of a de-mapping jitter test is to find the maximum peak to peak jitter caused by off setting the frequency mapped PDH signal relative to that of the VC-n used to transport this payload. The test set up is shown in Fig. 10.11.
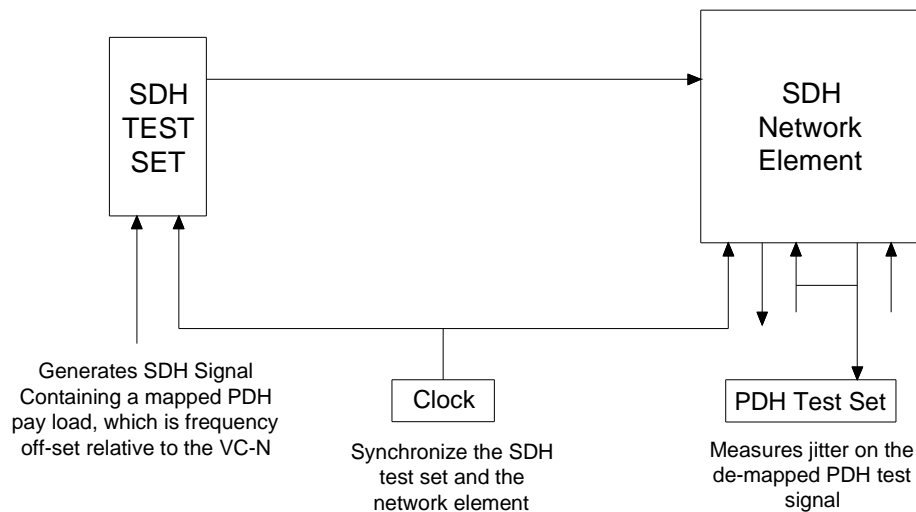
Fig. 10.11 De-Mapping Jitter Test

Here, the SDH test set and NE must be synchronized with the same clock, which ensures that no unexpected pointer adjustment occurs during testing and that only de-mapping jitter is measured.

10.10 Testing With "Built-In" Capability Of SDH NE And Use Of Overheads:

Network management, detection and location of fault, performance monitoring, protection switching, alarms simulation and duration etc are possible with the additional benefits inherent in SDH NE. Exploitation of SDH Analyzer (Designed as per TEC Spec. NO.G/SDA-01/02 Feb.97) can also help performing those tests.

10.11 Testing's with Network Management:

SDH NE is capable of supporting network management. The functions can be summarized as below.

- Fault management, which includes fault detection and location.
- Performance management, which includes conversion of alarms, error data etc into information.
- Configuration management, which includes conversion of information data.
- Software download.
- Telecom Management Network (TMN) interface (Q3 interface).

10.11.1 Performance Monitoring:

The mechanism within SDH is used to derive the error performance, short interruption parameters and unavailability parameters based on eroded blocks and the BIP-n is used on frame by frame basis. These BIP checks inserted in the overheads associated with the selection, line, path maintenance spans. Errors detected in HO and LO paths BIPs cause FEBE signal to be sent up streams. Following are the performance monitoring parameters.

- Analysis of PDH streams: ES, SES, UAS, EFS, DM.
- Analysis of SDH streams: Error blocks, ESR, SESR, BBER, SIE, US etc derived from B1 in RS, B2, BIP2 and FEBE in TUs.

10.11.2 Alarm Simulation And Detection:

Major alarm signals based on overheads bytes, such as Loss Of Signal (LOS), Loss Of Frame (LOF) and Loss Of Pointer (LOP) cause Alarm Indication Signal (AIS) to be transmitted down stream. In response to different AIS signals, Far End Remote Failure (FERF) and Remote Alarm Indication (RAI) as applicable are sent up stream, to warn about trouble in down streams.

10.11.3 Alarms in STM-1:

1. LOS
2. LOF
3. AULOP (Auxiliary Unit LOP)
4. MSAIS (Multiplex Section AIS)
5. MSFERF
6. Path AIS
7. Path FERF
8. TULOP (Tributary Unit LOP)
9. TUAIS
10. TULOM (Tributary Unit Loss of Multiframe)

10.11.4 Alarms in STM-4/16:

1. LOS,
2. OOF (Out of Frame),
3. LOF,
4. MSAIS,
5. MSRAI.

10.11.5 Protection Switching

The protection switching can be tested for the following.

- Equipment protection
- Multiplex Section Protection (MSP)
- VC path protection

Overhead bytes are used for protection switching purpose.

Objective:

1. The short-term variation of significant instants of digital signal from their ideal position is called jitter. **T**/F
2. The long-term variation of significant instants of digital signal from their ideal position is called wander. **T**/F
3. One UI is of one data bit width. **T**/F
4. For testing of transport capability test the BER and mapping /de-mapping tests are conducted. **T**/F
5. For testing of payload pointer tests, the timing offset and tributary output jitter tests are conducted. **T**/F
6. Clock synchronization test is conducted by verifying the line frequency, pointer activity and sync status byte. **T**/F
7. Jitter testing includes optical jitter tolerance, optical output jitter, PDH tributary jitter, pointer adjustment jitter and de- mapping jitter. **T**/F
8. Network management includes fault management, performance management, configuration management, and software download and telecom management network. **T**/F

Choose the correct answer-

1. Jitter is the (a)
   a) Short-term variation of significant instants of digital signal from their ideal position.
   b) Long-term variation of significant instants of digital signal from their ideal position.

2. For testing of transport capability tests- (a)
   a) The BER and mapping /de-mapping tests are conducted.
   b) The timing offset and tributary output jitter tests are conducted.

3. Clock synchronization test is conducted by (c)
   a) Verifying the line frequency   b) Pointer activity
   b) Sync status byte.   c) All

4. Jitter testing includes- (e)
   a) Optical jitter tolerance   b) Optical output jitter,
   c) PDH tributary jitter   c) Pointer adjustment jitter
   d) De- mapping jitter   e) All

Subjective:

1. What do you know about jitter and wander in SDH?

2. What are the parameters to measure synchronization quality?

3. What is path synchronization?

4. What are the objectives of testing?

5. Explain the SDH functional tests?

6. Explain how to verify clock synchronization?

7. Explain mapping and de-mapping tests?

8. Explain what do you understand about jitter testing?

*****

CHAPTER-11

Ethernet over SDH
GFP, VCAT and LCAS

Objectives: By going through this chapter, the trainee must be in a position to understand

1. Ethernet frame format and Ethernet services

2. Why Ethernet is required over SDH.

3. Encapsulation techniques with Generic Framing Protocol, Virtual Concatenation and Link Capacity Adjustment Scheme

11.1 Introduction:

Internet market has been growing at a greater rate. Growth is a basic issue which caused to be the need for expanding the scope of Ethernet area. What are the existing transmission resources to be used? One of the best Telecom resources is SDH or WDM in the world. SDH and related WDM (Wavelength Division Multiplex) optical transport network are considered to be the foundation for the physical layer of the broadband IP and B-ISDN. SDH have been deployed all over the world in recent ten years. Transferring Ethernet Frames (including those of Ethernet, Fast Ethernet and Gigabit Ethernet) over SDH or WDM is a simple and cheap technique to connect LANs within a private and public network.

11.2 Ethernet Services

Ethernet is the ubiquitous transport in LAN for computer networking. All enterprise data traffic Starts off and ends up as Ethernet. It provides a cost-effective interface, generally inexpensive compared to other network interfaces. As a broadcast-oriented medium, Ethernet is a good match for IP. It can scale from 10 Mb/s to 10 Gb/s of bandwidth. Furthermore, it is geographically independent. Ethernet can be the foundation for the Service Providers to develop a portfolio of new data services such as:

1. LAN Interconnect or Transparent LAN services (TLS)
2. Internet Access
3. Ethernet Private Line
4. Virtual Private LAN services (VPLS).

These primary data services can lead to other more sophisticated IP managed services for storage or security.

11.3 Ethernet over SDH (EoS)

SONET/SDH is presently the most prevalent transport infrastructure .Ethernet is by far the most popular user data interface. So we need efficient methods for carrying Ethernet over SONET.

But Ethernet
 ➢ comes in bursty "frames" (packets)
 ➢ uses basic rates of 10, 100, 1000 Mbps

While SONET/SDH

> ➢ is constant bit rate

> ➢ is designed for various rates such as 1.6, 2.176, 6.784 Mbps

Standards we will encounter

IEEE 802.3 Ethernet
ISO 3309 HDLC
RFC1661 PPP (ex 1548)
RFC1662 PPP in HDLC framing (ex 1549)
RFC2615 PoS (ex 1619)
G.707 SDH (especially the new section 11 – VCAT)
G.709 OTN
G.7041 GFP
G.7042 LCAS for SDH
G.7043 VCAT for PDH
X.85 IP over SDH using LAPS
X.86 Ethernet over SDH using LAPS

Let us discuss the need for **Ethernet over SDH** (EoS)

Ethernet over SDH (EoS) was developed primarily to provide a simple, flexible and cost-effective solution to customers offering Ethernet based services. An EoS transport solution fundamentally addresses the following key issues

Auto Negotiation (AN): It is to negotiate and select a common speed and mode of communication between two link partners.

Generic Framing Procedure (GFP): It is the Framing protocol to encapsulate Ethernet frames to generate an SDH payload

Virtual Concatenation (VCAT): It is the Bandwidth provisioning scheme. Bandwidth mapping of the SDH payload to SDH channels, which are either high-order or low-order virtual containers (VCs)

Link Capacity Adjustment Scheme (LCAS): It is the scheme for hitless adjustment (addition & deletion) of link capacity (Bandwidth)

Link Integrity (LI): It is for point to point communication, alive feature checks end to end (client to client) integrity of the link and if there is a breach of integrity anywhere in the link, then forcefully the health Client side(s) are made down

Flow Control: It is the rate shaping mechanism to avoid packet drops

Auto negotiation: Auto negotiation is a feature to detect the link partner capabilities. It allows the devices at both ends of a link segment to advertise abilities, acknowledge receipt and understand the common mode(s) of operation that both devices share

Ethernet Frame Format

7 bytes	1 byte	6 bytes	6 bytes	2 bytes	Data / Pad				4 bytes
Preamble	Start Frame Dilimiter	Dest MAC Add	Source MAC Add	length	DSAP	SSSP	CTRL	NLI	FCS

Preamble: This is a stream of bits used to allow the transmitter and receiver to synchronize their communication. The preamble is an alternating pattern of binary 56 ones and zeroes.

Start Frame Delimiter: This is always 10101011 and is used to indicate the beginning of the frame information.

Destination MAC: This is the MAC address of the machine receiving data. Network Interface Card (NIC) listening to the wire is checking this field for its own MAC address.

Source MAC: This is the MAC address of the machine transmitting data.

Length: This is the length of the entire Ethernet frame in bytes. Although this field can hold any value between 0 and 65,535, but for different Ethernet cards it can be 1500 or 9216 or 9600 as that is usually the maximum transmission frame size for most serial connections. Ethernet networks tend to use serial devices to access the Internet.

Data: The data is inserted here. This is where the IP header and data is placed if you are running IP over Ethernet. Contained within the data/padding section of an IEEE 802.3 frame are four specific fields:

DSAP - Destination Service Access Point, **SSAP** - Source Service Access Point

CTRL - Control bits for Ethernet communication, **NLI** - Network Layer Interface

FCS: This field contains the Frame Check Sequence (FCS) which is calculated using a Cyclic Redundancy Check (CRC). The FCS allows Ethernet to detect errors in the Ethernet frame and reject the frame if it appears damaged.

Encapsulation Techniques: In order to transport client data, which is Ethernet in the case of EoS (Ethernet on SDH) an adaptation mechanism, is required.

Following are the commonly used or emerging encapsulation techniques:

1. X.86-LAPS (Link Access Procedure – SDH)   this is defined in ITU-T Recommendation X.86
2. GFP (Generic Framing Procedure)   this is defined in G.7041

How does GFP differ from LAPS?

It uses a cell delineation scheme similar to ATM instead of Flags like HDLC. It carries a fixed amount of overhead per frame regardless of size. Transmission order is MSB first.

GFP (Generic Framing Protocol)

What is GFP?

It is Generic framing procedure which uses a technology to map Ethernet into VC-n. It provides a standard mapping/framing technique for Layer 2 signals into SONET/SDH

Benefits of GFP

It helps Internetworking and connection between end-to-end SONET/SDH paths. It is more efficient than HDLC (High Level Data Link Control) protocol & maintaining a fixed overhead

The Traffic management and QoS control are significantly easier .It is more robust than HDLC and less susceptible to bit errors. & is compatible with OTN (Optical Transport Network)/WDM interfaces in addition to SONET/SDH.

GFP permits multiple protocols from different ports or links to share the same transport path, resulting in more efficient use of available bandwidth

Types of Generic Framing Protocol:

GFP-F Frame Mode - Direct replacement for HDLC
Variable length packets, maps entire client frame into one GFP-F frame
Supports 10/100 Mbps, Gigabit, 10 Gigabit Ethernet

GFP-T Transparent Mode

Fixed length packets, does not have to map complete Ethernet frame into GFP-T thus reduces latency in the system

It supports 8B/10B block-coded clients: Gigabit Ethernet, Fiber Channel, FICON (Fibre Connection) and ESCON (Enterprise Systems Connection) is a data connection created by IBM, and is commonly used to connect their mainframe computers to peripheral devices such as disk storage and tape drives. it is an optical fiber, half-duplex, serial interface. It originally operated at a rate of 10 Mbyte/s, which was later increased to 17Mbyte/s. The current maximum distance is 43 kilometers.
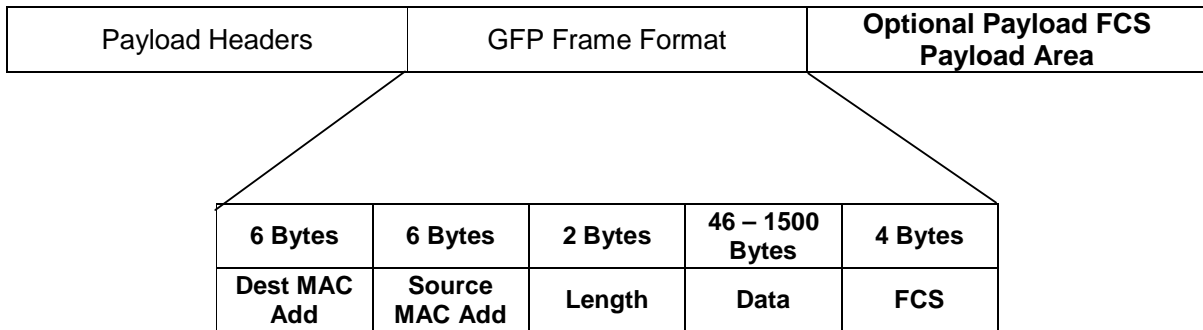
GFP Frame Format

Ethernet	IP/PPP	POS	RPR	FC	FICON	ESCON	Other Client Signals
Framed Mapped GFP		**GFP Client Specific Aspect (Client Dependent)**				**Transparent Mapped GFP**	
GFP Common Aspect			**(Client Independent)**				
SONET/SDH Path			**OTN Path**				

GFP Frame Format

8 bytes   4 bytes

Payload Headers	GFP Frame Format	**Optional Payload FCS Payload Area**

6 Bytes	6 Bytes	2 Bytes	46 – 1500 Bytes	4 Bytes
Dest MAC Add	Source MAC Add	Length	Data	FCS

Maximum Transmission Unit (MTU): The maximum size of the GFP payload area in octets is 65535.

Efficiency Calculation for a GFP Frame:

Efficiency of GFP Frame (η) = (No of bytes in Ethernet Frame)**/**
(No of bytes in Ethernet Frame + GFP Framing Overhead bytes)

End to End Data Rate Calculations:

End to End Data Rate = provisioned bandwidth x η of GFP frame

Example:

For a data of 46 bytes, 18 bytes of Overhead information is added to make an Ethernet frame of 64 bytes. Now for this Ethernet frame 12 bytes of GFP header is added

So the % η of a GFP frame $= \frac{(64)}{(64+12)} \times 100\% = 84.2\%$

End to End Data Rate = provisioned bandwidth * η of GFP frame

5 VC-12's are provisioned for 10Mbps Ethernet data

So the provisioned bandwidth is 5 x 2.176Mbps = 10.88Mbps

End to End Data Rate for a GFP frame with an η of 84.2% = 10.88Mbps x 84.2% = 9.16Mbps

Note: VC-12 comprises of 34 bytes, hence 34 x 8000frames/sec x 8bits/byte gives the data rate of VC-12 which is 2.176Mbps.

VCAT (Virtual Concatenation)

Virtual Concatenation is an inverse multiplexing technique (also known as byte slicing) used to split SDH bandwidth into logical groups (at transmitter end), which may be transported or routed independently, and recombination (multiplexing) into contiguous SDH B/W is done at the receiver end.

Virtual Concatenation breaks the contiguous bandwidth into individual VCs, transports the individual VCs and recombines these VCs to a contiguous bandwidth at the end point of the transmission
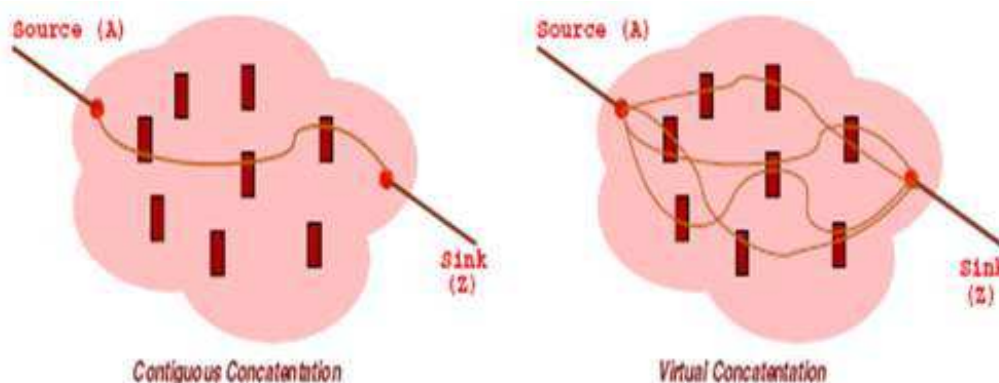
Virtual Concatenation – Granularity Advantage

Splits SDH bandwidth up into right-sized groups

Where to go with 10 MBit Ethernet ?

VC Type	VC Bandwidth	VC Payload
VC – 11	1664 kbit/s	1600 kbit/s
VC – 12	**2240 kbit/s**	**2176 kbit/s**
VC – 2	6848 kbit/s	6784 kbit/s
VC – 3	**48 960 kbit/s**	**48 384 kbit/s**
VC – 4	150 336 kbit/s	149 760 kbit/s
VC – 4 - 4c	601 344 kbit/s	599 040 kbit/s
VC – 4 - 16c	2 405 376 kbit/s	599 040 kbit/s
VC – 4 - 64c	9 621 504 kbit/s	9 584 640 kbit/s
VC – 4 - 256c	38 486 016 kbit/s	38 338 560 kbit/s

Why not
5 x VC – 12 ?

10 Mbits
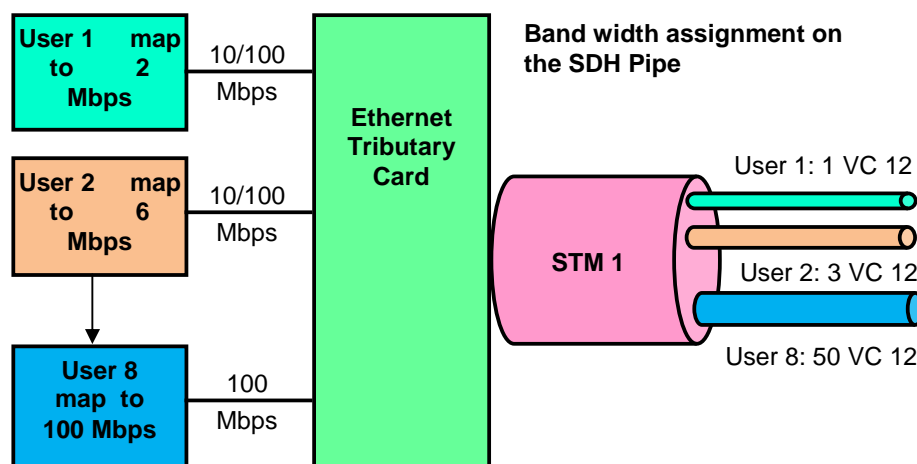
sensible ?

Realizes fine granularity mapping

Fig: Virtual Concatenation – Granularity Advantage

VCAT- Higher Order and Lower Order

Higher order- VC-3 (48.384 Mbps) or VC-4 (149.760Mbps) Gigabit Ethernet (1000   Mbps)

Lower order – VC-12 (2.176 Mbps)   Fast Ethernet (10/100 Mbps)

Advantages of Virtual Concatenation

Scalability: Allows bandwidth to be tuned in small increments on demand to match desired data rate and avoid wastage. Traditional contiguous concatenation comes in coarse increments.

Efficiency: More easily routed through a network and aids to eliminate stranded bandwidth. Allows for more efficient usage of an existing network's available bandwidth.

Compatibility: Requires only end nodes of the network to be aware of the containers being virtually concatenated. Transparent to core network elements.

Resiliency: Individual members of a virtually concatenated group can be routed as diversely as possible across a network. So if one member is lost, the others are likely to be operational with a reduced bandwidth.
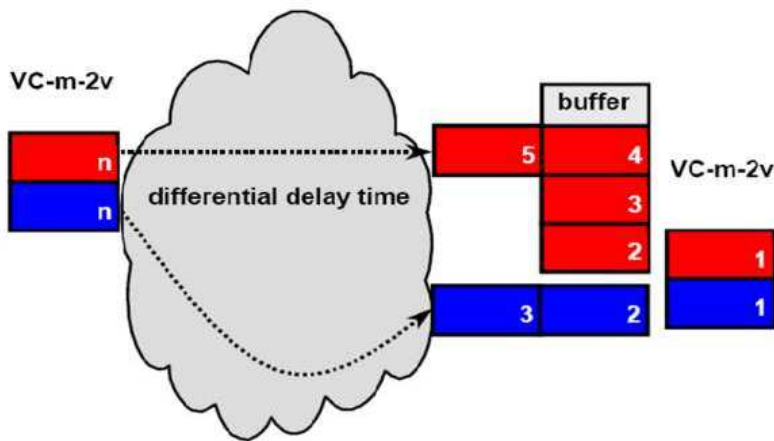

To cater for 10 Mbps Ethernet data 5 VC-12s are provisioned on a VCG
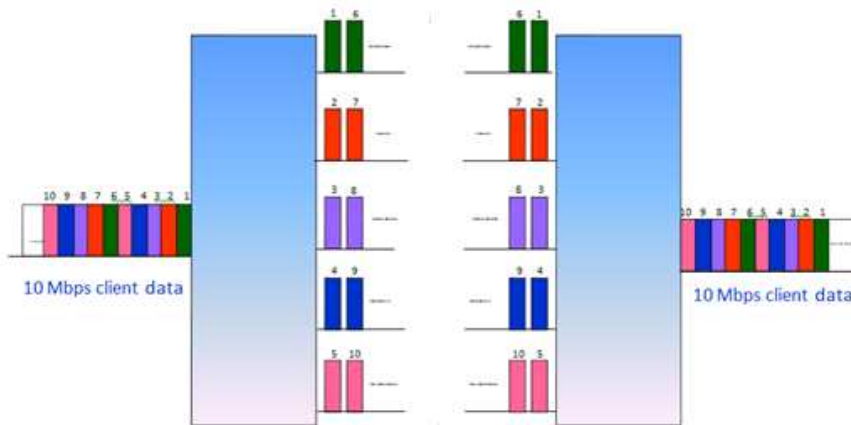
Differential Delay
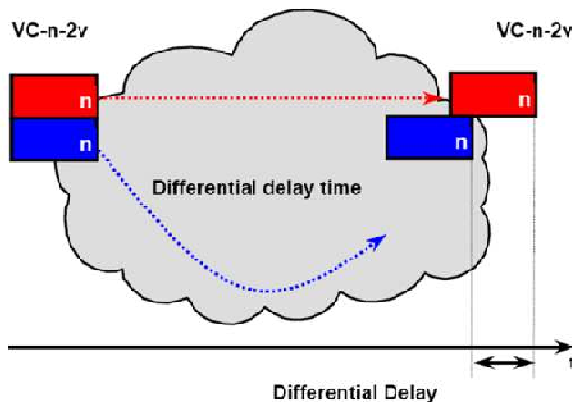
Differential Delay Compensation

Differential Delay: Differential delay measures the difference in time among the channels of a multi channel with respect to the maximum differential delay allowed for a signal to arrive at its destination. VCAT standard allows a differential delay of up to 256ms to be compensated by the receiver. In practice, the maximum amount of differential delay that can be compensated is implementation specific.

If the Differential delay > the maximum value then we encounter loss of data carrying capability in that direction (no point in keeping that channel in VCAT group) . VCAT allows that channel to be temporarily removed from the data carrying channels.

Example: In Tejas Systems:

> The maximum differential delay supported on the TP01 card is 64 ms
> The maximum differential delay supported on the TR01 card is 50 ms
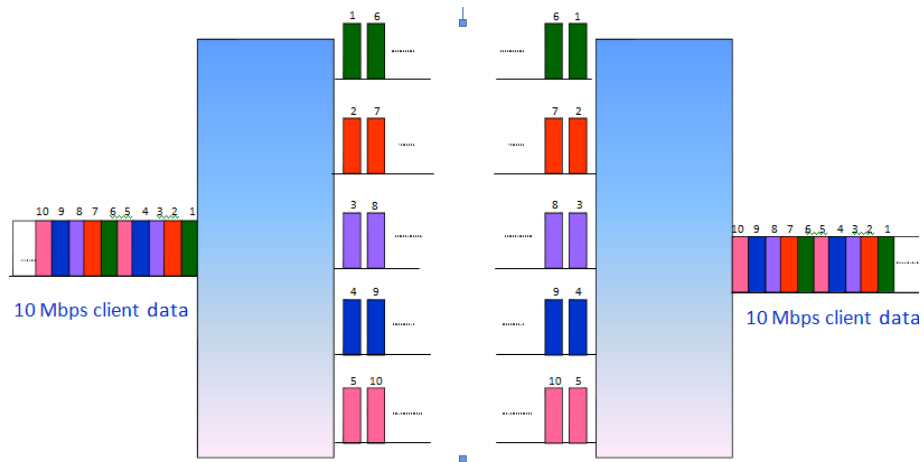> The maximum differential delay supported on the LQ02 card varies from 48 to 56 ms

LCAS (Link Capacity Adjustment Scheme)

LCAS is Link capacity adjustment scheme. It enhances the VCAT to allow the hitless increase and decrease of used bandwidth. LCAS is a protocol for providing data support over SDH-transport pipes (VC- 12/3/4) dynamically by adding or removing of a container to a VC group is carried out with LCAS without affecting the traffic. LCAS guarantees the continuous availability of the service without traffic interruption with reduced bandwidth
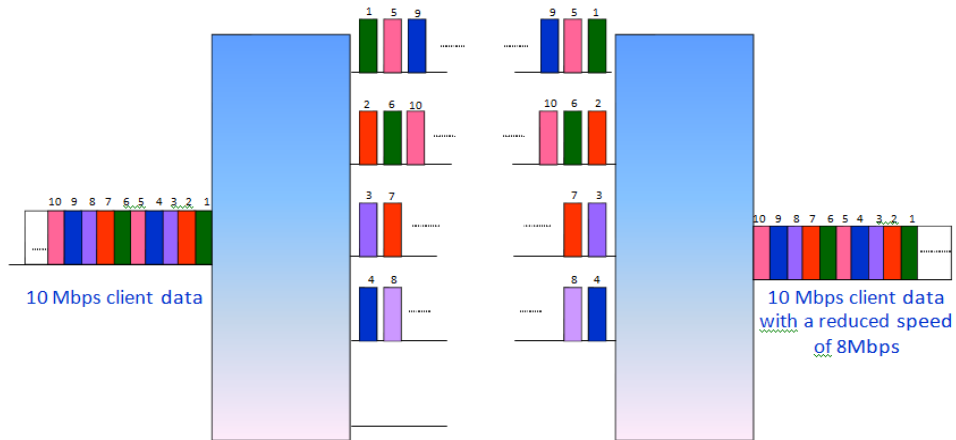
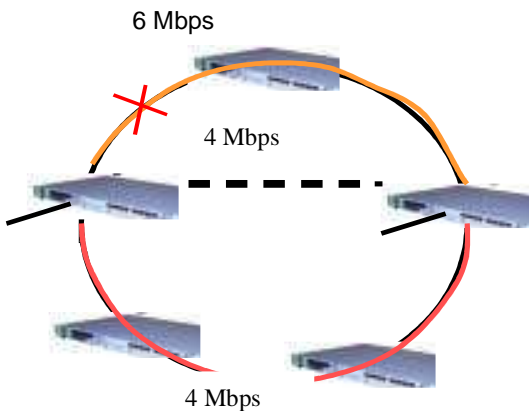Note: For LCAS to work VCAT is required but vice versa is not true.

Normal Scenario:

To cater for 10 Mbps Ethernet data 5 VC-12s are provisioned on a VCG

10 Mbps client data

10 Mbps client data

Scenario with deletion of a VC-12

10 Mbps client data

10 Mbps client data
with a reduced speed
of 8Mbps

LCAS Protection feature

6 Mbps

4 Mbps

4 Mbps

In this 10 Mbps traffic is provided by giving 6 Mbps (3 VC-12) along the upper path and 4 Mbps (2 VC-12) along the below path between the ingress and egress node In case of failure as shown in the figure the bandwidth would come down to 4 Mbps without the traffic being hit

This would provide protection for at least 4 Mbps of traffic even when there is fiber cut and hence a cheaper solution compared to full protection but clear differentiator compared to unprotected connection

Flow Control-Leaky Bucket

When the VCG BW is less than the client data rate, then PAUSE Frames as per 802.3x are generated and all the traffic is chocked. After the pause time is elapsed, the traffic will be transmitted again

Link Integrity

It allows detecting faults along the end-to-end Ethernet transport connection .Link Integrity Enabled forces the ETH (corresponding to the VCG) port to go down
Following faults can be detected

- Near-end Ethernet Link Failure

- SDH Link Failures

- CSF/Far-end Ethernet Link Failure