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Network Topologies & Error Performance Monitoring in SDH Technology

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Abstract —

This paper is dedicated to analysis and review of network topologies used in SDH technology and also the future aspects of optical networks. This in depth analysis is done so that one can formulate the next generation SDH networks. This paper also include various Error performance monitoring in SDH , based on Bit-Interleaved Parity (BIP) checks calculated on a frame by frame basis.

***Index Terms*— SDH/SONET, ATM, LOS, LOP, LOF, BIP 2, STS-N, ETHERNET.**

I. INTRODUCTION

SDH (Synchronous Digital Hierarchy) is a standard for telecommunications transport and designed by International Telecommunication Union (ITU) formerly known as International Telegraph and Telephone Consultative Committee (CCITT). SDH was first introduced in 1992 in the telecommunication network and has since been deployed at rapid rates in all levels of network infrastructure. It's based on overlaying a synchronous multiplexed signal onto a light stream transmitted over fiber optic cable. SONET was originally developed to support voice traffic. The key role of optical networks as the transport infrastructure is to carry client traffic between client networks. Client traffic can be either circuit traffic, e.g., synchronous optical network (SONET) circuits and asynchronous transfer mode (ATM) virtual path/virtual channels, or packet traffic e.g. Internet protocol (IP) packets, which can be characterized as traffic flows by forwarding equivalence classes. Optical Network and Management System defining in a SONET/SDH is based on optical layer Sections. The increased configuration flexibility and bandwidth availability of SDH provides significant advantages over the older telecommunication systems.

Before SDH, the 1st Generations of fiber systems in the PSTN used proprietary architectures, equipment line codes, multiplexing formats, and maintenance procedures. The users of this equipment wanted standards so that they could mix and match equipment from different suppliers. The task of creating such a standard was taken up in 1984 by ECSA (Exchange Carriers Standards Association) in the US to establish a fixed standard. The resulting international standard is known as SDH.

II. THE SONET/SDH RATES

The SONET frame in its electrical nature is called Synchronous Transport Signal level N (STS-N). The SDH equivalent is called Synchronous Transport Module level N (STM-N). After conversion into optical pulses, its known as Optical Carrier Level. The Line rates for different levels of SDH signals are shown in table below.

Signal Designation			**Line Rate *(Mbps)***
SONET	SDH	Optical	
STS -1	STM-0	OC-1	51.85
STS –3	STM-1	OC-3	155.52
STS – 12	STM-4	OC-12	622.08
STS – 48	STM-16	OC-18	2488.32
STS - 192	STM-64	OC-192	9953.28

III. Advantages of SDH

In response to the demand for increased bandwidth, reliability, and high-quality service, SDH developed steadily during the 1980s eliminating many of the disadvantages inherent in PDH. In turn, network providers began to benefit from the many technological and economic advantages this new technology introduce including:

- **High transmission rates.** Transmission rates of up to 10 Gbps can be achieved in modern SDH systems making it the most suitable technology for backbones – the superhighways in today's telecommunications networks.
- **Simplified add and drop function.** Compared the older PDH system, low bit rate channels can be easily extracted from inserted into the high-speed bit streams in SDH. It now no longer necessary to apply the complex and costly procedure of demultiplexing then remultiplexing the plesiosynchronous structure.
- **High availability and capacity.** With SDH, network providers can react quickly and easily to the requirements of their customers.
- **Reliability.** Modern SDH networks include various automatic back-up circuit and repair mechanisms which are designed to cope with system faults and are monitored by management.
- **Interconnection.** SDH makes it much easier to set up gateways between different network providers and to SONET system. The SDH interfaces are globally standardized, making it possible to combines from different manufacturers into a single network thus reducing equipment costs.

IV. Frame structure

The STM-1 frame is the basic transmission format for SDH. The frame lasts for 125 microseconds; therefore there are 8000 frames per second. The STM-1 frame consists of overhead plus a virtual container capacity. The 1st 9 columns of each frame make up the Section Overhead and the last 261 columns make up the Virtual Container (VC) capacity. The VC plus the pointers (H1, H2, and H3 bytes) is called the Administrative Unit (AU).Carried within the VC capacity, which has its frame structure of 9 rows and 261 columns, is the Path Overhead and the Container. The 1st column is for Path Overhead; it is followed by the payload container, which can itself carry other containers. Virtual Containers can have any phase alignment within the Administrative Unit, and this alignment is indicated by the Pointer in row four, as described later in the Pointers section. Within the Section Overhead, the first three rows are used for the Regenerator Section Overhead, and the last five rows are used for the Multiplex Section Overhead. The STM frame is transmitted in a byte-serial fashion, row-by-row, and is scrambled immediately prior to transmission to ensure adequate clock timing content for downstream regenerators.

V. SDH error performance monitoring

Error performance monitoring in the SDH is based on Bit Interleaved Parity (BIP) checks calculated on a frame by frame basis. These BIP checks are inserted in the Regenerator Section Overhead, Multiplex Section Overhead and Path Overheads. In addition, Higher- Order Path Terminating Equipment (HO PTE) and Lower Order Path Terminating Equipment (LO PTE) produce Remote Error Indications (REI) based on errors detected in HO path and LO Path BIP respectively. The REI signals are sent back to the equipment at the originating end of a path.

1. Loss Of Signal – LOS

LOS is raised when the synchronous signal (STM-N) level drops below the threshold at which a BER of 1 in 10^3 is predicted. It could be due to a cut cable, excessive attenuation of the s9ignal, or equipment fault. The LOS state will clear when two consecutive framing patterns are received and no new LOS condition is detected.

2. Out Of Frame Alignment – OOF
   OOF state occurs when several consecutive SDH frames are received with invalid (errored) framing patterns (A1 and A2 bytes). The maximum time to detect OOF is 625 microseconds. OOF state clears within250 microseconds when two consecutive SDH frames are received with valid framing patterns.
3. Loss of Frame Alignment (LOF)
   LOF state occurs when the OOF state exists for a specified time in microseconds. The LOF state clears when an in-frame condition exists continuously for a specified time in microseconds. The time for detection and clearance is normally 3 milliseconds.
4. Loss Of Pointer (LOP)
   LOP state occurs when N consecutive invalid pointers are received or N consecutive New Data Flags (NDF) are received (other than in a concatenation indicator), Where N =8,9 or 10. LOP state is cleared when three equal valid pointers or three consecutive AIS indications are received. LOP can be identified as: AU-LOP (Administrative Unit Loss of Pointer) or TU-LOP(Tributary Unit Loss of Pointer)
5. Alarm Indication Signal (AIS)
   AIS is an all-ONES characteristic or adapted information signal. It's generated to replace the normal traffic signal when it contains a defect condition in order to prevent consequential downstream failures being declared or alarms being raised. AIS can be identified as: MS-AIS(Multiplex Section Alarm Indication Signal) or AU-AIS(Administrative Unit Alarm Indication Signal) or TU-AIS(Tributary Unit Alarm Indication Signal)
6. Remote Error Indication (REI)
   An indication returned to a transmitting node (source) that an errored block has been detected at the receiving node (sink). This indication was previously known as FEBE (Far End Block Error). REI can be identified as:
   1. MS-REI(Multiplex Section Remote Error Indication)
   2. HP-REI(Higher-order Path Remote Indication)
   3. LP-REI(Lower-order Path Remote Indication)
7. Remote Defect Indication (RDI)
   A signal returned to the transmitting Terminating Equipment upon detecting a Loss of Signal, Loss of Frame or AIS defect.RDI was previously known as FERF (Far End Receiver Failure). RDI can be identified as:
   1. MS-RDI (Multiplex Section Remote Defect Indication)
   2. HP-RDI (Higher-order Path Remote Defect Indication)
   3. LP-RDI (Lower-order Path Remote Defect Indication)
8. Remote Failure Indication (RFI)
   A failure is a defect that persists beyond the maximum time allocated to the transmission system protection mechanisms. When this situation occurs, an RFI is sent to the far end and will initiate a path protection switch if this function has been provisioned. RFI can be identified as LP-RFI (Lower-order Path Remote Failure Indication).
9. B1 Error
   Parity errors evaluated by byte B1 (BIP-8) of an STM-N shall be monitored. If any of the eight parity checks fail, the corresponding block is assumed to be in error.
10. B2 Error

Parity errors evaluated by byte B2(BIP-24xN) of an STM-N shall be monitored. If any of the N x 24 parity checks fail, the corresponding block is assumed to be in error.

11. B3 Error

    Parity errors evaluated by byte B3 (BIP-8) of a VC-N (N=3,4) shall be monitored. If any of the eight parity checks fail, the corresponding block is assumed to be in error.

12. BIP 2 Error

    Parity errors contained in bits 1 and 2(BIP-2) of byte V5 of a VC-m (m=11, 12, 2) shall be monitored. If any of the two parity checks fail, the corresponding block is assumed to be in error.

13. Loss of Sequence Synchronization (LSS)

    Out of service bit error measurements using pseudo-random sequences can only be performed if the reference sequence produced on the receiving side of the test set-up is correctly synchronized to the sequence coming from the object under test. In order to achieve compatible measurement results, it's necessary that the sequence synchronization characteristics are specified. The following requirement is applicable to all ITU-T 0.150 Recommendations dealing with error performance measurements using pseudo-random sequences. Sequence synchronization shall be considered to be lost and re-synchronizations shall be started if:

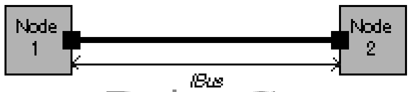
    1. The bit error ratio is≥0.20 during an integration interval of 1 second; or

    2. It can be unambiguously identified that the test sequence and the reference sequence are out of phase.

VI. Network Configurations

1. Point to Point

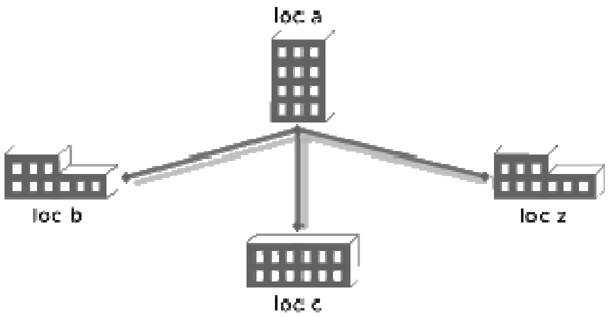
The simplest network configuration involves two terminal multiplexers linked by fibre with or without a regenerator in the link. In this configuration, the SDH path and the Service path (for example, E1 or E3 links end-to-end) are identical and this synchronous island can exist within an asynchronous network world. In the future, point-to-point service path connections will span across the whole network and will always originate and terminate in a multiplexer.



Point to Point Connection

2. Point to Multipoint

A point-to-multipoint (linear add/drop) architecture includes adding and dropping circuits along the way. The SDH ADM (add/drop multiplexer) is a unique network element specifically designed for this task. It avoids the current cumbersome network architecture of demultiplexing, Cross-connecting, adding and dropping channels, and then re-multiplexing. The ADM typically is placed in an SDH link to facilitate adding and dropping tributary channels at intermediate points in the network.



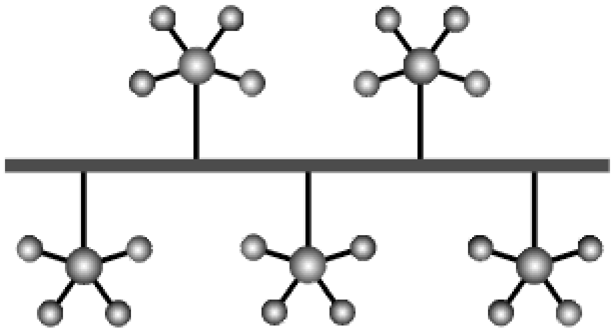
Point-to-MultiPoint

3. Mesh Architecture

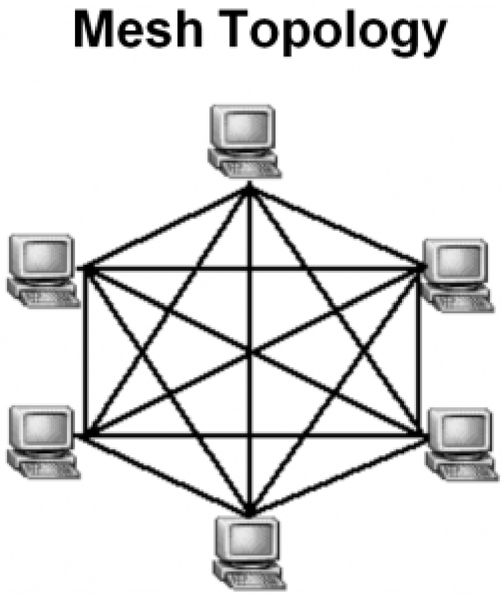
The meshed network architecture accommodates unexpected growth and change more easily than simple point-to-point networks. A cross connects function concentrates traffic at a central site and allows easy re-provisioning of the circuits (see Figure 27). There are two possible implementations of this type of network function:

a. Cross-connection at higher-order path levels, for example, using AU-4 granularity in the switching matrix.

b. Cross-connection at lower-order path levels, for example, using TU-12 granularity in the switching matrix.



Tree network



4. Ring Architecture

The SDH building block for a ring architecture is the ADM. Multiple ADMs can be put into a ring configuration for either Bi-directional or Unidirectional traffic. The main advantage of the ring topology is its survivability; if a fibre cable is cut, for example, the multiplexers have the local intelligence to send the services affected via an alternate path through the ring without a lengthy interruption. The demand for survivable services, diverse routing of fibre facilities, flexibility to rearrange services to alternate serving nodes, as well as automatic restoration within seconds, have made rings a popular SDH topology.

VII. CONCLUSION

After the huge advances in network communications, a new kind of network infrastructure was needed to support the massive amount of traffic data that flowed through the globe. PDH had been a good standard until then, but it wasn't designed to gain advantage of the newer possibilities that fibre optics was enveloping. A new standard that allowed bigger bandwidths and that could take advantage of the fibre optics capabilities was needed in order for the network structures to fulfil the needs of the growing global communications.

Future improvements on network management include Ethernet over SDH, a set of protocols that allow Ethernet traffic to be carried over synchronous digital hierarchy networks in an efficient and flexible way. The same functions are available using SONET (a predominantly North American standard).

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