A Brief Overview of SONET Technology

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Introduction

This document is a broad outline of what Synchronous Optical NETwork (SONET) technology is, and how it works.

Prerequisites

Requirements

There are no specific requirements for this document.

Components Used

This document is not restricted to specific software and hardware versions.

Conventions

For more information on document conventions, refer to the Cisco Technical Tips Conventions.

SONET Basics

SONET defines optical signals and a synchronous frame structure for multiplexed digital traffic. It is a set of standards that define the rates and formats for optical networks specified in ANSI T1.105, ANSI T1.106, and ANSI T1.117.

A similar standard, Synchronous Digital Hierarchy (SDH), is used in Europe by the International Telecommunication Union Telecommunication Standardization Sector (ITU−T). SONET equipment is generally used in North America, and SDH equipment is generally accepted everywhere else in the world.

Both SONET and SDH are based on a structure that has a basic frame format and speed. The frame format used by SONET is the Synchronous Transport Signal (STS), with STS−1 as the base−level signal at 51.84 Mbps. An STS−1 frame can be carried in an OC−1 signal. The frame format used by SDH is the Synchronous

Transport Module (STM), with STM−1 as the base−level signal at 155.52Mbps. An STM−1 frame can be carried in an OC−3 signal.

Both SONET and SDH have a hierarchy of signaling speeds. Multiple lower−level signals can be multiplexed to form higher−level signals. For example, three STS−1 signals can be multiplexed together to form an STS−3 signal, and four STM−1 signals multiplexed together to form an STM−4 signal.

SONET and SDH are technically comparable standards. The term SONET is often used to refer to either.

SONET Transport Hierarchy

Each level of the hierarchy terminates its corresponding fields in the SONET payload, as such:

Section

A section is a single fiber run that can be terminated by a network element (Line or Path) or an optical regenerator.

The main function of the section layer is to properly format the SONET frames, and to convert the electrical signals to optical signals. Section Terminating Equipment (STE) can originate, access, modify, or terminate the section header overhead. (A standard STS−1 frame is nine rows by 90 bytes. The first three bytes of each row comprise the Section and Line header overhead.)

Line

Line−Terminating Equipment (LTE) originates or terminates one or more sections of a line signal. The LTE does the synchronization and multiplexing of information on SONET frames. Multiple lower−level SONET signals can be mixed together to form higher−level SONET signals. An Add/Drop Multiplexer (ADM) is an example of LTE.

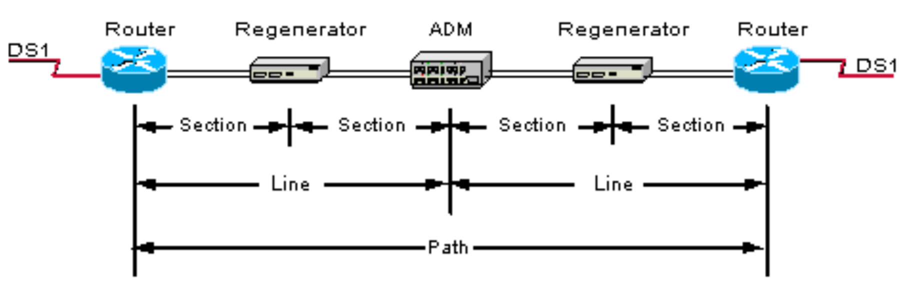
Path

Path−Terminating Equipment (PTE) interfaces non−SONET equipment to the SONET network. At this layer, the payload is mapped and demapped into the SONET frame. For example, an STS PTE can assemble 25 1.544 Mbps DS1 signals and insert path overhead to form an STS−1 signal.

This layer is concerned with end−to−end transport of data.

Configuration Example

The optical interface layers have a hierarchical relationship; each layer builds on the services provided by the next lower layer. Each layer communicates to peer equipment in the same layer and processes information, and passes it up or down to the next layer. As an example, consider two network nodes that are to exchange DS1 signals, as shown in this figure:



At the source node, the path layer (PTE) maps 28 DS1 signals and path overhead to form an STS−1 Synchronous Payload Envelope (SPE) and hands this to the line layer.

The line layer (LTE) multiplexes STS−1 SPE signals and adds line overhead. This combined signal is then passed to the section layer.

The section layer (STE) performs framing and scrambling and adds section overhead to form an STS−n signal.

Finally, the electrical STS signal is converted to an optical signal for the photonic layer and transmitted over the fiber to the distant node.

Across the SONET network, the signal is regenerated in optical regenerators (STE−level devices), passed through an ADM (an LTE−level device), and eventually terminated at a node (at the PTE level).

At the distant node, the process is reversed from the photonic layer to the path layer where the DS1 signals terminate.

SONET Framing

A standard STS−1 frame is nine rows by 90 bytes. The first three bytes of each row represent the Section and Line overhead. These overhead bits comprise framing bits and pointers to different parts of the SONET frame.

There is one column of bytes in the payload that represents the STS path overhead. This column frequently "floats" throughout the frame. Its location in the frame is determined by a pointer in the Section and Line overhead.

The combination of the Section and Line overhead comprises the transport overhead, and the remainder is the SPE.

For STS−1, a single SONET frame is transmitted in 125 microseconds, or 8000 frames per second. 8000 fps * 810 B/frame = 51.84 Mbs, of which the payload is roughly 49.5 Mbs, enough to encapsulate 28 DS−1s, a full DS−3, or 21 CEPT−1s.

An STS−3 is very similar to STS−3c. The frame is nine rows by 270 bytes. The first nine columns contain the transport overhead section, and the rest is SPE. For both STS−3 and STS−3c, the transport overhead (Line and Section) is the same.

For an STS−3 frame, the SPE contains three separate payloads and three separate path overhead fields. In essence, it is the SPE of three separate STS−1s packed together, one after another.

In STS−3c, there is only one path overhead field for the entire SPE. The SPE for an STS−3c is a much larger version of a single STS−1 SPE.

STM−1 is the SDH (non−North American) equivalent of a SONET (North American) STS−3 frame (STS−3c to be exact). For STM−1, a single SDH frame is also transmitted in 125 microseconds, but the frame is 270 bytes long by nine rows wide, or 155.52 Mbs, with a nine−byte header for each row. The nine−byte header contains the Multiplexer and Regenerator overhead. This is nearly identical to the STS−3c Line and Section overhead. In fact, this is where the SDH and SONET standards differ.

SDH and SONET are not directly compatible, but only differ in a few overhead bytes. It is very unlikely that Cisco will ever use a framer that does not support both.

SONET is very widely deployed in telco space, and is frequently used in a ring configuration. Devices such as ADMs sit on the ring and behave as LTE−layer devices; these devices strip off individual channels and pass them along to the PTE layer.

All current Cisco line cards and Port Adapters (PAs) act as PTE−layer devices; these devices terminate the full SONET session and L2 encapsulation. They are Packet Over SONET (POS) cards, which indicate serial transmission of data over SONET frames. There are two RFCs that describe the POS process: RFC 1619, PPP over SONET/SDH, and RFC 1662, PPP in HDLC−like Framing.

These Cisco products *cannot* sit directly on a SONET or SDH ring. One of them must hang off of some LTE−layer device, such as an ADM. Equipment such as an Integrated SONET Router (ISR) has both PTE and LTE functionality, so it can terminate and pass through data.

Configuration Issues

These parameters affect configuration of SONET devices:

- **Clocking** The clocking default value is line, and is used whenever clocking is derived from the network. The **clock source internal** command is typically used when two Cisco 12000 Series Internet Routers are connected back−to−back, or are connected over dark fiber where no clocking is available. In either case, each device must have its clock source set to internal. For a more detailed explanation, refer to Configuring Clock Settings on POS Router Interfaces.
- **Loopback** Loopback is a line and internal (DTE) value. This is a SONET section loopback if done on the controller. If done on the individual interface, these are individual path loopbacks.
- **Framing** Most Cisco framers support both SONET and SDH.
- **Payload scrambling** This value is normally set to On.
- **S1S0 flag** This value must be between 0 and 3; the default value is 0. With SONET, `s1so` must be set to 0, and with SDH it must be set to 2. Value 3 corresponds to the received Alarm Indication Signal (AIS).
- **J0 flag − 0−255** This setting is the section trace identifier. It is only required for section tracing.
- **C2 flag − 0−255** This setting specifies the STS path signal label (5 to 7 are configured with the **pos flag** command).
- **Alarm reporting** Alarm reporting allows you to specify which alarms are reported. The permitted values are b1−tca, b2−tca, sf−ber, sd−ber, los, lof, ais−l, and rdi−l. (This value is configured with the **pos report** command).
- **Alarm thresholds** The alarm threshholds setting specifies the Bit Error Rate (BER) thresholds that signal an alarm. (This value is configured with the **pos threshold** command).

Debugging

Provided in this section is a screen capture from the **show controllers pos x/y** command that displays the status of the SONET controller.

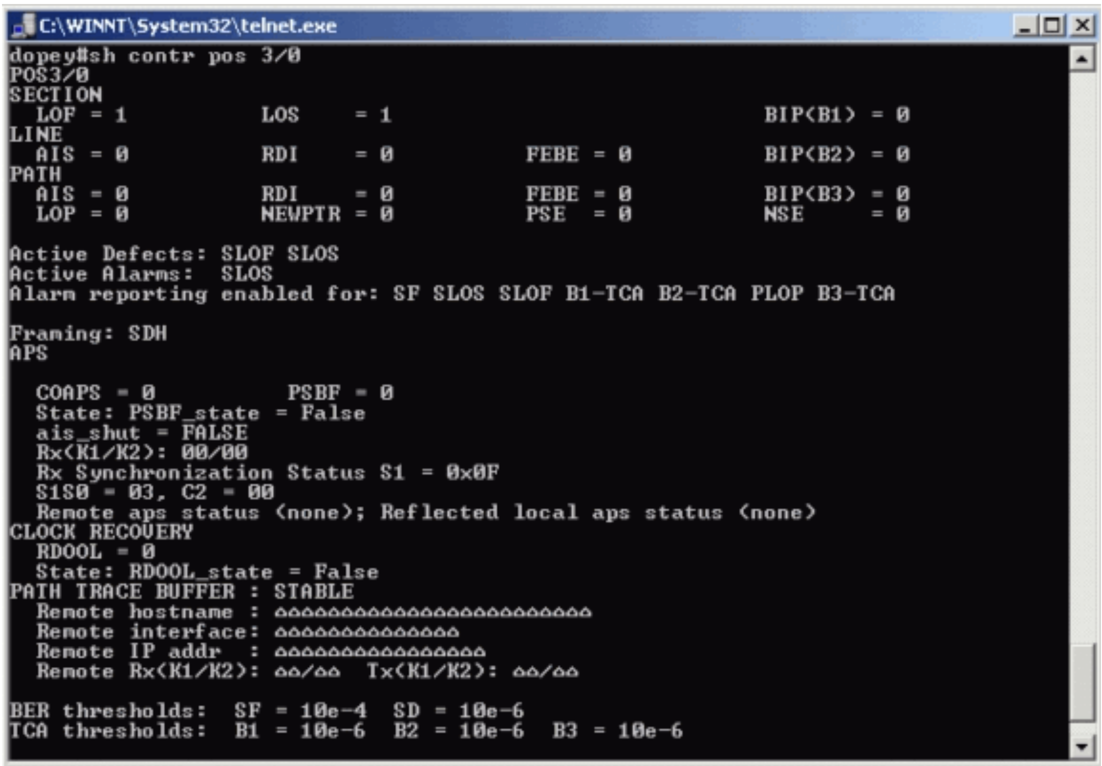
If the link is down/down, check for active alarms and defects. Troubleshooting in this case is essentially the same as serial troubleshooting. If you look at the SONET controller (refer to the example given), it can provide plenty of L1 and SONET information. Defects and alarms in SONET are similar to the same alarms when you troubleshoot and diagnose T1/E1 and T3/E3 (LOS, LOF, AIS (Blue Alarm), and so on) issues.

Active defects and active alarms fields show the current status of the POS controller, and point to the problem.

The numbers for errors under the Section, Line, and Path are accumulators, and tell you the number of times the condition has occurred; these numbers do not indicate if the error is currently happening.

Bit Interleaved Parity (BIP) errors are parity errors that correspond to a specific SONET layer: BIP(B1) corresponds to Line, BIP(B2) to the Section, and BIP(B3) to the Path layer parity errors.

When you look at the output of the **show controllers pos x/y** command, pay attention to which SONET layers accumulate errors: SONET Line, Section, or Path. When you troubleshoot SONET problems or errors, the first thing to do is to isolate the bad section.



```
C:\WINNT\System32\telnet.exe
dopey#sh contr pos 3/0
POS3/0
SECTION
  LOF = 1          LOS    = 1                          BIP(B1) = 0
LINE
  AIS = 0          RDI    = 0          FEBE = 0        BIP(B2) = 0
PATH
  AIS = 0          RDI    = 0          FEBE = 0        BIP(B3) = 0
  LOP = 0          NEWPTR = 0          PSE  = 0        NSE     = 0

Active Defects: SLOF SLOS
Active Alarms:  SLOS
Alarm reporting enabled for: SF SLOS SLOF B1-TCA B2-TCA PLOP B3-TCA

Framing: SDH
APS

  COAPS = 0          PSBF = 0
  State: PSBF_state = False
  ais_shut = FALSE
  Rx(K1/K2): 00/00
  Rx Synchronization Status S1 = 0x0F
  S1S0 = 03, C2 = 00
  Remote aps status (none); Reflected local aps status (none)
CLOCK RECOVERY
  RDOOL = 0
  State: RDOOL_state = False
PATH TRACE BUFFER : STABLE
  Remote hostname : 
  Remote interface: 
  Remote IP addr  : 
  Remote Rx(K1/K2):      Tx(K1/K2):

BER thresholds:  SF = 10e-4  SD = 10e-6
TCA thresholds:  B1 = 10e-6  B2 = 10e-6  B3 = 10e-6
```

Related Information

- **SONET Documentation and Information**
- **SONET Graphical Overview**
- **A Brief Overview of Packet Over SONET APS**
- **Understanding the Basic Differences Between SONET and SDH Framing in Optical Networks**
- **Technical Support − Cisco Systems**

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