Backbone Optical Transmission Network Using 10-Gbit/s SONET

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OVERVIEW: The Hitachi OC-192 10 Gbit/s SONET (synchronous optical network) transmission system is the highest speed rate SONET system in North America that can transmit both IP (Internet protocol)-based traffic and voice-based traffic. In the SONET network systems, lower speed rate OC-48 and OC-12 tributary cards can process concatenated signals in which IP-based traffic is mapped. A time slot assignment matrix with STS (synchronous transfer signal)-1 granularity makes it possible to transport both STS-1 path traffic and concatenated traffic of STS-3c, STS-12c, and STS-48c in the same OC-192 line. Hitachi is also developing 40-Gbit/s devices for the next-generation of SONET systems.

INTRODUCTION

THE increase in traffic in IP (Internet protocol)-based and ATM (asynchronous transfer mode)-based network applications requires a very high-speed optical transmission backbone network using both TDM (time division multiplexing) and WDM (wavelength division multiplexing) technologies. The SONET (synchronous optical network) 10-Gbit/s optical transmission system is not only the next step up from the 2.4-Gbit/s system, but also the key system for future applications. OC-192 is currently the highest SONET speed rate in North America. This is equivalent to STM-64 of SDH (Synchronous Digital Hierarchy).

As shown in the Fig. 1, the Hitachi OC-192 system is used for conventional voice-, IP-, and ATM-based network applications. This paper presents several features of the system and its application in future networks.

SYSTEM OVERVIEW

The Hitachi OC-192 transmission system operates at a 10-Gbit/s line rate. Its specifications are summarized in Table 1. The system is configured in either a linear configuration or a ring configuration. It has an ITU-T optical grid for the OC-192 line interface.

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Configuration</td>
<td>Line terminal, 4/2F-BLSR, LRE</td>
</tr>
<tr>
<td>Line</td>
<td>OC-192 ITU-T grid (100-GHz spacing)</td>
</tr>
<tr>
<td>Tributaries</td>
<td>OC-48/OC-48c, OC-12/OC-12c, OC-3/OC-3c</td>
</tr>
<tr>
<td>Path connection</td>
<td>STS-1, STS-3c, STS-12c, STS-48c</td>
</tr>
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</table>

4/2F-BLSR: 4/2-fiber bi-directional line switched ring
LRE: line regenerator equipment
STS: synchronous transport signal

Fig. 1—OC-192 4F-BLSR Network Configuration.
and tributary interfaces for OC-48, OC-12, and OC-3 with concatenation processing capability. The ADM (add-drop multiplexer) has an STS-1 TSA (time slot assignment) matrix. With these features, this system can be used for several core network applications.

IP AND ATM APPLICATIONS

The amount of IP-based traffic has increased tremendously and is expected to be a major portion of the total traffic in North America in the near future. Some people argue that IP-based traffic should not be SONET-based, but that it should be directly connected to DWDM (dense wavelength division multiplexing) systems. This may be true when the IP-based traffic is the majority of traffic at some time in the future. However, SONET multiplexing is still very useful when network providers need to have common transmission facilities both for voice and IP/ATM. In addition, a SONET BLSR (bi-directional line switched ring) is a well established traffic restoration technology and will give network providers very robust network reliability until optical restoration technologies become available.

IP routers and ATM switches currently have OC-12 interfaces with STS (synchronous transfer signal)-12c concatenation (sometimes called OC-12c). OC-48 interfaces with STS-48c concatenation (OC-48c) will be available soon. The key requirement for the OC-192 interfaces with regard to this traffic is the accommodation of the concatenation format and the add-drop capability of the concatenated signals. Hitachi’s OC-192 system incorporates the following features to meet these requirements.

(a) Concatenation

The OC-192 system can process concatenated signals such as STS-48c (OC-48c), STS-12c (OC-12c) and STS-3c (OC-3c). A concatenation indication signal is automatically detected by SONET pointer bytes in a tributary circuit. For example, the input signal from an OC-48 tributary contains an STS-48c concatenation indication signal, which tells the OC-192 system to process the input signal as a concatenated signal. The OC-48 signal can consist of four STS-12 signals or 48 STS-1s signals. The OC-48 and OC-12 tributary cards have circuitry that processes either concatenated signals or non-concatenated signals. Special tributary cards are not required for the concatenated signals. With this feature, an IP router or an ATM switch with an OC-48c interface can be directly connected to the OC-192 system using the OC-48 tributary cards.

(b) TSA (Time Slot Assignment)

The Hitachi OC-192 system has a TSA switch matrix with STS-1 granularity. This matrix can connect STS-1, STS-3c, STS-12c, and STS-48c signals. Therefore, any combination of the concatenated and non-concatenated signals can be multiplexed in any time slot in the OC-192 output. Fig. 2 shows an example of multiplexing using the TSA matrix.

(c) Protection

There is a lot of discussion concerning IP over WDM. This method of multiplexing is attractive, but more study is required for network protection without SONET rings. Therefore, SONET is still being used for IP networks because it has an established ring

Fig. 2—STS Path Connection.
protection capability. All IP signals in the OC-192 system are fully protected by BLSR (bi-directional line switched ring) or MS-SPRing (multiplex section shared protection ring).

CONVENTIONAL VOICE-BASED TRAFFIC APPLICATIONS

Many telecommunication carriers are continuing to serve conventional voice-based traffic transported by DS-3 digital paths. Even though IP-based traffic is growing rapidly, for the time being, it should be possible for the same transmission facility to carry both IP-based and conventional voice-based signals. The Hitachi OC-192 system has the capability of STS-1 grooming, so it can easily accommodate DS-3 signals that are mapped into STS-1 paths. The TSA matrix allows any combination of voice-based and IP-based signals to be multiplexed in the same OC-192 line so that the fiber facility can be used efficiently. The network configuration is shown in Fig. 1.

OC-192 OVER WDM

In most applications, the OC-192 system is used with DWDM to maximize the capacity of a fiber facility. The Hitachi OC-192 system can be used with any DWDM system that can transmit OC-192 signals because the Hitachi system supports the ITU-T wavelength grid with 100-GHz spacing. However, the performance of this system is best when it is combined with a Hitachi DWDM system. Hitachi’s DWDM system can transmit up to 32 channels of the OC-192 signal over a maximum span length.

The most important feature of the DWDM system is stable OC-192 transmission. At a speed of 10 Gbit/s, fiber non-linearity and fiber dispersion can cause waveform distortion, so it is important to be able to prevent fiber non-linearity. Fiber non-linearity depends heavily on the output power per channel from the DWDM. Thus, it is essential to control the output power. The Hitachi DWDM system maintains a constant output power per channel regardless of the number of channels, input power level, or the change in fiber loss. Therefore, stable multiwavelength OC-192 transmission is possible when the Hitachi OC-192 system is used in conjunction with the DWDM system.

MANAGEMENT SYSTEM

The Hitachi OC-192 system provides a fully TMN (telecommunication management network) compliant element manager (EM) and graphical local craft terminal (GLCT) for the SONET/WDM product family. These graphical user interfaces provide a complete set of operation, administration, maintenance and provisioning features to meet the needs of today’s network environment.

The EM has a Q3 interface for the NE (network element) and both Q3 and TL-1 interfaces for the northbound OS (operation system). These interfaces make the system compatible with the conventional TL-1-based OS and ready for future Q3-based network management systems. The EM’s subnetwork management function gives it a better ability to perform fault management of a network of NEs. The GLCT supports both serial RS232 and TCP/IP connections to the NEs. This allows individual NEs or subnetworks of NEs to be managed via a corporate LAN network or direct connection. Utilizing a full complement of standards based operations interworking features such as CMISE (common management information service element), TL1, FTAM (file transfer access and management) and directory services, both the EM and GLCT products will support today’s traditional network topologies and tomorrow’s Web-based network management solutions.

40-Git/s TECHNOLOGIES

40-Gbit/s optical transmission systems are being considered for the next-generation optical transmission systems beyond the 10-Gbit/s systems. The 40-Gbit/s system will be able to transmit data four times as fast as the 10-Gbit/s system by TDM (time division multiplexing). To achieve this high transmission rate, each component in the 40-Gbit/s system will have to operate four times as fast as each component in the 10-Gbit/s system, requiring the development of new optical and electronic devices. In addition to high-speed operation, low cost and low power consumption

<table>
<thead>
<tr>
<th>Parameter</th>
<th>InP HBT</th>
<th>SiGe HBT</th>
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<tbody>
<tr>
<td>hfe</td>
<td>20</td>
<td>720</td>
</tr>
<tr>
<td>rbb'</td>
<td>20 ohm</td>
<td>210 ohm</td>
</tr>
<tr>
<td>ft</td>
<td>147 GHz @ 17 mA</td>
<td>95 GHz @ 2 mA</td>
</tr>
<tr>
<td>fmax</td>
<td>210 GHz</td>
<td>108 GHz</td>
</tr>
<tr>
<td>BVCEO</td>
<td>8 V</td>
<td>2V</td>
</tr>
</tbody>
</table>

hfe: current gain
rbb': base resistance
ft: cut-off frequency
fmax: maximum frequency of oscillation
BVCEO: collector-emitter breakdown voltage with base open
HBT: heterojunction bipolar transistor
are keys for success. Hitachi is developing new devices using new materials and structure. For the optics, the optical modulator on the transmitter side is the key device. A semiconductor optical modulator with a low drive voltage of less than 2.5 V and a large modulation bandwidth of 42 GHz has recently been developed.

The ICs for a 40-Gbit/s system can either be analog or digital. Table 2 shows two electronic devices for a 40-Gbit/s system\(^1\). An InP HBT (heterojunction bipolar transistor) for analog ICs has low base resistance and enables the design of wide-band ICs. This transistor also has a high breakdown voltage, so it can be used to make a modulator driver IC with large output. The SiGe HBT shows a high cut-off frequency at low collector current, so it is suitable for digital ICs. The low current operation helps keep power consumption low. The manufacturing process of SiGe HBTs is similar to that of conventional Si bipolar transistors, so the manufacturing cost is low. Table 3 shows ICs manufactured for a trial 40-Gbit/s system. Hitachi made a preamplifier, a main amplifier, and a driver IC with InP HBT. Digital ICs with SiGe HBT were also made, which are a 2:1 multiplexer, a 1:2 demultiplexer, and a decision circuit operating at 40 Gbit/s.

### CONCLUSIONS

The Hitachi OC-192 transmission system can multiplex and transmit STS-1 and concatenation signals such as OC-48c and OC-12c. The automatic concatenated processor in OC-48 and OC-12 tributary cards and the STS-1 based TSA matrix enable combined signal transmission. With these features, the OC-192 system is a flexible and efficient core transport network that can accommodate both emerging IP-based traffic and conventional voice-based traffic.

### REFERENCES


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