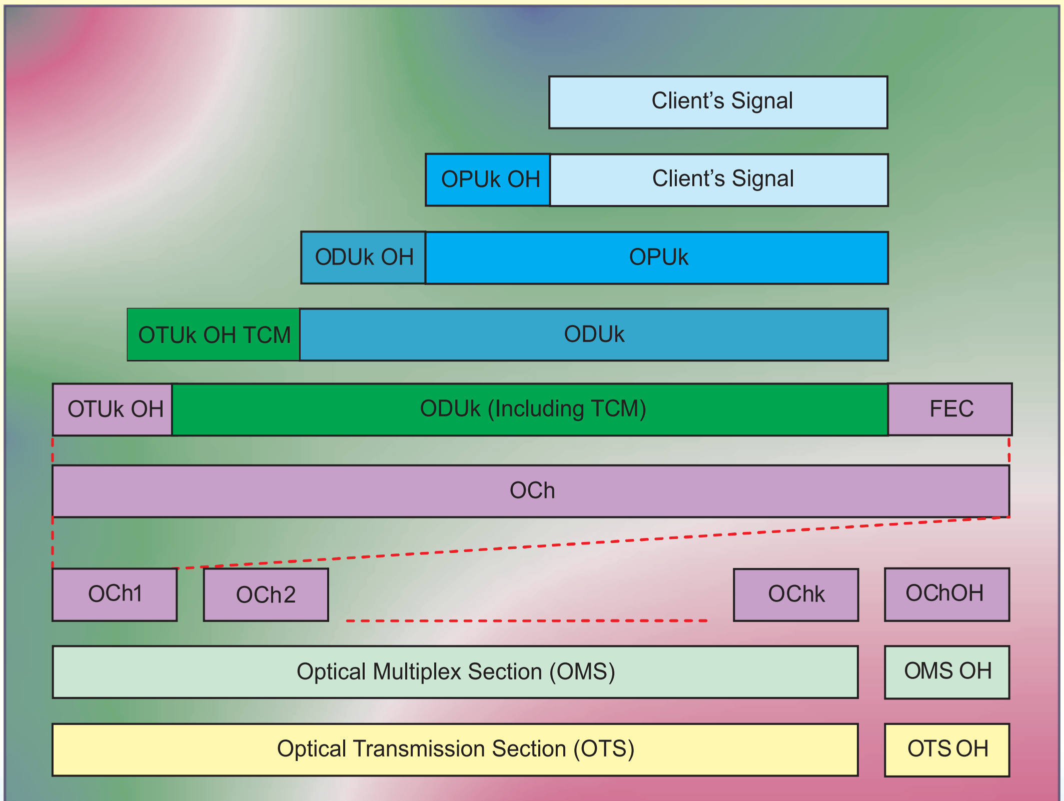
TEC
TELECOMMUNICATION ENGINEERING CENTRE
टी ई सी संचारिका
NEWSLETTER
VOL 14 April 2010 ISSUE 1

OPTICAL TRANSPORT NETWORK (OTN): THE FUTURE TRANSPORT MECHANISM



Schematic diagram of Optical Transport Network Layers

IN THIS ISSUE

1.0 Introduction

Explosion of bandwidth demand in the field of telecommunications has left the telecom operators bewildered as to how to negotiate and mitigate this exponential increase, effectively and efficiently. Though the volume of voice traffic has more or less stabilized, the data traffic has taken off very strongly. With the advent of the Video on Demand (VoD), it is expected that the situation will further worsen. Keeping in view the futuristic growth, telecom operators are in need of a carrier class network with minimal Capital Expenditure (CAPEX) and Operational Expenditure (OPEX). The network needs to be carrier class because, under the circumstances, it must provide scalability, manageability, survivability and bandwidth efficiency and at the same time offer flexibility for new services. Telecom operators today are also looking for a converged network solution conducive to such kind of a scenario. They need to reap the benefits of both voice optimized and OAM capable SONET/SDH technology with the bandwidth expandability of DWDM technology. Optical Transport Network (OTN) provides a vehicle for a converged network for both these technologies facilitating SONET/SDH like network operations, administration, maintenance, and provisioning (OAM&P) functionality, without altering the individual services.

2.0 Why OTN technology?

SONET/SDH is a connection oriented circuit switched technology initially designed to carry mainly voice traffic; it is now widely used as a physical layer protocol to carry IP packets over optical networks. Wavelength Division Multiplexing (WDM), on the other hand, is also a circuit switching network, providing end-to-end permanent connections at constant bit rates. Differing from the time division multiplexing approach in SDH, WDM adopts a wavelength division multiplexing approach, using different wavelengths of laser beams to carry different digital signals over a single optical fibre to achieve higher overall line rates.

SONET/SDH is a mature transport infrastructure and provides efficiently managed network complexity. But today, this technology is looked down as bandwidth inefficient and not scalable. Although WDM technology provides bandwidth expandability, it lacks OAM capability.

These factors are the drivers behind emergence of a flexible technology, known as OTN. Apart from combining the benefits of both SONET/SDH and WDM technologies, the main aim of the optical transport network (OTN) is to converge the multi-service transport of packet based data and legacy traffic.

3.0 Benefits of OTN technology

OTN offers numerous advantages to network operators relative to SONET/SDH and DWDM technologies. The reasons, carriers are moving toward OTN, include:

- OTN provides flexible adaptation of the client signals and is a less complex technology than SONET/SDH.
- Low overheads and hence reduced latency for transporting signals over WDM networks.
- Reduced technology complexity and optimized overhead allow low CAPEX and OPEX.
- It is protocol agnostic – transparent to the client management information in the overhead.
- OTN provides end-to-end standardized service management.
- More levels of Tandem Connection Monitoring (TCM) than SONET/SDH.
- Forward Error Correction (FEC) mechanism allows greater reach between optical nodes and/or higher bit rates on the same fibre. This may provide some comfort in the Indian environment which has too many fibre cuts resulting in increasing loss on fibre over a period of time.
- OTN layer provides sub-lambda grooming at granularity coarser than SONET/SDH, but finer than DWDM.

- Provides protection protocols similar to SDH, which is missing in DWDM.
- Provides in-band management channels like SDH, which DWDM had to rely on OSC for management burning a wave.

4.0 OTN technology defined:

ITU-T has defined Optical Transport Network (OTN) as "composed of a set of Optical Network Elements connected by optical fibre links, able to provide functionality of transport, multiplexing, switching, management, supervision and survivability of optical channels carrying client signals". Additionally it is able to provide "Transport for all digital payloads with superior performance and support for the next generation of dynamic services with operational efficiencies not expected from current optical wavelength division multiplexing (WDM) transport solutions" and "Support for a wide range of narrowband and broadband services like SDH/SONET, IP based services, Ethernet services, ATM services, Frame Relay services and Audio/Video services".

Simply, OTN could be described as a future version of WDM inclusive of the advantages and experiences from SDH. The popular belief that the future of the telecom network lies in photonics, OTN can provide a bridge between electronic networks and all-optical networks. OTN is an emerging technology used in NGN transport stratum. This transplants the functions of OAM&P (Operation, Administration, Management and Provisioning) in SDH into WDM networks, and consequently, improves the performance of WDM networks in network administration. In addition, some advanced fault management and performance monitoring mechanisms are integrated into OTN to provide carrier-class QoS guarantee.

To create an OTU frame, a client signal rate is first adapted at the OPU layer. The adaptation consists of adjusting the client signal rate to the OPU rate. Its overhead contains information to support the adaptation of the client signal. Once adapted, the OPU is mapped into the ODU. The ODU maps the OPU and adds the overhead necessary to ensure end-to-end supervision and tandem connection monitoring (up to six levels). Finally, the ODU is mapped into an OTU, which provides framing as well as section monitoring and FEC.

In order to map client signals via ITU G.709, they are encapsulated using the structure illustrated in figure on front page.

5.0 OTN Layers and structures:

5.1 OTN Digital Layer:

The Digital Layer of OTN consists of the following hierarchical layers:

- Optical Channel Payload Unit (OPU): The OPU maps (encapsulates, digitally wraps) the client signal (e.g., SONET/SDH, IP-packets, ATM cells, Ethernet frames, etc.) and performs rate justification, if needed.
- Optical Channel Data Unit (ODU): The ODU consists of the OPU and the ODU overhead. The ODU overhead functionality is similar to the path overhead in SONET/SDH. It provides multiplexing, protection switching, end-to-end path supervision, tandem connection monitoring, BIP for signal quality supervision, maintenance signals, and data communication channels.
- Optical Channel Transport Unit (OTU): The OTU is the highest layer in the electrical domain. Its functionality is similar to the Section Overhead in SONET/SDH and includes BIP calculation, Trail Trace ID, and Forward Error Correction (FEC).

5.2 OTN Optical Layer

The Optical Layer of OTN consists of the following hierarchical layers:

Optical Channel (OCh): It is a single wavelength containing optical and electrical functions. It provides signal generation and recovery, and management overhead for the optical channel.

Optical Multiplex Section (OMS): It consists of multiplexed and de-multiplexed payload wavelengths and provides amplification, dispersion compensation and management overhead for the multiplexed section.

Optical Transmission Section (OTS): It is the physical optical signal consisting of multiplexed wavelengths plus an optical supervisory channel wavelength. It also provides optical amplification, dispersion compensation and management overhead for the physical OTS.

6.0 OTN structure and framing:

6.1 OTN signal structure:

The OTN signal structure is hierarchical where an OPU maps or encapsulates a client signal and performs rate justification, if needed. Once adapted, the OPU is mapped into the ODU. The ODU maps the OPU and adds the overhead to provide multiplexing, protection switching, end-to-end path supervision and tandem connection monitoring. Finally, the ODU is mapped into an OTU, which provides framing as well as section monitoring and FEC.

The structured OTUk (k = 1, 2, 3) are transported using the Optical Channel (OCh); each channel is assigned a specific wavelength of the ITU-T grid.

Several channels can be mapped into the OMS (Optical Multiplex Section) and then transported via the OTS (Optical Transmission Section) layer.

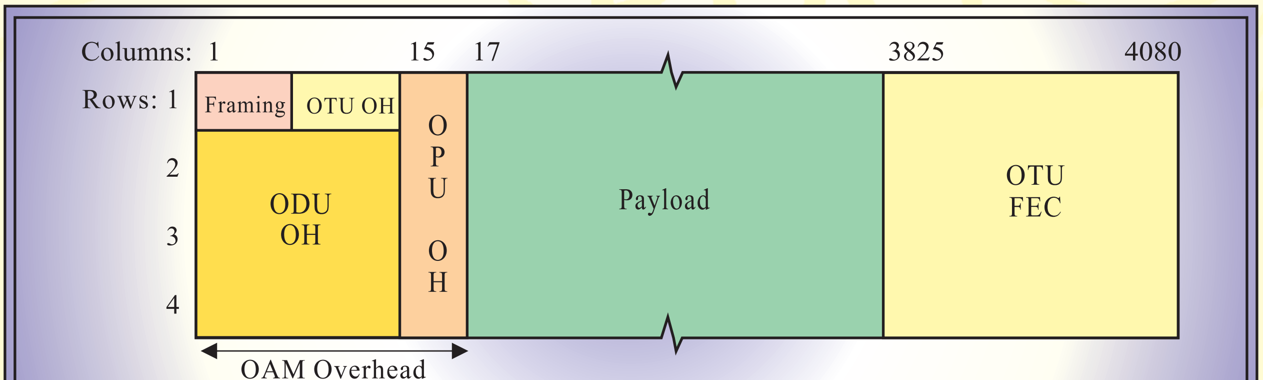
The OCh, OMS and OTS layers have their own overheads for management purposes at the optical level. The overheads of these optical layers are transported outside of the ITU-T grid in an out-of-band channel called the optical supervisory channel (OSC).

When the OTN frame structure is complete (OPU, ODU and OTU), ITU-T G.709 provides OAM&P functions that are supported through the overheads.

6.2 OTN Frame

The G.709 OTN frame is constituted of three parts - the overhead, the payload, and the FEC. OTN is basically protocol agnostic. Apart from the payload of the types of SONET/SDH and multiplexed G.709 signals, it also supports native data protocols such as Asynchronous Transfer Mode (ATM) and GFP which can also be mapped directly into the payload area of the G.709 frame.

Optical Transport Hierarchy (OTH) is also known as a "digital wrapper" because of its ability to enclose any service in digital optical containers. It has hierarchical layers similar to SDH/SONET. The OTN is composed of OTH and the optical layers with the addition of a supervisory channel for management purposes.



OTN Frame

6.3 OTN rates

Optical Transport Hierarchy (OTH) defines three switching rates, as shown in Table 1. The OTN multiplexing function is similar to PDH to the fact that four ODU1 signals are multiplexed into ODU 2, and four ODU 2 signals are multiplexed into ODU 3 signals.

Level	SDH/SONET Line Signal (G.707/ T1.105)	OPU rate (±20 ppm) (Gbps)	ODU rate (±20 ppm) (Gbps)	OTU rate (±20 ppm) (Gbps)
k = 1	STM-16/ OC-48	2.48832	239/238 x 2.48832 ≈2.498775	255/238 x 2.48832 ≈2.666057
k = 2	STM-64/ OC-192	238/237 x 9.95328 ≈9.995277	239/237 x 9.95328 ≈10.037274	255/237 x 9.95328 ≈10.709225
k = 3	STM-256 /OC-768	238/236 x 39.81312 ≈40.150519	239/236 x 39.81312 ≈40.319219	255/236 x 39.81312 ≈43.018414

Table 1. OTN Rates

6.4 Rates under Standardization

- OTU4/ODU4 (100G): This frame format will have defined client signals as 100GbE, etc. The final rate is expected to be close to 112 Gbps. It will support multiplexing of a variety of combination of client signals to attain the final rate as – 10 x ODU2/ODU2e, 2 x ODU3 + 2 x ODU2/ODU2e, 40 x ODU1, 80 x ODU0.
- ODU2e: Likely rate is ~11.096 Gbps and will support transparent 10GbELAN mapping.
- ODU0: GbE is likely to be mapped to ODU0. 2 x ODU0 will be multiplexed into ODU1. Multiplexing to other rates is under progress.

7.0 Forward Error Correction (FEC)

FEC allows an increase in the optical link budget by providing a method to correct errors, thereby reducing the impact of network noise and other optical phenomena experienced by the client signal travelling through the network.

OTN uses Reed-Solomon (RS 255/239) FEC algorithm which adds 7% overhead on the line rate. It helps to improve the Optical Signal to Noise Ratio (OSNR) up to 8.5 dB. This results in an increased span length, saving 3R regeneration sites and thereby enabling more OADM nodes deployed along the signal path. This makes it more efficient to evolve from simple point-to-point and mesh to OADM and ROADM topologies.

8.0 Tandem Connection Monitoring (TCM)

TCM enables the user and its signal carriers to monitor the quality of the traffic that is transported between segments or connections in the network. This allows fault and error diagnostics into the operator domains of the end-to-end signal path. ITU-T G.709 allows six levels of tandem connection monitoring to be configured. There are various types of monitored connection topologies – cascaded, nested and overlapping. The TCM connection monitors the BIP-8 and REI errors for each connection level. In case of any errors, it provides an indication of the quality of service offered at each segment of the network, which delivers a valuable tool for the user and carrier to isolate faulty sections of the network.

9.0 OTN Equipment

There are several different types of optical transport network equipment being deployed, based on the OTN standards. The most common types include:

- Regenerators,
- OTN terminal equipment,
- Optical Add/Drop Multiplexer (OADM),
- Reconfigurable Optical Add/Drop Multiplexer (ROADM),
- Optical cross connect (OXCs).

OTN terminal equipment is used for point-to-point connections through WDM networks, mapping the client signals into OPUs, sometimes multiplexing multiple signals in the electrical domain, and finally performing mapping/multiplexing in the optical domain.

OADMs, OXCs, and some types of regenerators primarily process the OTN signals in optical domain.

In recent years, Reconfigurable OADMs (ROADMs) have become popular. The key building blocks of today's ROADM node can be categorized into three primary functions:

- Wavelength add/drop filters or switches
- Dynamic power control and remote monitoring capabilities at the optical layer
- Optical service channel termination and generation.

10.0 Future of OTN

OTN basically integrates the best features of the two main transport technologies currently in use across the globe – SONET/SDH and WDM. It is intended to provide robust management features of SONET/SDH and at the same time support the bandwidth intensive transport networks of WDM. Thus OTN delivers management functionality to WDM networks – functionality so long deprived to the WDM network. OTN is compatible to both these legacy transport technologies and provides full transparency of existing communication protocols such as IP, PoS, GFP, etc. The implementation of FEC and TCM enable OTN to evolve as the most efficient, cost effective, and most attractive transport network solution.

11.0 Conclusion

With 3G services and 4G services in the offing, network operators anticipate encountering a crunch situation to handle the emerging traffic. Further, the launch of WiMAX may further aggravate the problem. Under such an emerging scenario, network operators expect their network to be capable of handling astronomical amount of traffic and to manage the traffic effectively and efficiently. SDH/SONET provides strong management capability but suffers from bandwidth restrictions. WDM, on the other hand, provides sufficient bandwidth but suffers from poor management aspects.

Integration of these technologies offers a solution to the problem, as it will involve providing integrated services on a common network infrastructure. Thus, a new transport technology is required to provide a converged transport solution for TDM as well as packet-based services. The OTN technology introduces such a solution, while offering flexibility for new services as well. Additionally, OTN provides an operator compatibility, scalability, and transparency in the network. Since OTN employs the existing infrastructure, network operators will find this technology offering low cost of ownership as well.

OTN Standards and References:

1. ITU-T Rec. G.709 - Network Node Interface for the Optical Transport Network (OTN)
2. ITU-T Rec. G.798 - Characteristics of optical transport network hierarchy equipment functional blocks
3. ITU-T Rec. G.8251 - Control of Jitter and Wander within OTN
4. ITU-T Rec. G.871 - Framework for optical transport network
5. ITU-T Rec. G.872 - Architecture of Optical Transport Networks and Recommendation
6. ITU-T Rec. G.873 - Optical Transport Networks Requirements
7. ITU-T Rec. G.873.1- OTN Linear Protection
8. ITU-T Rec. G.874 - Management aspects of the Optical Transport Network elements
9. ITU-T Rec. G.874.1 - OTN protocol neutral management information model for the network element view.
10. ITU-T Rec. G.875 - OTN management information model for the network element view.
11. ITU-T Rec. G.959.1 - OTN physical layer interfaces
12. www.innocor.com
13. www.jdsu.com
14. www.ciena.com
15. www.exfo.com

Important Activities of TEC during December 2009 to March 2010

New /Revised GRs/IRs

- GR on Unified Threat Management,
- GR on Interactive Voice Response System,
- GR on e-Commerce,
- GR on Firewall System, GR on Call Centre,
- GR on V 5.2 Interface, GR on SIP Terminal,
- GR on Integrated Access Device,
- GR on IMS TISPAN Architecture,
- IR for Switching Node with network to Network Interface (NNI) at 2048Kbits/s,
- GR on Fraud Management and Control Centre, GR on Subscriber Identity Module,
- GR on Universal Subscriber Identity Module,
- GR on Small Size Base Station Sub System,
- GR on MPLS-TP Based Carrier Ethernet Network (CEN) for Access Network Applications,
- GR on MPLS - TP Based Carrier Ethernet Network (CEN) for Metro Aggregations Network Applications,
- GR on Next Generation SDH Analyser,
- GR on 40/80 Channel DWDM equipment with channel bit rate up to 40G,
- GR on Optical Splice Closure for Optical Fibre Cables,
- GR on PON OTDR (Type-A) for FTTH Applications
- GR on PON OTDR (Type-B) for FTTH Applications,
- GR on PON Power Meter for FTTH Applications
- GR on OTDR (Type-I) for long haul Applications,
- GR on Fibre Distribution Frame,
- GR on IP over Satellite Network,
- GR on Termination Box for Optical Fibre Cables,
- GR on OTDR (Type-II) for long haul Applications,
- GR on Fibre Termination & Distribution Box for FTTH Applications,
- GR on Digital Circuit Multiplication Equipment (DCME) with 20:1 gain,
- GR on Frequency Counter (10Hz to 18GHz),
- GR on Frequency Counter (10Hz to 40GHz),
- GR on Spectrum Analyser (1 MHz to 3 GHz),
- GR on RF Power Meter (50 MHz to 40Ghz),
- Standard on Environmental Testing of Telecommunication Equipment –QM-333,
- GR on Microduct for FTTH Applications,
- GR on Electronic Telephone Instrument,
- GR on Video Ringback Tone,
- GR on ENUM Server,
- GR on Video Surveillance Platform,
- GR on Internet Data Centre.

Approvals issued by TEC during the period Dec. 2009 to March 2010

Interface Approvals..................45
Certificate of Approvals...........14

टी ई सी संचारिका
अप्रैल 2010
भाग 14
अंक 1

दूरसंचार इंजीनियरिंग केन्द्र
खुर्शीद लाल भवन
जनपथ
नई दिल्ली - 110001

Editor : Sunil Purohit, DDG (S) Phone : 23329354 Fax : 23318724 Email : ddgs.tec@gov.in

Mridul Printers - 9868117793