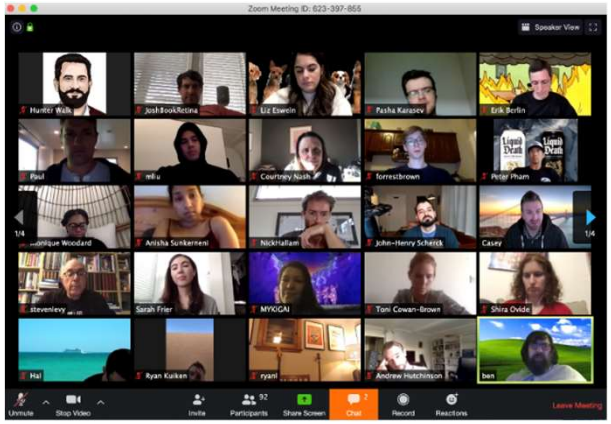
Optical Transport Network

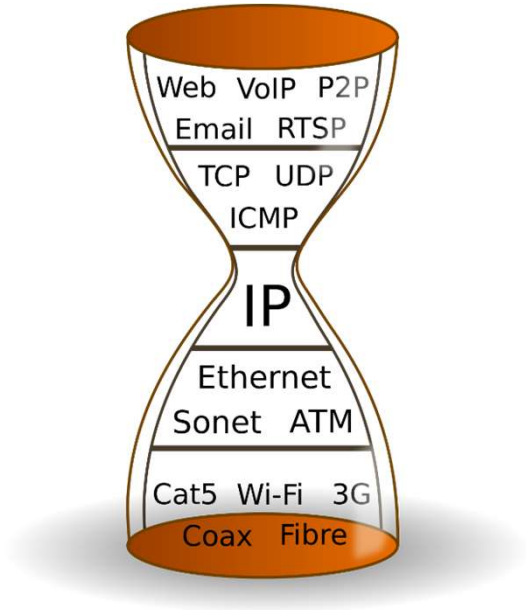
- Key Drivers in the Transition to OTN
- OTN Basics
- OTN Key Benefits

Key Drivers in the Transition to OTN

- Ubiquity of Ethernet and IP-based packet communications
- Insatiable demand for bandwidth

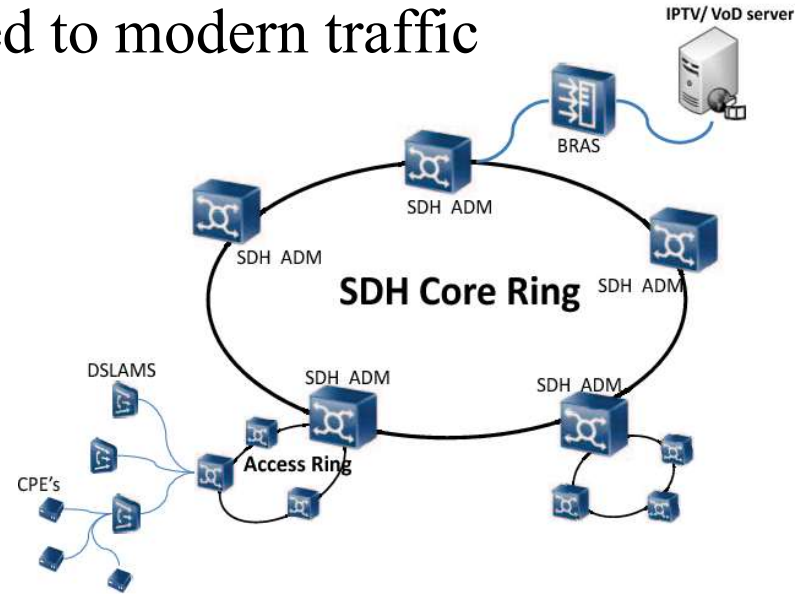
  Nielsen's Law: *high-end user's connection speed grows by 50% per year*





Key Drivers in the Transition to OTN

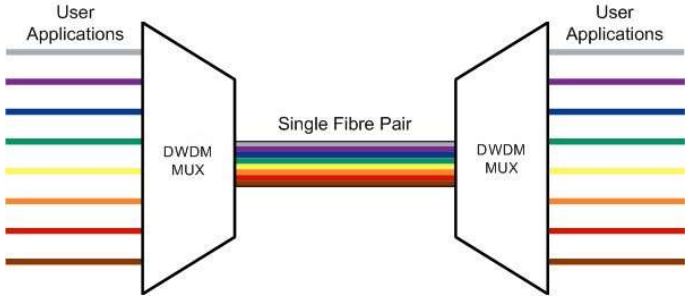
- SDH networks
  - originally designed for voice transportation
  - adaptations developed to map data traffic over it (POS and GFP)
  - SDH equipment becoming obsolete
  - vendors announcing end-of-life for their SDH products
- Need of new transport technology adapted to modern traffic



Key Drivers in the Transition to OTN

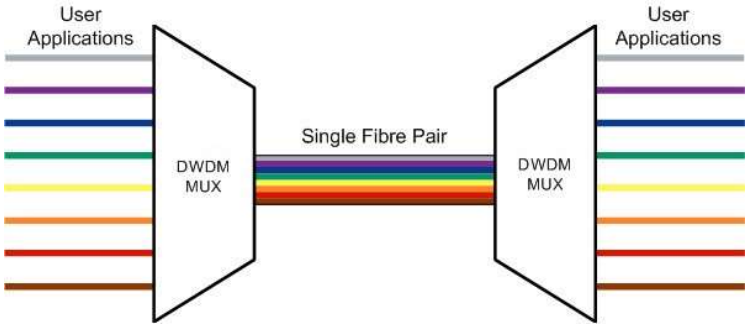
- Wavelength-division multiplexing (WDM) technology
  - first answer to bandwidth challenges and demands of packet-based applications
- WDM provided necessary technology to deliver bandwidth through multiple wavelengths within same fibers
- Meant enormous reduction in cost of bandwidth
- Possibility of carrying multiple applications and services over same physical network

Optical Transport Network – OTN



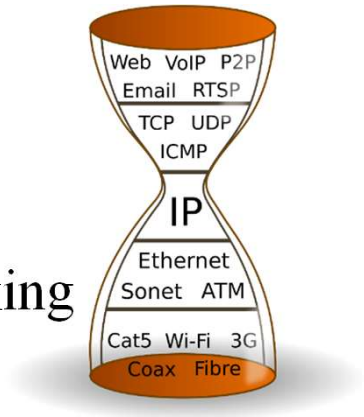
- ITU-T recommendation G.709/Y.1331
- Describes means of communicating data over optical network
- Standardized method for transparent transport of services over optical wavelengths in Dense WDM (DWDM)
- OTN increasingly recognized as the standard to meet ever-increasing demand for bandwidth

Optical Transport Network – OTN



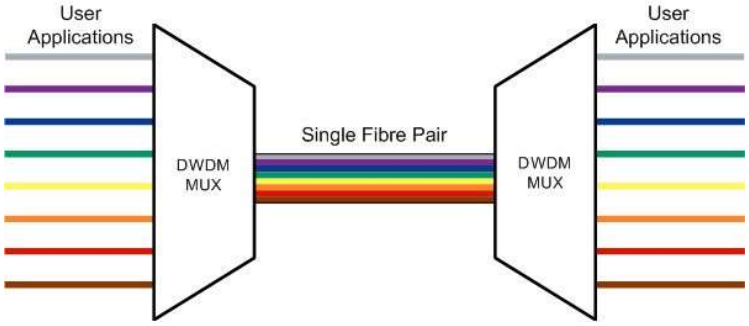
- Provides robust OAM features for WDM networks
- Update in 2009 enhanced to more tightly integrate with Ethernet data rates and packet formats
- OTN and Ethernet are now inseparable in most networks
  - OTN ideal protocol for transport of Ethernet over DWDM
    - e.g., Ethernet between data centers

Optical Transport Network – OTN



- Designed to provide data transport in format native to data networking
  - IP-based traffic mapping into OTN much more efficient than SDH
  - tight integration of IP and OTN via Ethernet is much more appropriate to modern mix of networking protocols and traffic
  - 40 Gbit/s line rate cap of SDH (STM-256) no longer barrier to data rate increases
- Allows carriers and service providers to evolve to mesh overlay
  - combining SDH, Ethernet and OTN payloads
  - providing effective means to build modernized infrastructure but still carry legacy traffic

What makes OTN Essential

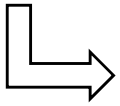


- Only optical technology defined to encapsulate high-capacity payloads needed by packet-network entities
  - E.g. Ethernet switches and routers
- Only optical transport protocol that scales beyond 40 Gb/s
  - OTN highest container (OTU4) can accommodate 100 Gigabit Ethernet
- Plays key role in making network open and programmable

OTN Basics – Differences with respect to SDH

OTN	SONET/SDH
Asynchronous mapping of payloads	Synchronous mapping of payloads
Timing distribution not required	Requires tight timing distribution across networks
Designed to operate on multiple wavelengths (DWDM)	Designed to operate on multiple wavelengths
Scales to 100 Gb/s (and beyond)	Scales to a maximum of 40 Gb/s
Performs single-stage multiplexing	Performs multi-stage multiplexing
Uses a variable frame size and increases the frame size as client size increases	Uses a fixed frame rate for a given line rate and increases frame size (or uses concatenation of multiple frames) as client size increases
FEC sized for error correction to correct 16 blocks per frame	Not applicable (no standardized FEC)

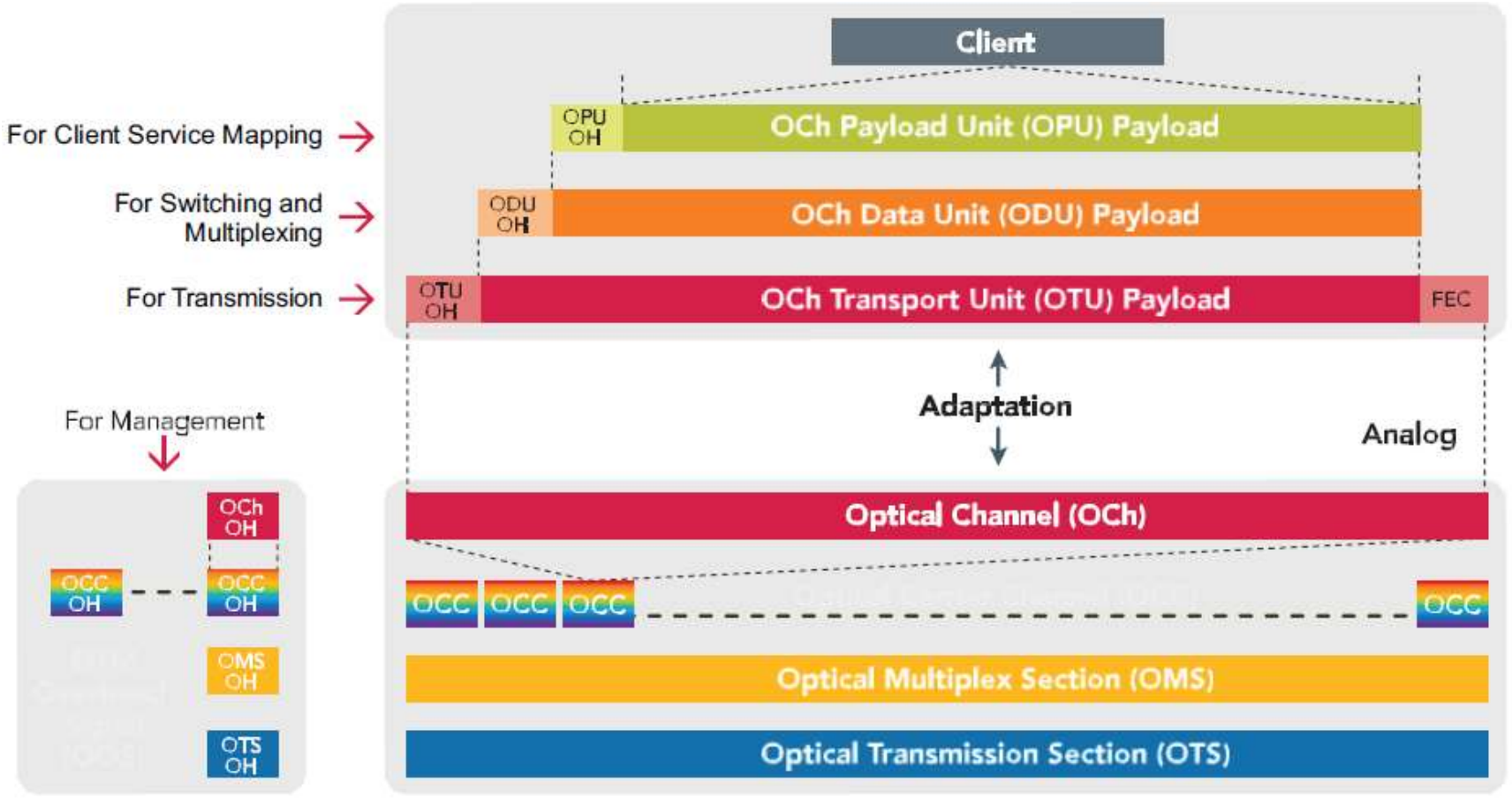
Standardized FEC



OTN Basics

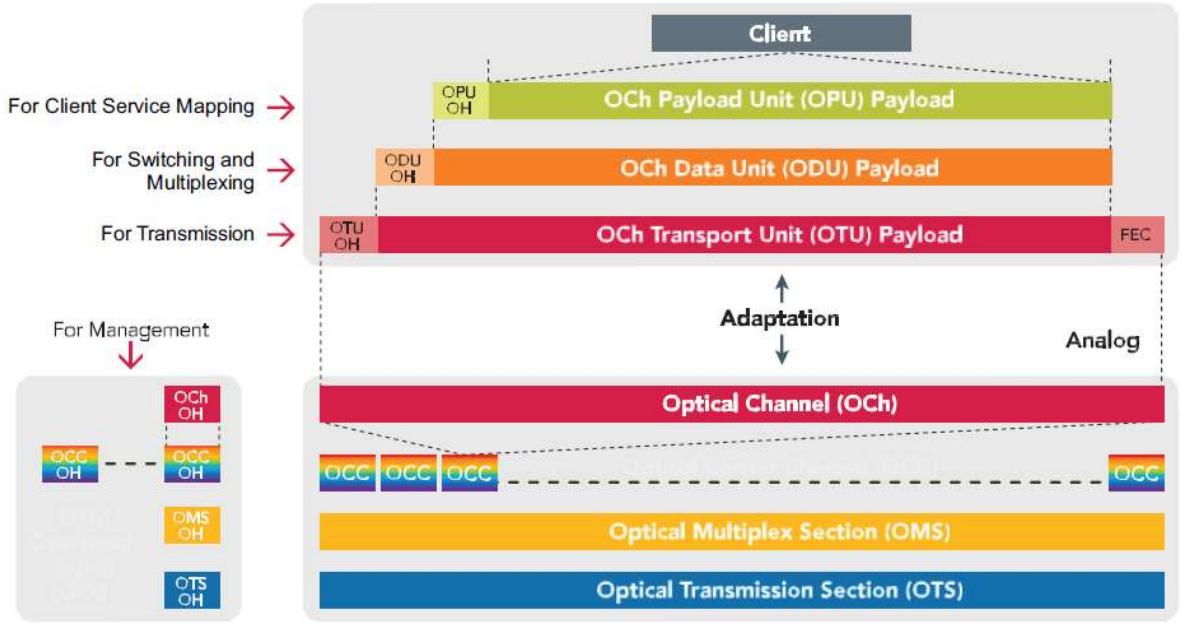
- G.709 standard defines the following functions:
  - Client payload encapsulation
  - OAM overhead → used to manage network resources and services
  - Forward Error Correction (FEC) → extend distance between repeaters
  - Multiplexing Hierarchy
- Together, deliver robust and manageable optical transport capabilities as in SDH with greater suitability for current traffic demands

OTN Basics – Optical Transport Module (OTM)



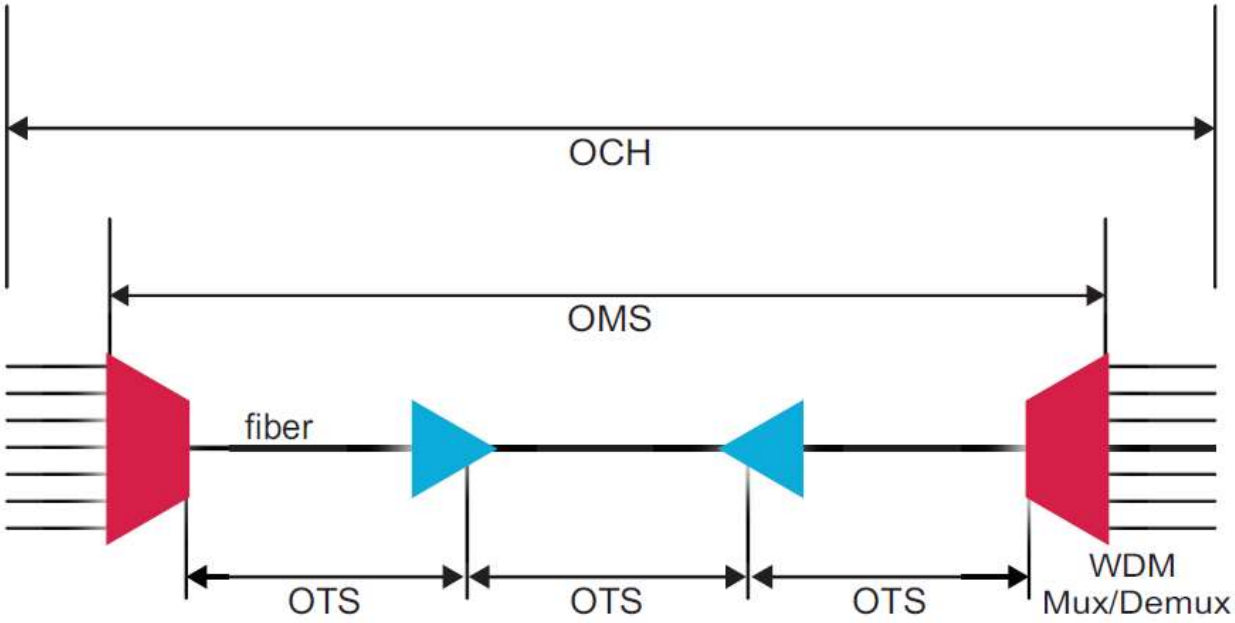
Structure transported across the optical line interface

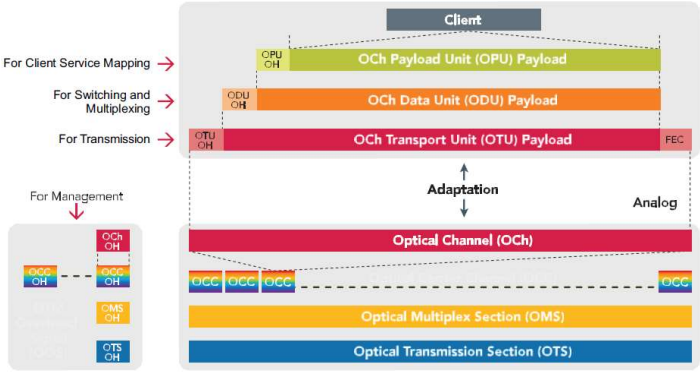
OTN Basics – Optical Transport Module (OTM)



- **Client**
  - e.g., SDH, Ethernet, etc.
- **OPU**
  - contains payload frames
- **ODU**
  - contains OPU plus overhead
- **OTU**
  - contains ODU plus section overhead (equivalent to SDH) plus FEC
- **Adaptation**
  - maps OTU into a wavelength and the Optical Channel (OCh)

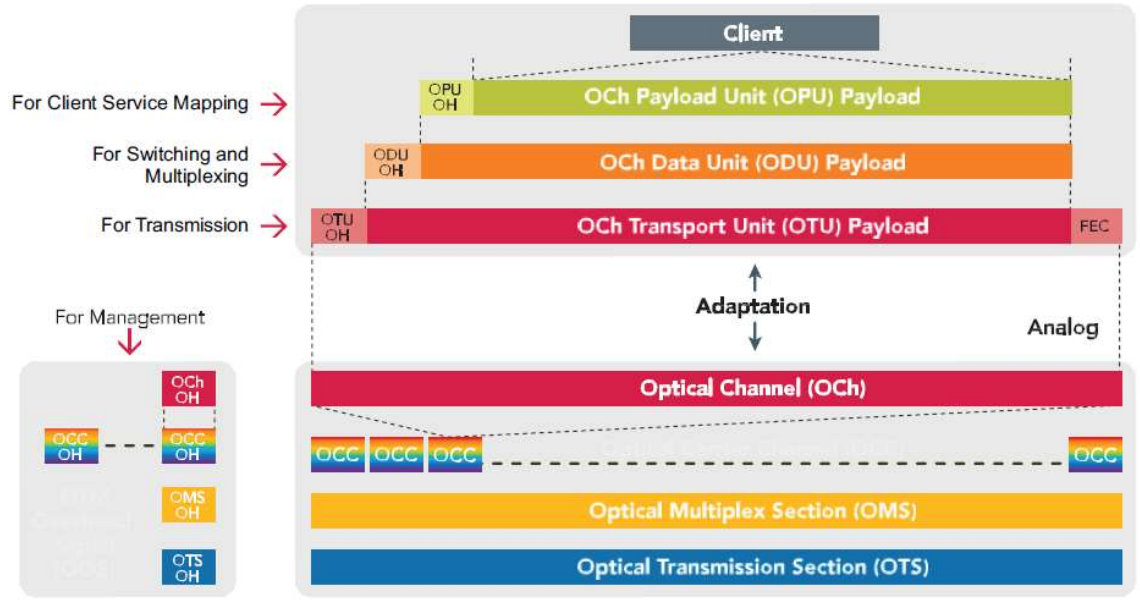
OTN Basics – Optical Transport Module (OTM)





- **Optical Multiplex Section (OMS)**
  - sits between two devices and can multiplex wavelengths onto a fiber
- **Optical Transmission Section (OTS)**
  - fiber between anything that performs optical function on the signal

OTN Basics – Bit Rates



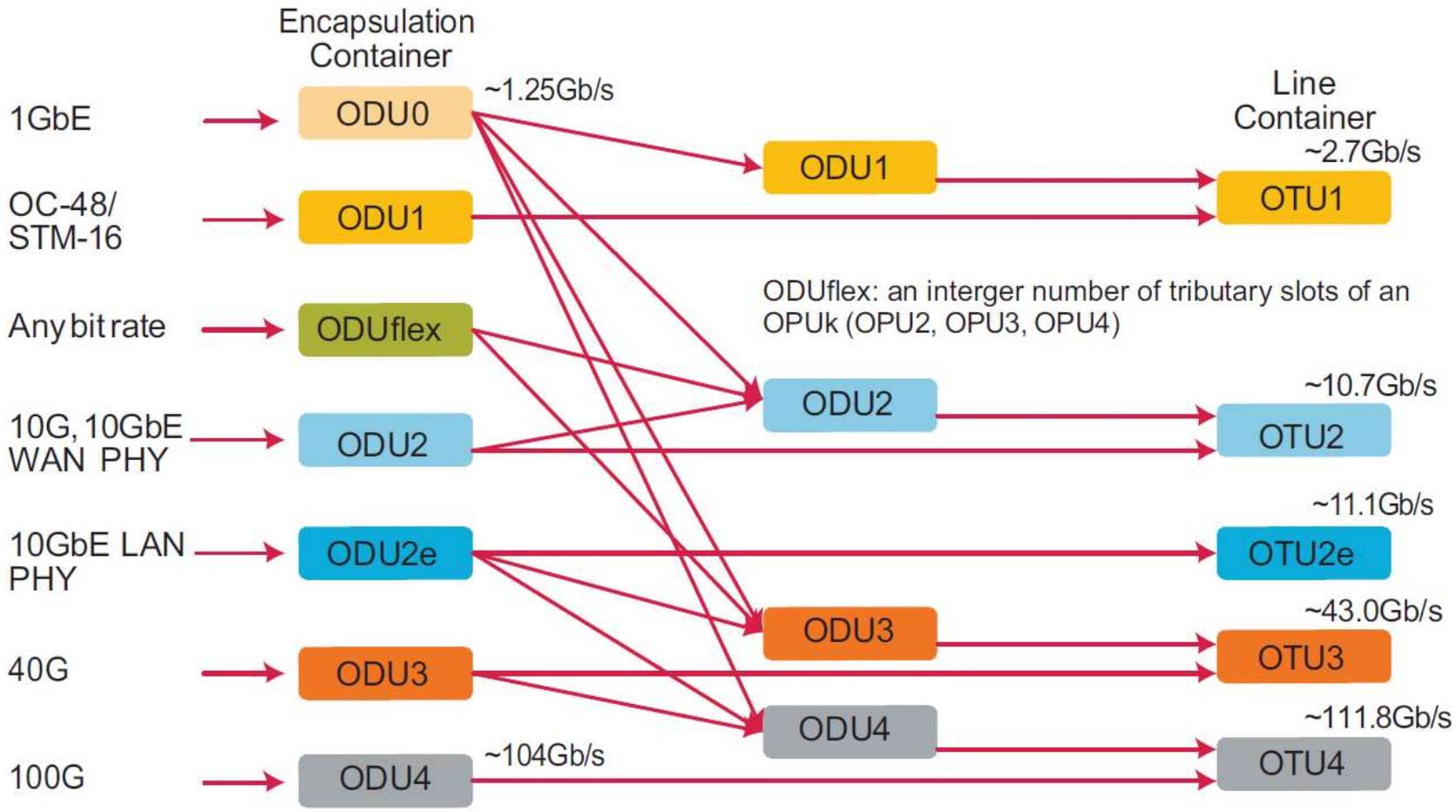
- OTN rates equal to or higher than bit rates of client traffic
- Two types of mappings into ODU defined
  - transparent – maps complete client payload into ODU (OTN rate higher than Client rate)
  - non-transparent – mapping removes some client signal overhead to conserve network capacity

OTN Basics – Standard Line Bit Rates

Signal	Approximate data rate (Gb/s)	Optimized for
OTU1	2.66	SONET OC-48 or SDH STM-16 signal transport
OTU2	10.70	SONET OC-192 or SDH STM-64 or 10GbE Wide Area Network (WAN) physical layer (PHY) transport
OTU2e	11.09	10GbE Local Area Network (LAN) PHY transport (for IP/Ethernet switches/ routers ports) at full line rate (10.3 Gb/s)
OTU3	43.01	SONET OC-768 or SDH STM-256 or 40GbE signal transport
OTU3e2	44.58	Transport of up to four OTU2e signals
ODU4	112	100GbE signal transport

OTN Basics – Multiplexing Hierarchy

Supports single- and multi-step multiplexing into higher containers at ODU



OTN Basics – Frame Structure

- FAS – Frame Alignment Signal
- Section Overheads (OUT, ODU, OPU)
- FEC – Forwarding Error Correction

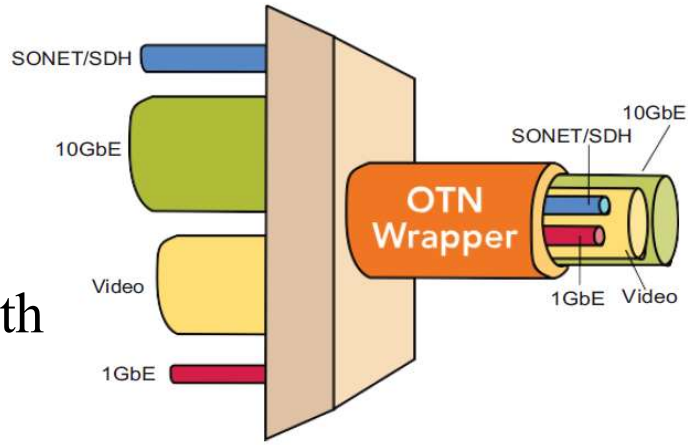
OTN Key Benefits

- **Flexibility in network architecture**
  - preserves existing investments in legacy transport (SDH)
  - supports rapid provisioning for adding services or change existing ones

  (future-proof technology)
- **Inherent Security**
  - OTN-channelized links and hard partitioning of traffic onto dedicated circuits → ensures high level of isolation, privacy and security
  - ability to use encryption at OTN layer (Layer 1)
    - provides high degree of end-to-end security at line rates

OTN Key Benefits

- **Cost optimization**
  - frame structures to transport multiple clients on single wavelength
    - reduces overall cost of transport
    - ensures efficient bandwidth utilization
- **Determinism**
  - dedicated, specific and configurable bandwidth
    - guarantees network capacity
    - managed performance for each client without contention between concurrent services or users



OTN Key Benefits

- **Scalability beyond 100G and 400G**
  - SDH not efficient for Ethernet/IP traffic or high-bandwidth services requiring speeds of 100 Gbit/s or higher
  - OTN efficiently supports high-bandwidth services such as 100G, 400G as well as Terabit payloads
- **Reliability**
  - Connection monitoring capabilities built into technology enable extensive performance monitoring
  - Coupled with built-in capabilities for service protection and fault-tolerance mechanisms as in SDH

OTN Key Benefits

- **Virtualized network operations**
  - capability to provide dedicated virtual circuits to network users enables operators to partition an OTN-switched network into optical virtual private networks (O-VPNs)
  - each O-VPN can provide dedicated, independent network resources to user

References

- Iannone, E. (2012). Telecommunication Networks. CRC Press.
- ITU-T, “Interfaces for the optical transport network”, Rec. G.709/Y.1331, Jun. 2020.
- Paul Littlewood and Earl Follis, “Optical Transport Networking”, Ciena Expert Series, White Paper, 2016.