Power Matters

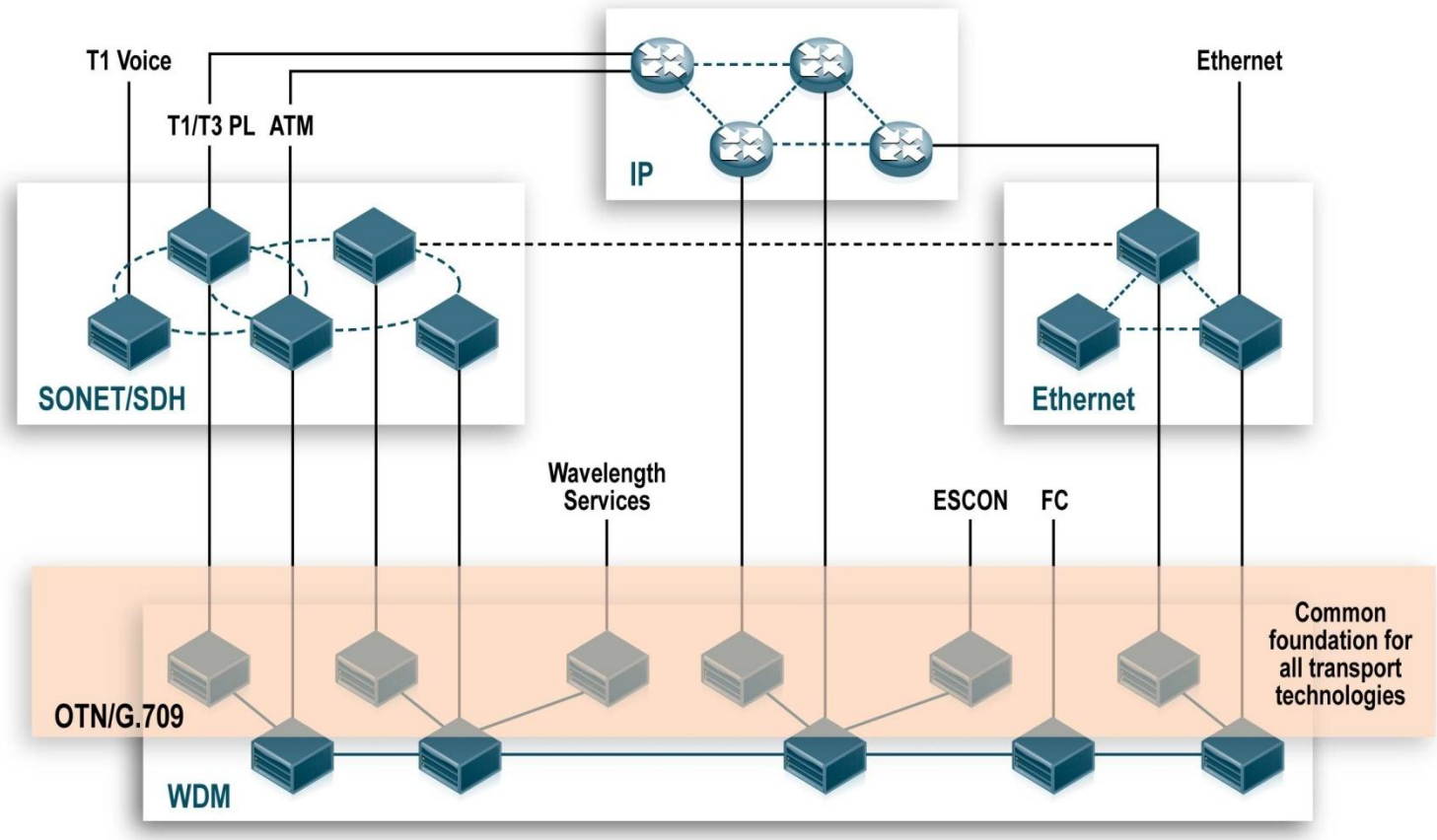
Microsemi

Optical Transport Network

Agenda

- OTN market trends
- Overview of optical transport network
- OTN timing issues
  - Asynchronous link
  - Timing transparency
  - Gapped clock generation and filtering
- Update on OTN standards

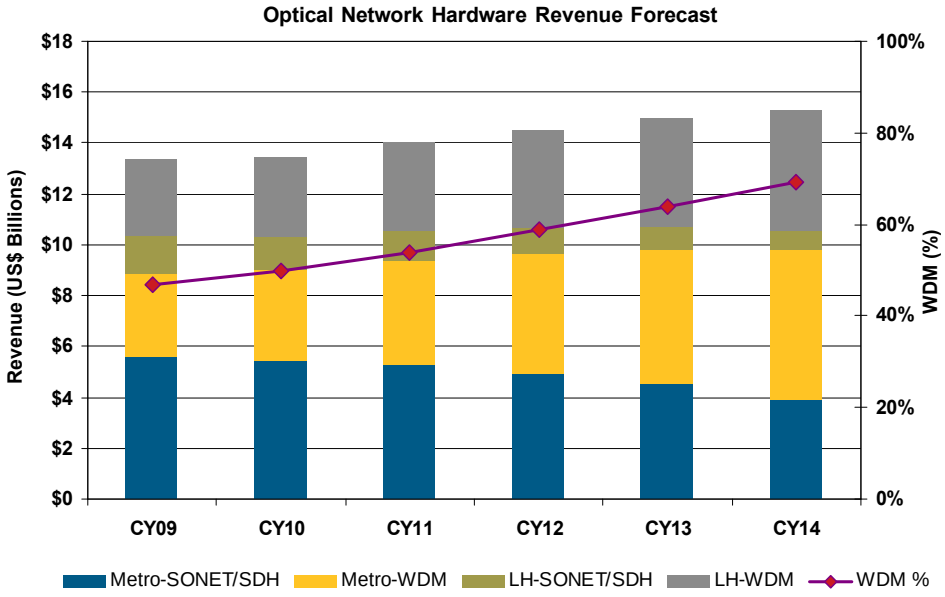
Optical Transport Network

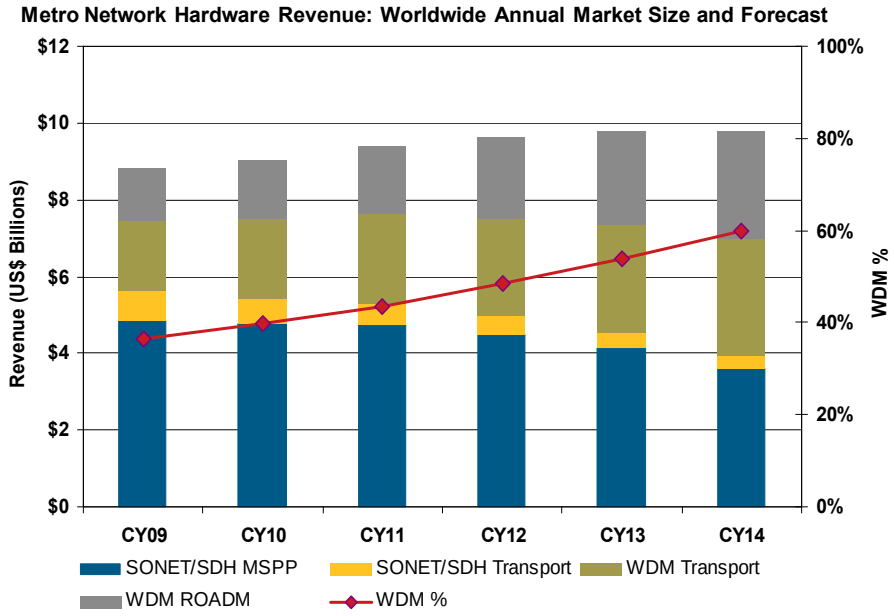


- Changing network traffic mix requires new transport flexibility and transparency
- OTN makes WDM manageable and provides a common foundation

OTN Market Trends

- WDM (OTN) is driving growth in optical network equipment
- Spending on WDM equipment is growing while spending on SONET/SDH equipment is slowing
- WDM spending will be about 70% of total spending in 2014

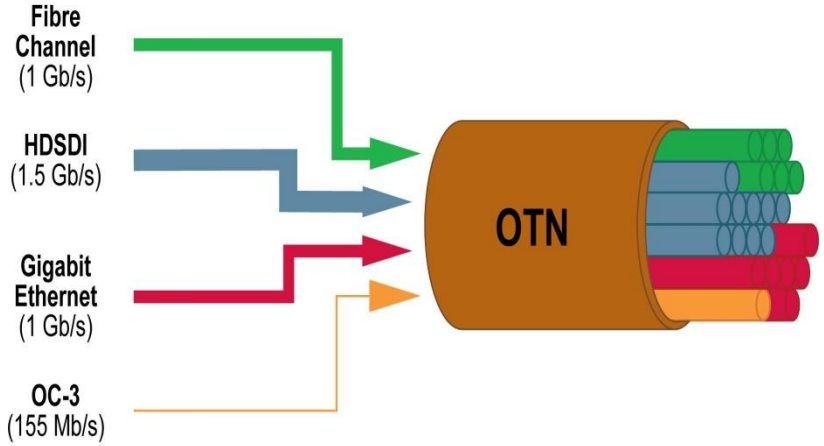




Source: Infonetics Optical Network Hardware, 2Q 2010 (August 2010)

OTN Overview

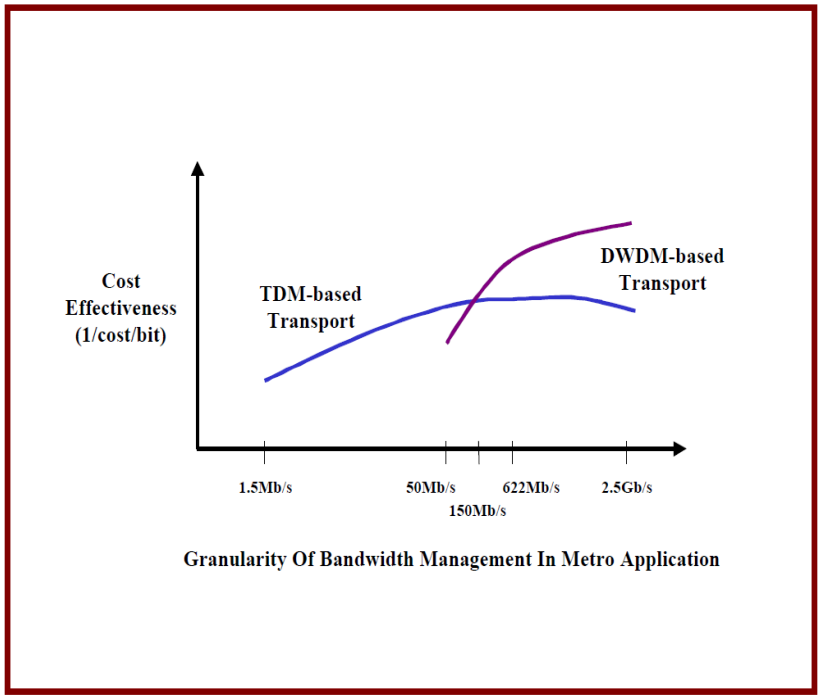
- OTN is a physical layer (Layer-1)
- ITU-T defines OTN as a set of Optical Network Elements (3R) connected by optical fiber links, able to provide the following for the optical channels carrying client signals:
  - Transport
  - Multiplexing
  - Switching
  - Management
  - Supervision and
  - Survivability
- OTN requires new network hardware



OTN Advantage

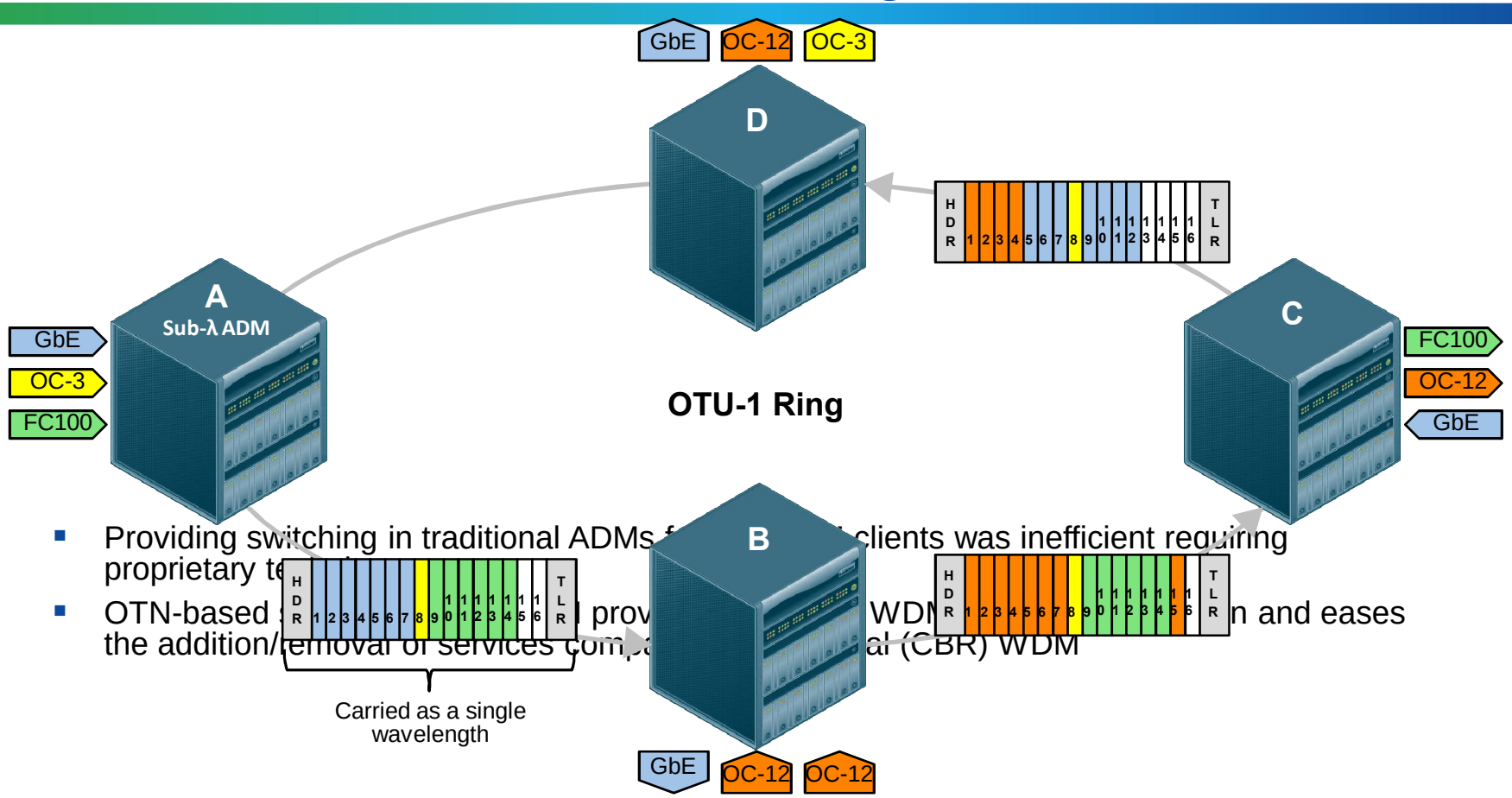
- Enables network convergence
- Reliable
  - OTN recovers from failures in less than 50 ms
  - OTN OAM channel provides functions in support of protection switching, fault analysis and service level reporting
- Interoperable – ITU standard
- Cost-efficient
  - OTN bandwidth aligns well with Ethernet and SONET/SDH rates (small overhead)
  - OTN is Asynchronous, hence it does not carry the costs and complexity associated with the SONET/SDH timing hierarchy
- Flexible
  - OTN can transport storage, SONET/SDH, digital video, Ethernet, and other traffic

OTN Enables the Use of DWDM Cost Efficiencies



Source: Optical Transport Networks – Evolution, Not Revolution, Allen and Rouse

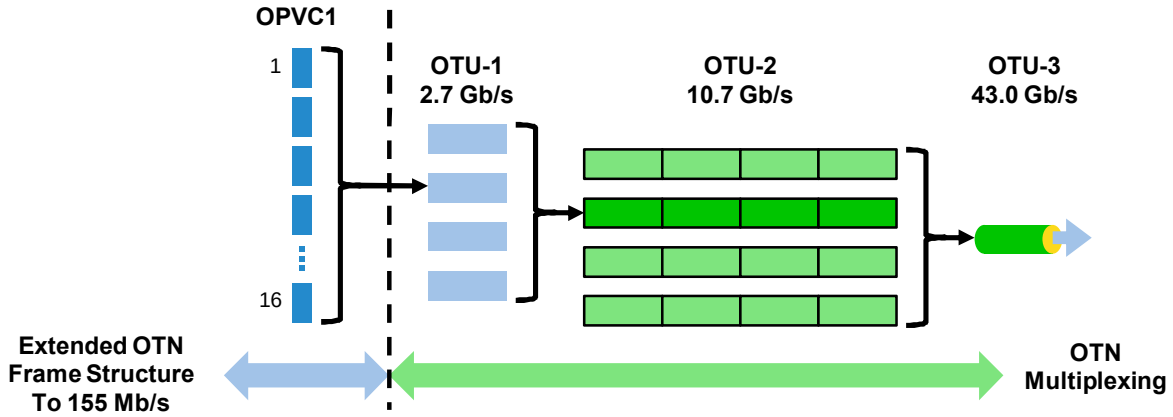
OTN Transport Flexibility



- Providing switching in traditional ADMs f clients was inefficient requiring proprietary te
- OTN-based S l prov WDM n and eases the addition/removal of services com al (CBR) WDM

OTN Line Rates

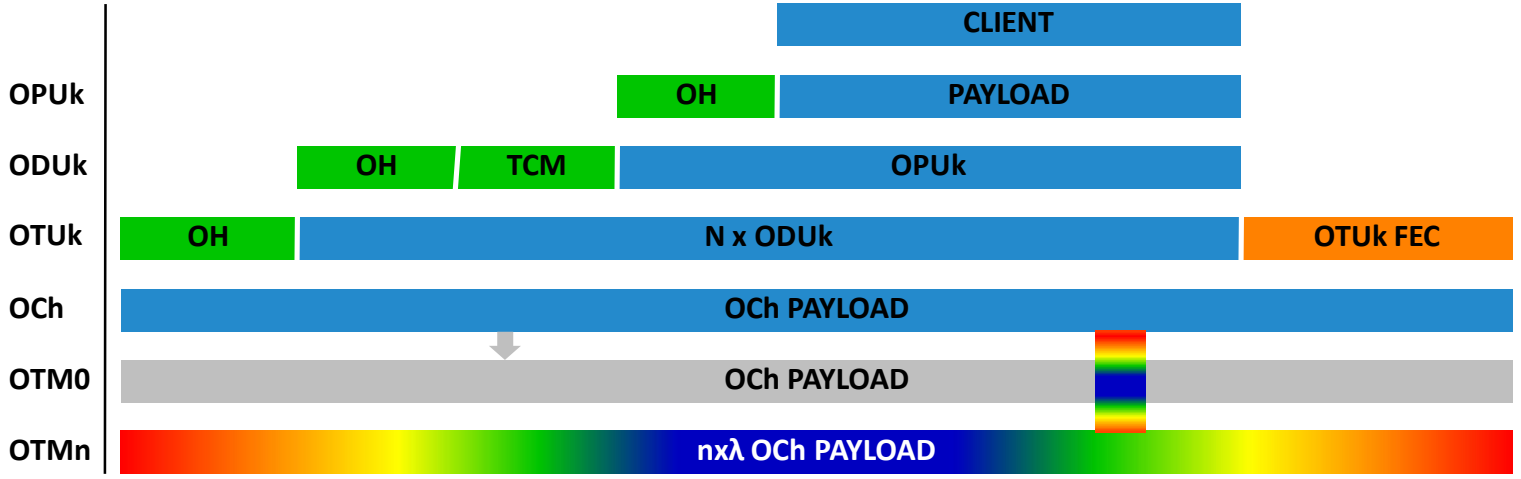
- OTN offers transparent transport of client signals with Forward Error Correction (FEC)
- Client signals are mapped into OTU transport frames
  - Client side interfaces with client signals: SONET/SDH, FC, TDM, Video etc é
  - OTN line side interfaces with the OTN WDM network
- OTU-n
  - OTU1 = 2.488Gbps signal X 255/238
  - OTU2 = 9.9532Gbps signal X 255/237
  - OTU3 = 39.8131Gbs signal X 255/236
  - OTU4 = 99.5328Gbs signal X 255/227



OTN Bit Rates

- **ODU-n**
  - ODU0 = 1.244Gbps signal
  - ODU1 = 2.488Gbps signal X 239/238
  - ODU2 = 9.9532Gbps signal X 239/237
  - ODU3 = 39.8131Gbps signal X 239/236
  - ODU4 = 99.5328Gbps signal X 239/227
  - ODU2e =10.3125Gbps signal X 239/237
  - ODU flex for CBR= Client Signal rate X 239/238
  - ODU flex for GFP= Configured bit rate

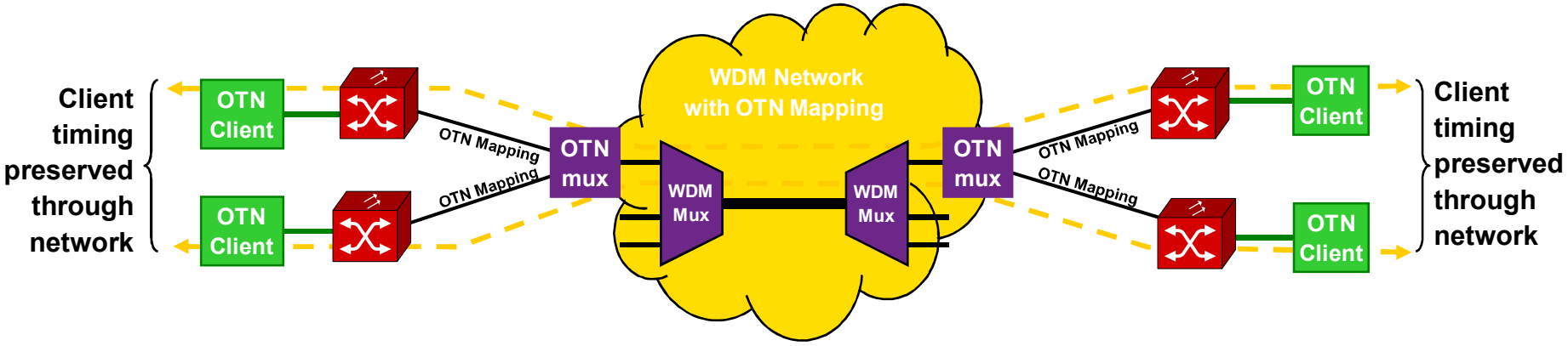
- **OPU-n**
  - OPU0 = 1.244Gbps signal X238/239
  - OPU1 = 2.488Gbps signal
  - OPU2 = 9.9532Gbps signal X 238/237
  - OPU3 = 39.8131Gbps signal X 238/236
  - OPU4 = 99.5328Gbps signal X 238/227
  - OPU2e =10.3125Gbps signal X 238/237
  - OPU flex for CBR= Client Signal rate
  - OPU flex for GFP= ODU flex signal X 238/239



CBR=Constant Bit Rate GFP=Generic Frame Procedure

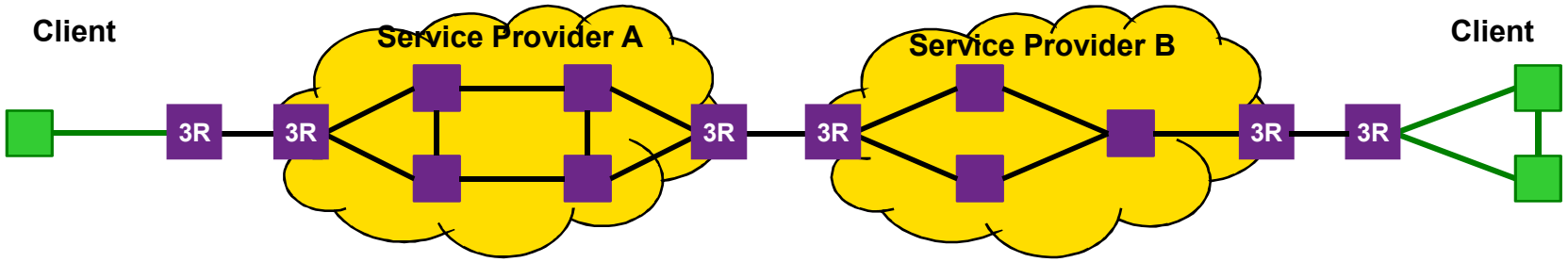
OTN Timing

- OTN physical layer is asynchronous and therefore does not require the sophisticated timing distribution associated with TDM hierarchy
  - TDM timing distribution sophistication relates to the complexity and cost to service providers for maintaining the network reference and timing hierarchy
- OTN includes per-service timing adjustments to carry:
  - Asynchronous services (GbE, ESCON)
  - Synchronous services (OC-3/12/48, STM-1/4/16, SDI)
  - Multiplexed synchronous and asynchronous services into a common wavelength



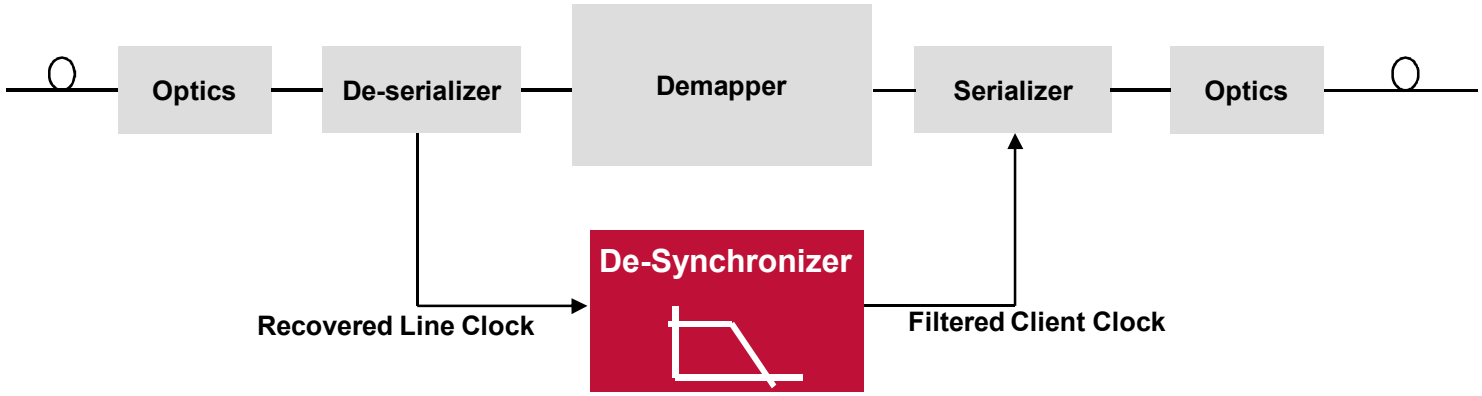
OTN Timing Transparency

- OTNôs transparency enables carrying any service, including SONET/SDH, without interfering with the client timing
- Timing transparency is important for offering wholesale services for third-party providers
- Every OTN network element (Transponder, Muxponder or high order to low order mapper needs to have a de-synchronizer (PLL) with maximum BW of 300Hz
  - When carrying asynchronous clients the de-synchronizer filters jitter introduced by the de-mapping process
  - When carrying synchronous clients the de-synchronizer filters jitter introduced by the de-mapping process and embedded phase information

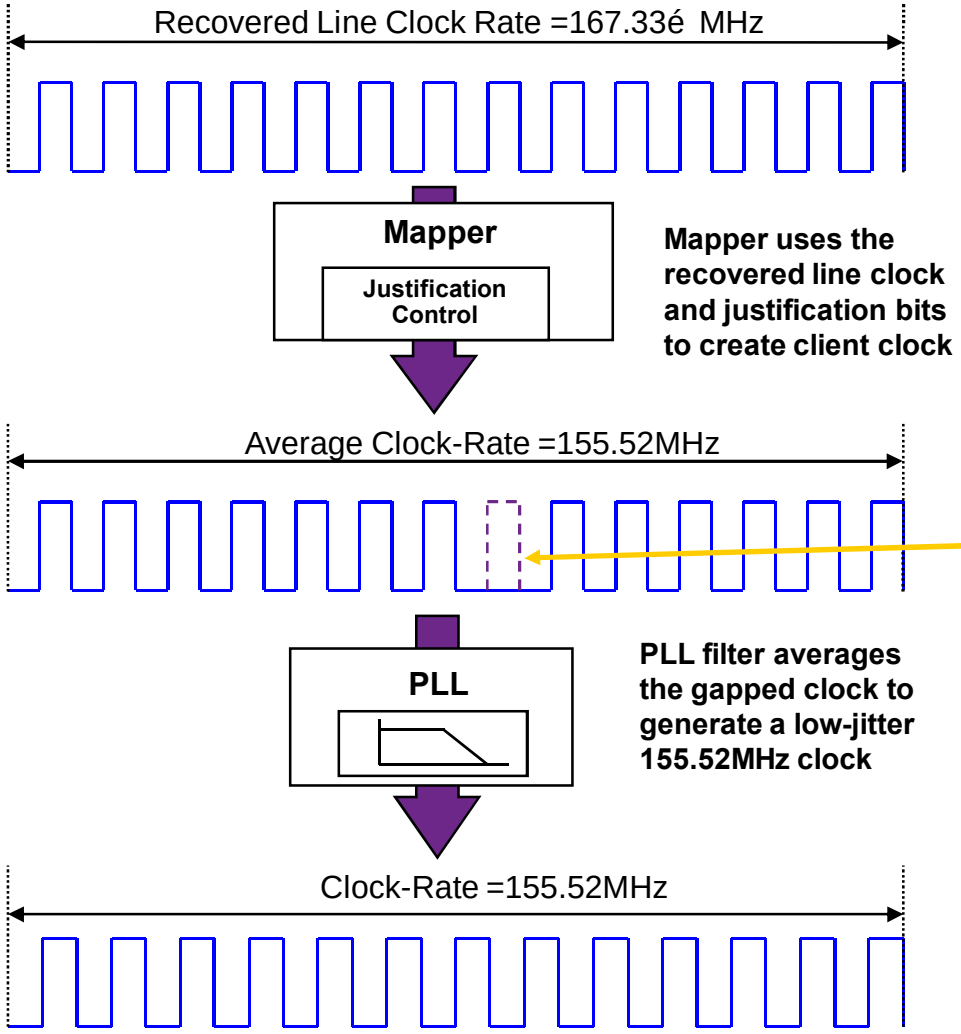


What Enables Timing Transparency!

- OTN network elements ï Transponder, Muxponder or high order to low order mapper need a de-synchronizer
- The de-synchronizer is a PLL with a first order filter with a maximum 3dB cut-off (bandwidth) of 300Hz

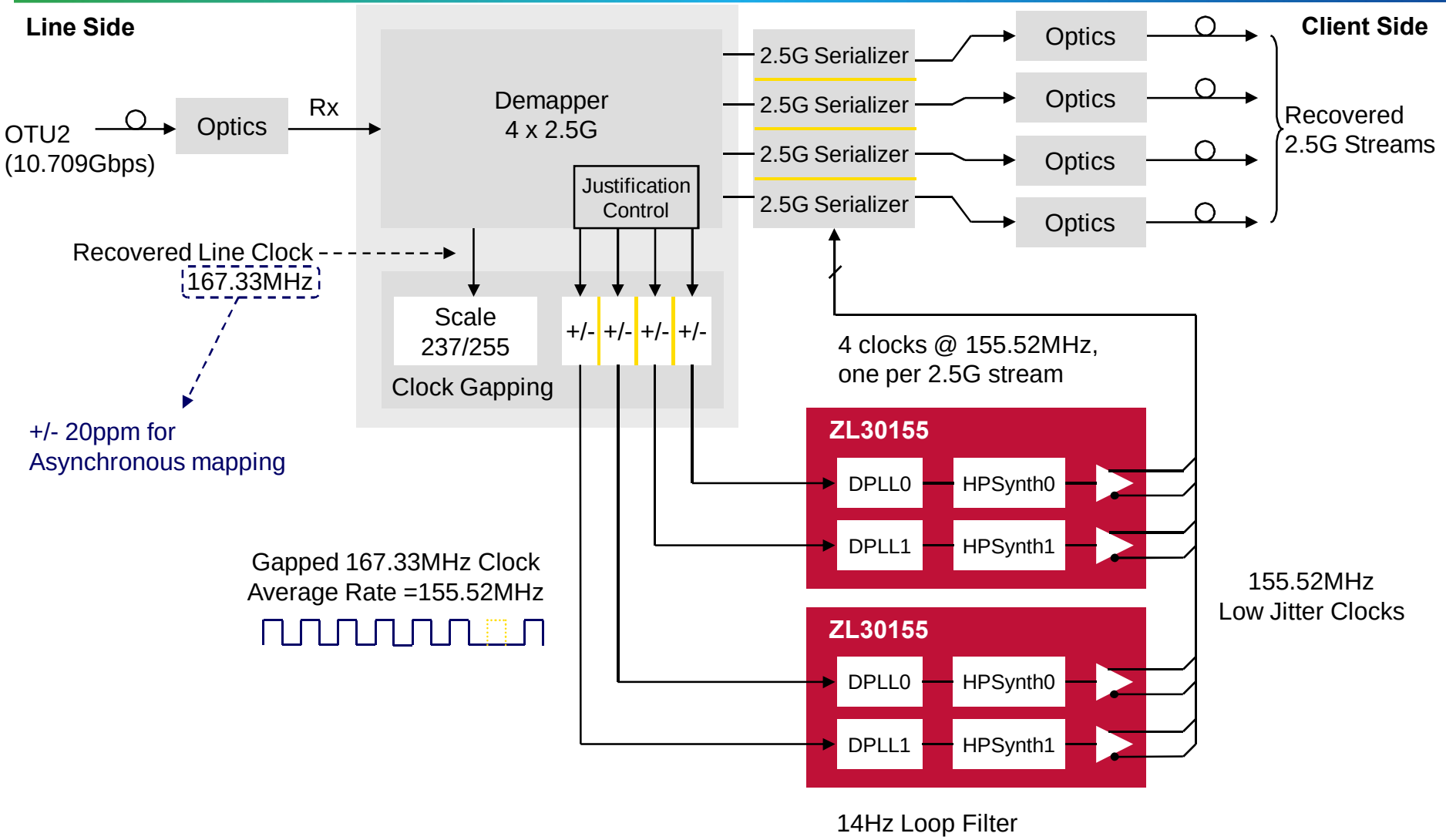


OTN Mapper Generated Gapped Clock

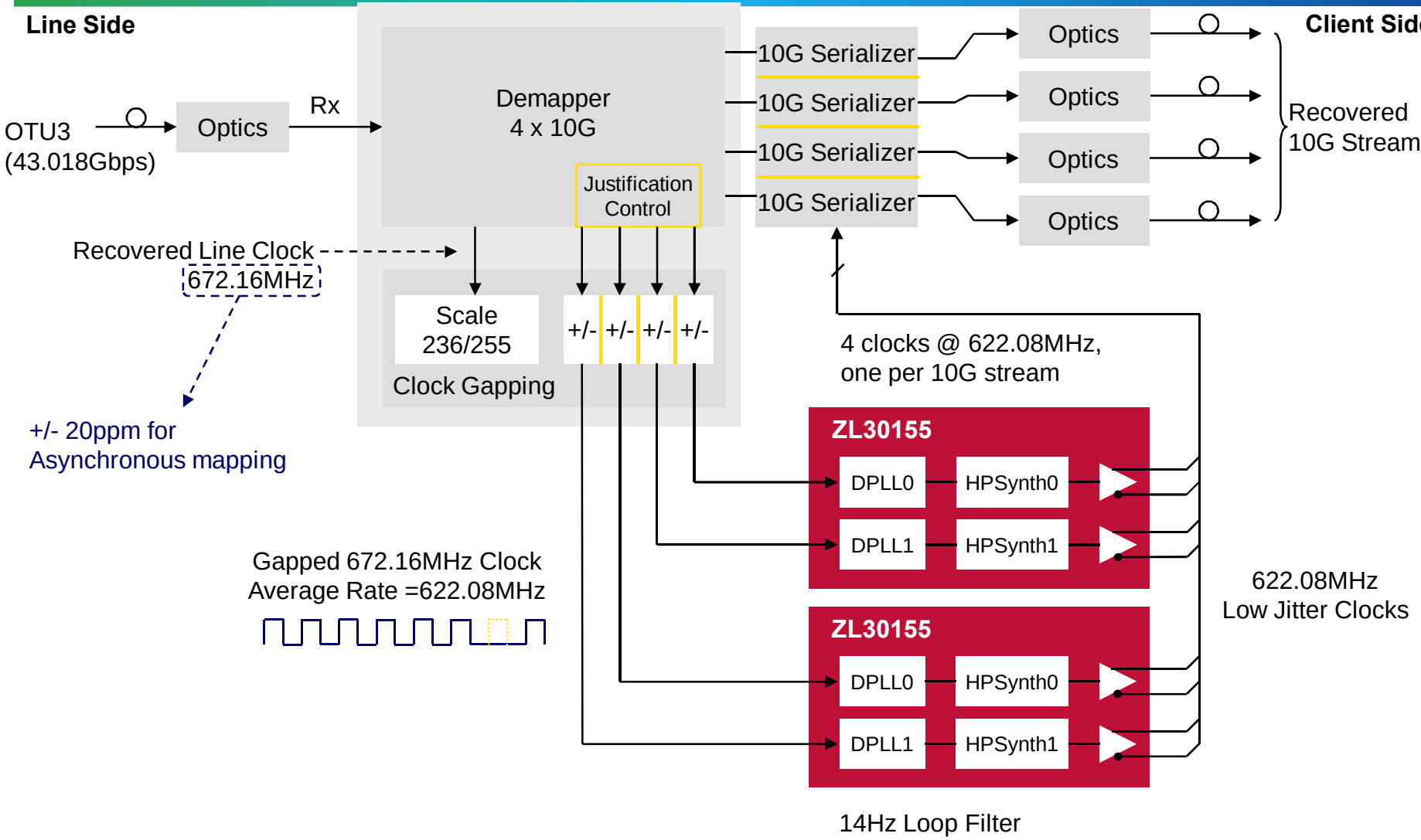


- The mapper creates the client clock rate by deleting pulses from the recovered OTN line rate. Or, the OTN line clock is “gapped” to make the average clock-rate equal the desired client clock-rate
- When the OTN carries an asynchronous client (i.e. FC), clock gaps can be added or deleted to prevent data buffer overflow or underflow conditions
- When the OTN carries a synchronous client (i.e. SDH), clock gaps can be added or deleted based on client associated phase information (justification information)

10G OTN Asynchronous Mapping Application Synchronous Client



40G OTN Asynchronous Mapping Application Synchronous Client



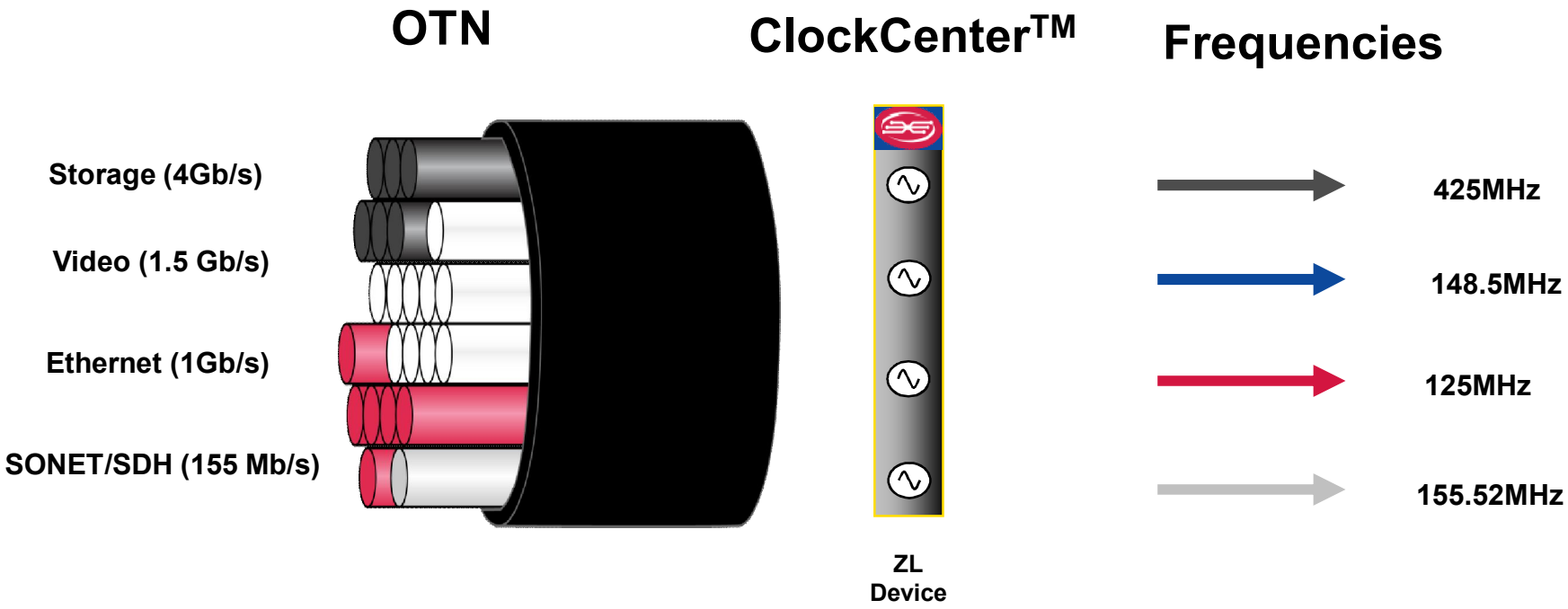
ITU-T OTN Standards Updates

- G.709 : Interfaces for OTN
  - Initial rev 2002, new revision was approved Dec. 2009
- G.798 : OTN Equipment functional characteristics
  - Initial rev 2006. Work in progress for a new revision
- G.8251 : OTN Jitter and Wander
  - Initial rev 2002.
  - Work in progress for a new revision, expected by end of 2010

ITU-T OTN Standards Updates ï G.8251

- Work is focused on OTN de-synchronizer bandwidth (BW) required for compliance to client jitter tolerance limits
  - Å New G.709 has added more 'clients' to OTN, each might need a different BW de-synchronizer, hence the need for a flexible loop BW
  - Å New G.709 has added GE clients supporting SyncE. Simulation presented at the standard shows that with the use of additional embedded phase information the 300Hz de-synchronizer BW can be used, otherwise a lower BW de-synchronizer is needed
  - Å New G.709 has added Video clients over OTN. Initial simulation presented at the standard indicates that these clients will require a loop BW in the 10Hz range (further analysis is needed)

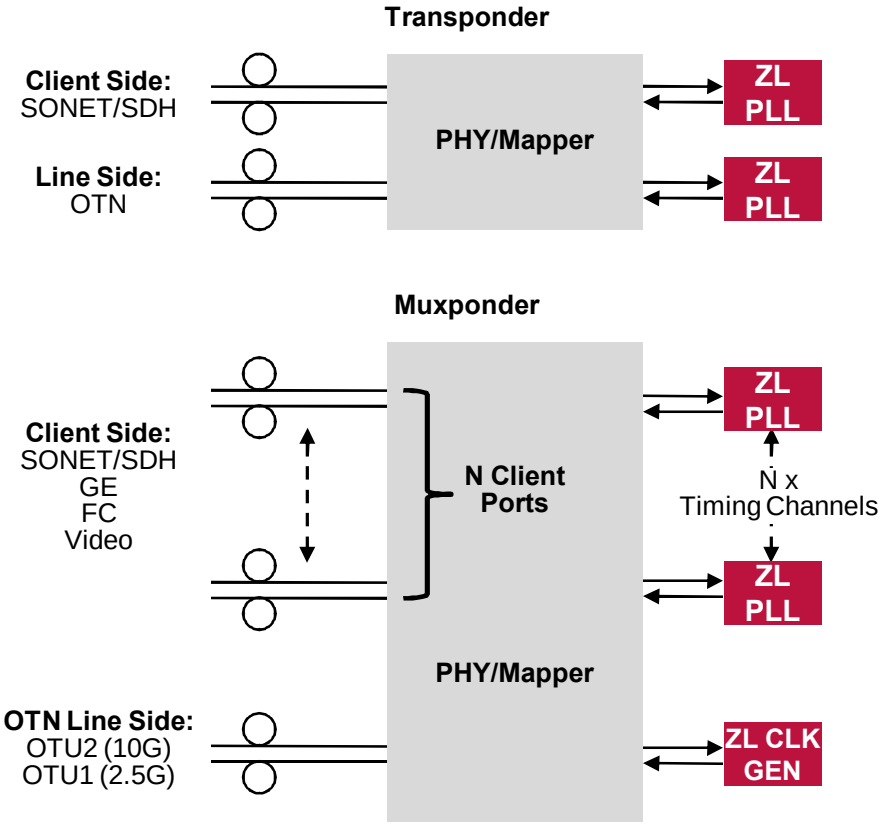
Microsemi OTN Offering



- Carriers deploying OTN to support greatest number of services on least amount of infrastructure
  - ClockCenter™ devices accept & generate any frequency to support any communication service over optical networks
    - Competing solutions require multiple devices to achieve the same flexibility

Microsemi Timing Applications in WDM/OTN

- For OTN equipment, Zarlink PLLs are used for line card timing
  - Clock rate translation from client to line rates
  - One PLL path per client port; clock rate programmability per client port is key



Key Timing Requirements:

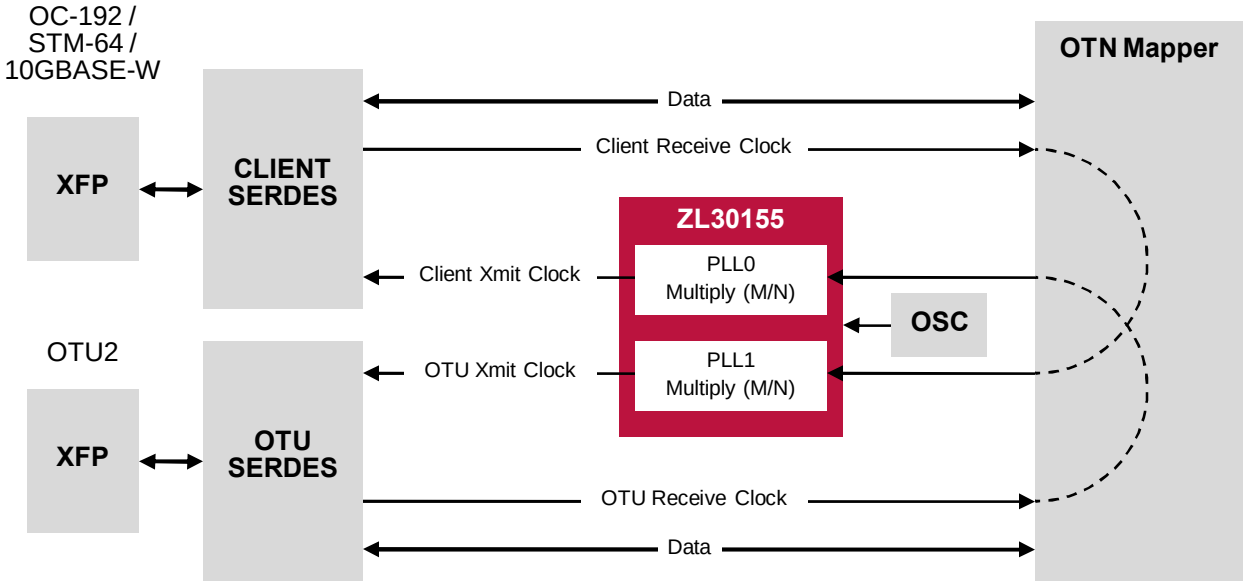
- Clock-rate translation
- Clock-rate programmability
- Low-frequency jitter filtering
- Low jitter generation
- Density
- Hitless reference switching
- Free run capability

Note:

- OTN equipment does not need timing cards (SETS/Stratum 3)
- Some hybrid equipment may use timing cards if they multiplex data into SONET/SDH before muxing into OTU-n frames

OTN Transponder Application

- ZL30155 ï Full duplex timing
  - Low-jitter, rate converted, synchronous clocks
- All clocks are jitter compliant and programmable by application



OTN Muxponder Application

- **ZL30165 – Full quad timing**
  - **Low-jitter, rate converted, synchronous clocks**
- **All clocks are jitter compliant and programmable by application**