

## L1.5VPNs: PACKET-SWITCHING ADAPTIVE L1 VPNs

- What:
  - L1.5VPN is functionally equal to connecting VPN access sites over dedicated L1/O connections to dedicated hub packet switch(es)
  - However, uses more cost-efficient implementation of distributed packet-forwarding at VPN edges and adaptive bandwidth L1 circuits for transport across the VPN
- Why:
  - Achieves in the order of 20:1 reduction in cost-base for premium-quality network connectivity:
    - For instance, L1.5VPN can provide non-oversubscribed packet-switched connectivity among up to 20 10Gbps access points over single 40G wavelength ring
    - Comparable-QoS (equal packet-hop count), non-adaptive L1 based implementations would require a wavelength loop per each access point i.e. 20 wavelengths in total on the same fiber route, plus 2x200Gbps of core packet-switch capacity
- How:
  - L1.5VPN provides a dynamically channelized bus over network to each egress point, with dynamically optimized bandwidth L1 circuit per each ingress access point
  - One such e.g. 10G bus provides same throughput as multiple ingress-point specific point-to-point 10G links, as the destination can only receive at its fixed rate e.g. 10G

## L3/2 VPNs: TECHNOLOGIES FROM ERA OF FIXED L1

- L3/2 VPNs mix unrelated traffic in same L1 connections and packet-switches, to avoid cost of dedicating L1 connection and packet-switch capacity per each contract
    - However, multi-domain packet-switching complicates network equipment and administration
    - ⇒ Increase in unit cost of network capacity offsets gains in utilization efficiency
  - Model for packet-layer shared capacity VPNs developed under *assumption of fixed L1*:
    - Using fixed-bandwidth L1 connections for variable bandwidth packet traffic is inefficient
    - ⇒ Efficiencies sought via stat-muxing unrelated traffic (i.e. hopefully non-correlated traffic from different contracts) in same L1 connections and packet-switches
      - Without over-booking (stat-muxing) L3/2 VPNs not any more efficient than L1 circuits of equal BW
- ⇒ Inevitably, due to laws of physics, such packet-layer sharing of network capacity causes:
- Non-deterministic QoS as performance of one contract affects and depends on other contracts
  - Increased complexity and cost of network technology platforms and OAM
  - On-going security concerns as traffic from unrelated contracts is mixed at packet-layer

- Assumption of semi-fixed L1 has become obsolete:
    - L1 optimization can achieve maximized network utilization efficiency *without doing cross-contract stat-muxing*, thus avoiding drawbacks of sharing capacity among unrelated contracts
    - L1 optimization implemented by OCS via Adaptive-Concatenation of STS-1s, to form adaptive-bandwidth L1 mesh between VPN access points
      - For direct interoperability with existing L2+ switches/routers, access interfaces of the L1.5VPNs are regular unchannelized point-to-point Ethernet/POS PPP links
  - The new reality after introduction of adaptive L1:
    - ✓ Spending money (hard cost) and resources (opportunity cost) in dealing with complexities due to packet-layer sharing of network capacity among unrelated contracts *no longer justifiable*
    - ✓ Efficiency and flexibility benefits of packet-layer shared capacity based VPNs achievable through adaptive L1 based packet-switching VPNs (L1.5VPNs) *at significantly lower cost*
- ⇒ Premium-quality, strictly secure dedicated network services made lower cost than the inferior-quality, packet layer shared capacity based services

## L1.5VPNs - NET-BENEFITS OVER L3/2VPNs

- Simplified, secure and transparent ***single-domain*** packet-forwarding:
  - ✓ Elimination of complexity and security issues of cross-domain addressing and route control
  - ✓ Addressing, e.g. MPLS-TP Labeling, can be automated via NMS-libraries or even down to HW, with same library Label values safely re-usable in any number of contracts in parallel
- Deterministic QoS due to ***true*** isolation between unrelated VPN contracts:
  - ✓ Behavior of any one contract does not negatively impact performance of other contracts
- High QoS due to ***minimization of packet-hop counts***:
  - ✓ VPN edge-to-edge L1 circuits avoid intermediate packet processing
    - ⇒ Minimized jitter via elimination of intermediate packet-buffering and potential points of congestion
    - ⇒ Packet-loss free L1 transport across VPN
- Scalability via ***reduction in packet-processing capacity requirements*** per node:
  - ✓ Need for packet processing at VPN node transport interfaces eliminated
  - ✓ In case of e.g. a node with 2x100G transport ring and 2x10G access IFs, reduction in packet processing capacity costs between L3/2VPN and L1.5VPN node:  $2x(100+10)/2x10$  i.e. 11:1
    - For illustration, see case of 100G transport with 10G access in Backup slides C. (end of presentation)

## L1.5VPNs - NET-BENEFITS OVER L2/1/0 PRIVATE LINES

- Packet-switched mesh connectivity vs. point-to-point transport:
    - ✓ VPN access site can reach to all other sites through even a single L1 connection
    - ✓ Need for packet switch/router hubs eliminated
  - Fully packet-layer transparent connectivity, due to elimination of packet-switching hubs
  - In the order of 20:1 reduction of WDM and core router/switch capacity costs
- ⇒ L1.5 VPNs an effective upgrade for the \$40B+/yr\* leased line service market

*\*Insight Research Private Line and Wavelength Services, 2008-2013*

## L1.5VPNs - MADE FOR GLOBAL BUSINESS

- Profitable network services regardless of customer's geography vs provider's fiber reach
  - L1.5VPNs allow a SP to profitably offer (MPLS) network services globally without having to spend on building, upgrading & operating worldwide MPLS/fiber networks
    - Up to 20:1 reduction in wavelength requirements via adaptive L1 makes it affordable to lease wavelengths from other carriers to connect given customer's worldwide sites
    - L1.5VPNs provide CPE controllable, transparent (e.g. MPLS-TP) packet-switched connectivity among sites connected over L1 capacity pool dedicated for given contract
      - ⇒ Eliminates need for costly core L3/2 routers/switches (e.g. IP/MPLS routers)
- Allows more capital-efficient, lower-risk and higher profitability business model for SPs:
  - Free of upfront CapEx, with direct OpEx (wavelength lease, OAM cost) reduction
  - Avoids having to predict where and how much customers need connectivity
  - Enables moving to customer-contract driven, location-independent business model

## L1.5VPNs - BEYOND ANY CURRENT VPNS

- L1.5VPNs: Premium-quality, dedicated capacity network services at cost lower than compromised-quality, shared capacity services
    - L1 optimization makes using per-contract-dedicated capacity more economical vs. using cross-contract shared capacity
    - The use of dedicated L1 connection and packet-switch capacity provides:
      - ✓ premium quality: deterministic, high QoS and inherent security
      - ✓ minimum administrative overhead costs
        - elimination of need for inter-domain addressing, route control and related security issues
        - self-operating, transparent network
        - straightforward SLAs
- ⇒ **Packet-switching flexibility and efficiency with L1 simplicity.**

## BACKUP SLIDES

- A. L1-optimization in OCS' L1.5VPNs
- B. Adaptive-Concatenation Mux Bus (AMB) --  
the basic construct for Adaptive-Mesh  
architecture of L1.5VPNs
- C. Order of 10:1 reduction in packet processing  
capacity requirements achieved with AMBs



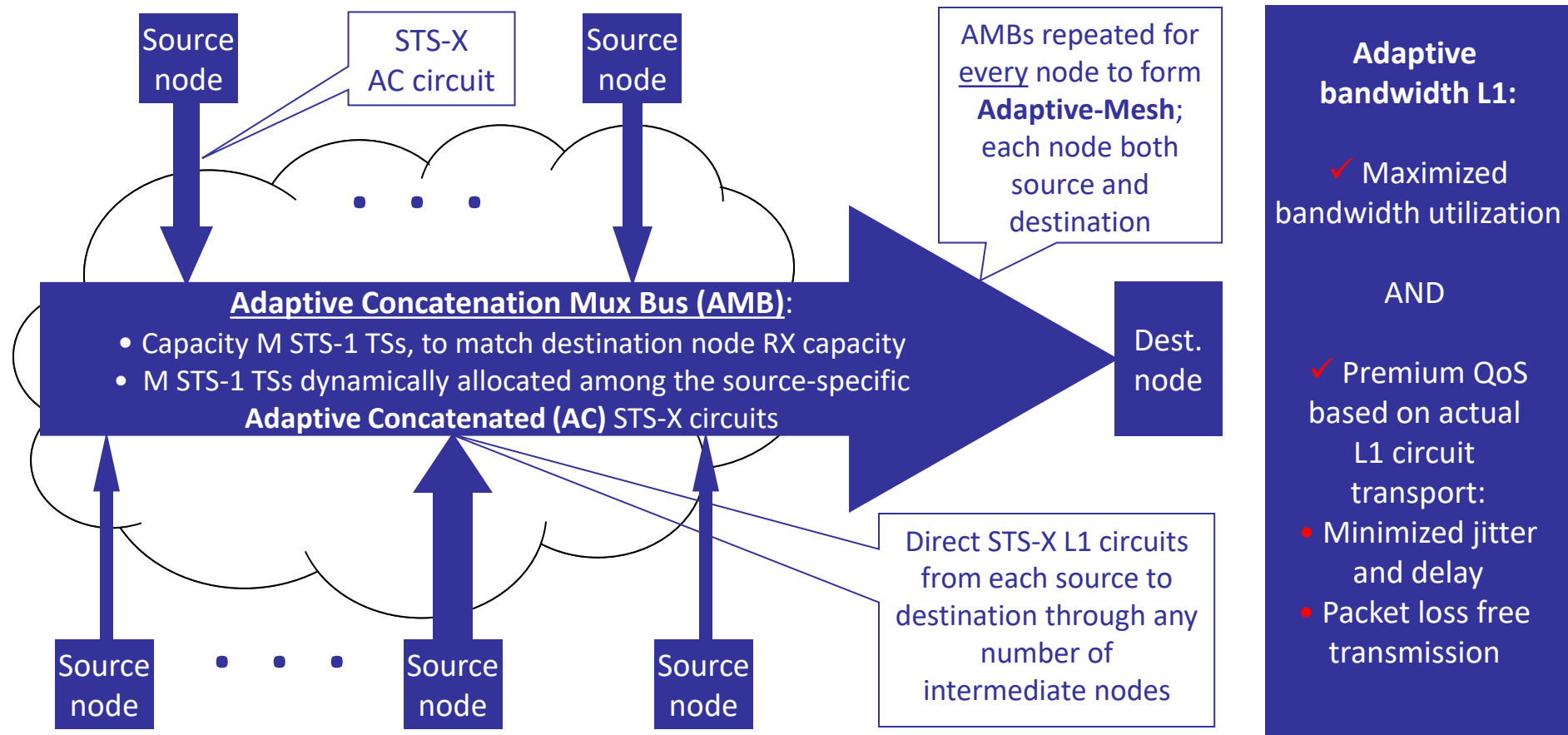
## A. L1 OPTIMIZATION IN OCS' L1.5VPNs

- Adaptive-Concatenation of STS-X timeslots for always-optimized mesh connectivity:
  - ✓ L1 capacity allocation optimization according to traffic load variations
  - ✓ realtime-dynamic
  - ✓ automatic
  - ✓ transparent
  - ✓ overhead-free
- Demonstrably achieves:
  - ✓ maximized bandwidth efficiency
  - ✓ QoS of direct circuit:  
minimized delay, jitter, packet loss free transport
  - ✓ architecturally minimized packet processing requirements via *dynamic L1 by-pass*



## BACKUP SLIDES

B. Adaptive-Concatenation Mux Bus (AMB) --  
the basic construct for Adaptive-Mesh  
architecture of L1.5VPNs



**Adaptive bandwidth L1:**

- ✓ Maximized bandwidth utilization

AND

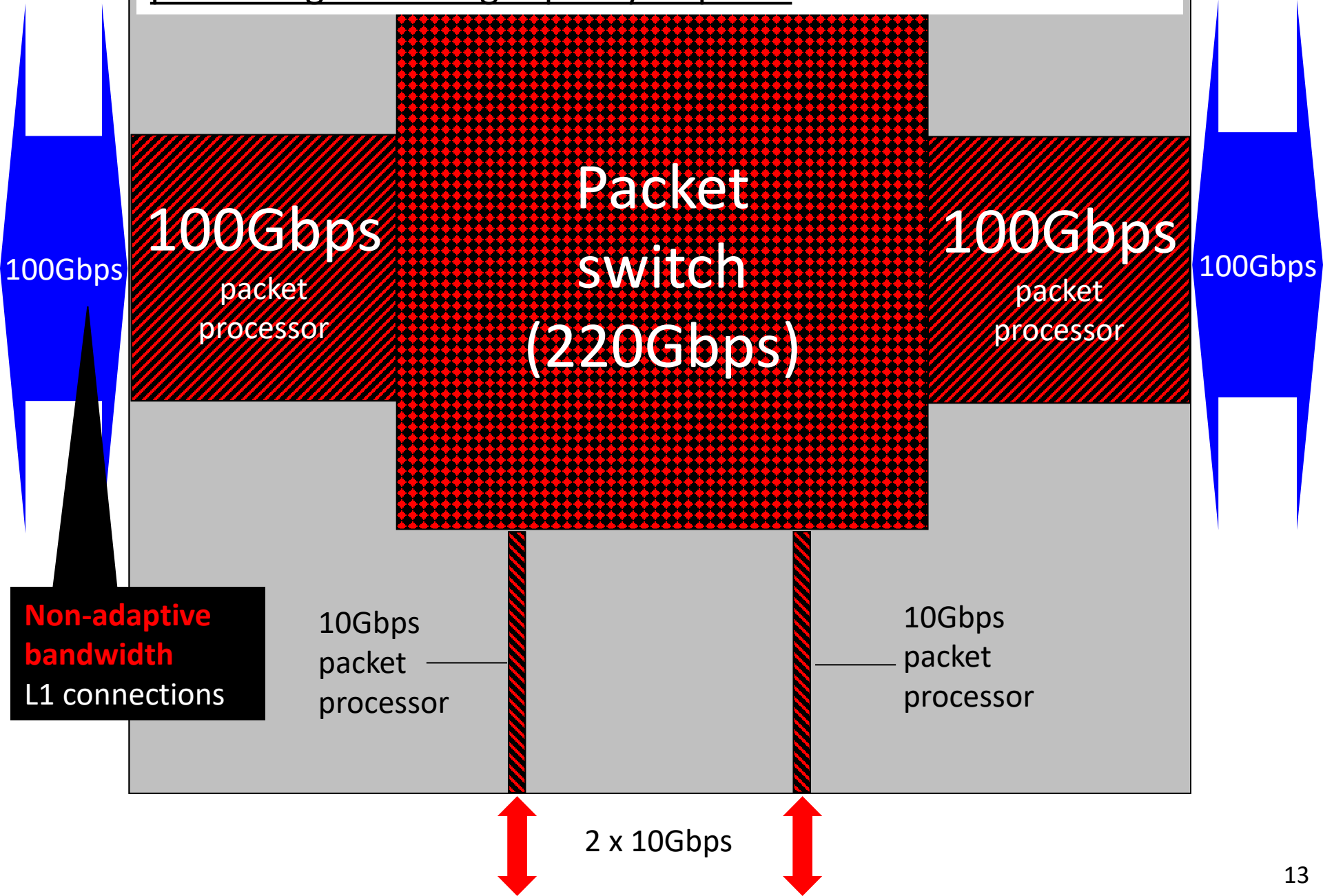
- ✓ Premium QoS based on actual L1 circuit transport:
  - Minimized jitter and delay
  - Packet loss free transmission

- Allocation of timeslots among the AMB sources optimized for every new STS row based on byte inflows from the sources to the destination of the AMB:
    - 72000 optimization cycles/second; capacity allocation unit ~ the size of min. length L2 packet
    - Continuously optimized L1 bandwidth allocation on individual packet / STS-1 row timeslot basis
  - AMBs continuously maximize network traffic throughput, within the constraints of their destination (customer) node RX capacities (e.g. STS-192 AMB for 10Gbps destination RX port):
    - AMBs consume minimum network capacity sufficient to maximize utilization of network egress interfaces
- ➔ **Maximized difference between revenue (throughput) and cost (capacity); maximized network profitability.**

## BACKUP SLIDES

- C. In the order of 10:1 architectural reduction in packet processing capacity requirements achieved with AMBs, while achieving maximized bandwidth efficiency and performance

Regular Packet Switching Node:  $2 \times 100 + 2 \times 10 = 220 \text{Gbps}$  packet processing+switching capacity required



AMB interface unit:  $2 \times 10\text{Gbps} = 20\text{Gbps}$  of packet forwarding capacity required for same access and transport bandwidth:

**10X architectural scalability gain**

- no packet switch; no routing/switching/forwarding tables
- minimized latency, jitter and packet-loss

Ten 10Gbps Adaptive-Concatenation Multiplexer Buses (AMBs)  
on 100Gbps carrier signal:  
Destination node controlled, source specific adaptive bandwidth  
L1 circuits on AMBs

**Adaptive  
bandwidth  
L1 connections**

10Gbps  
packet  
processor

10Gbps  
packet  
processor

2 x 10Gbps



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