L1.5VPNs: PACKET-SWITCHING ADAPTIVE L1 VPNs

- What:
  - L1.5VPN is functionally equal to connecting VPN access sites over dedicated L1/0 connections to 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:
  - <u>Achieves in the order of 20:1 reduction in cost-base for premium-quality network connectivity</u>:
    - 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

⇨ <u>Inevitably, due to laws of physics, such packet-layer sharing of network capacity causes</u>:

- – <u>Non-deterministic QoS</u> as performance of one contract affects and depends on other contracts
- – <u>Increased complexity and cost</u> of network technology platforms and OAM
- – <u>On-going security concerns</u> as traffic from unrelated contracts is mixed at packet-layer

IMPACT OF ADAPTIVE L1 ON VPN ECONOMICS

- 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*

⇨ <u>Premium-quality, strictly secure dedicated network services made lower cost than the inferior-quality, packet layer shared capacity based services</u>

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

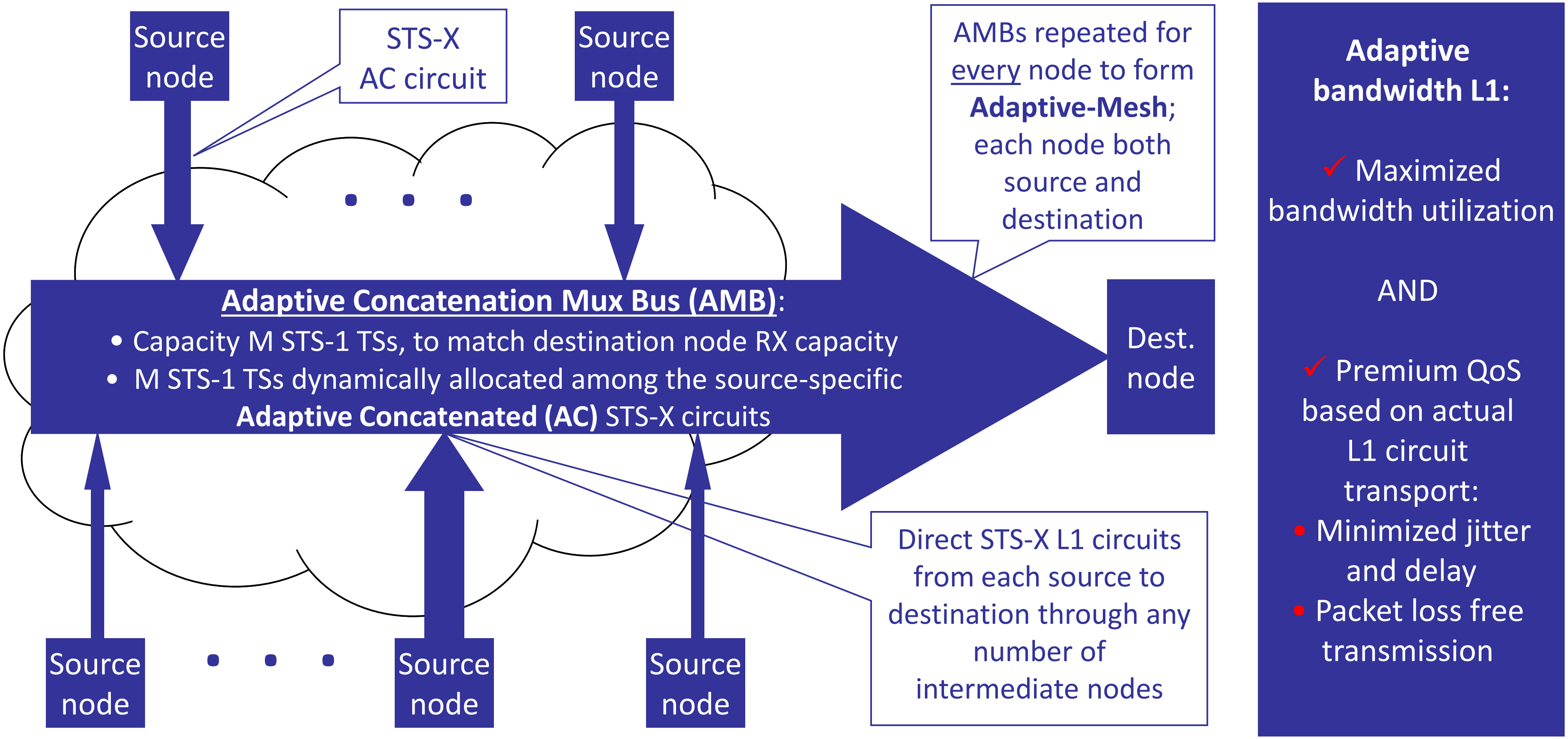
C. Order of 10:1 reduction in packet processing capacity requirements achieved with AMBs

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



- 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
  - → <u>Continuously optimized L1 bandwidth allocation on individual packet / STS-1 row timeslot basis</u>
- 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):
  - → <u>AMBs consume minimum network capacity sufficient to maximize utilization of network egress interfaces</u>

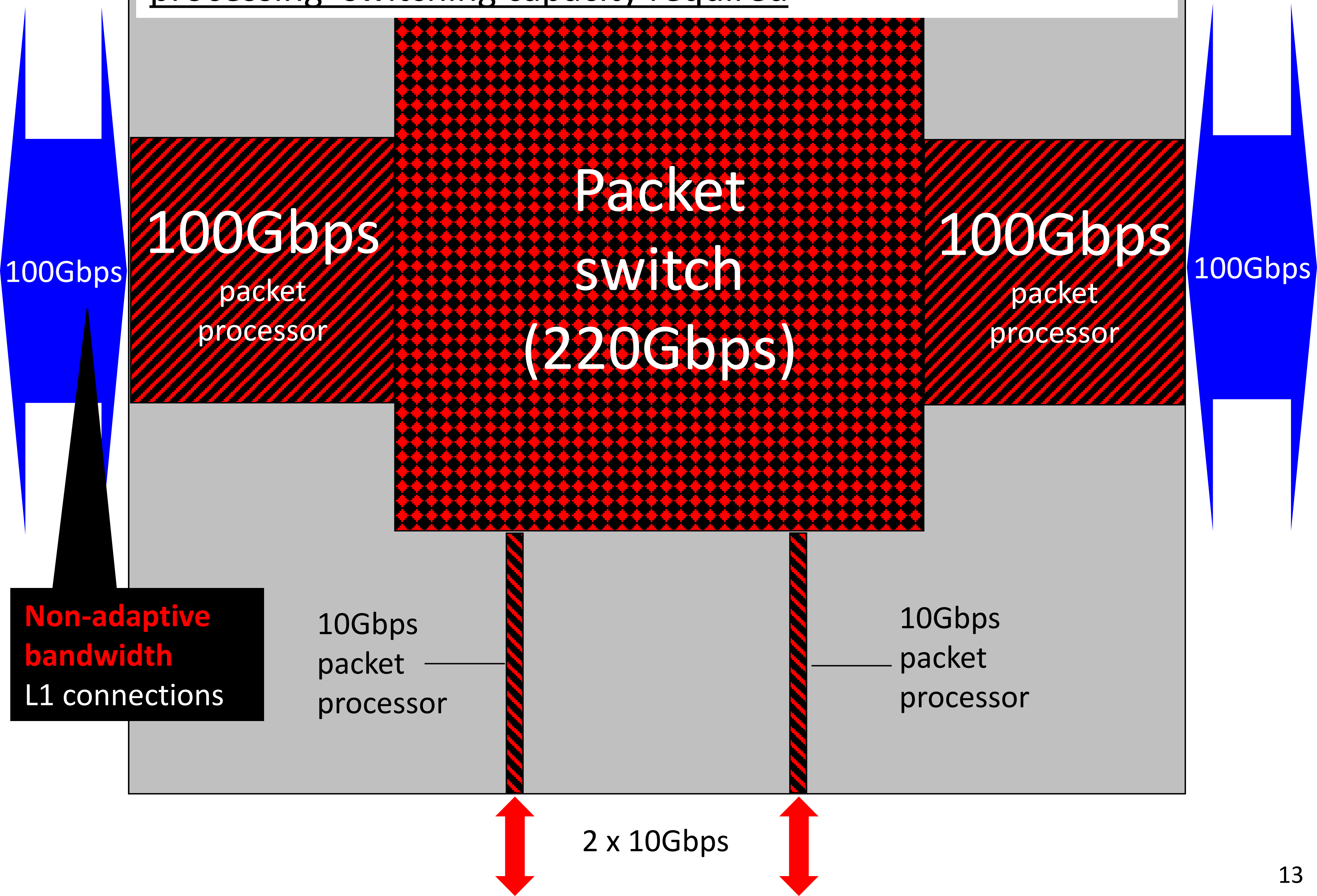
→ **<u>Maximized difference between revenue (throughput) and cost (capacity); maximized network profitability.</u>**

OPTIMUM COMMUNICATIONS

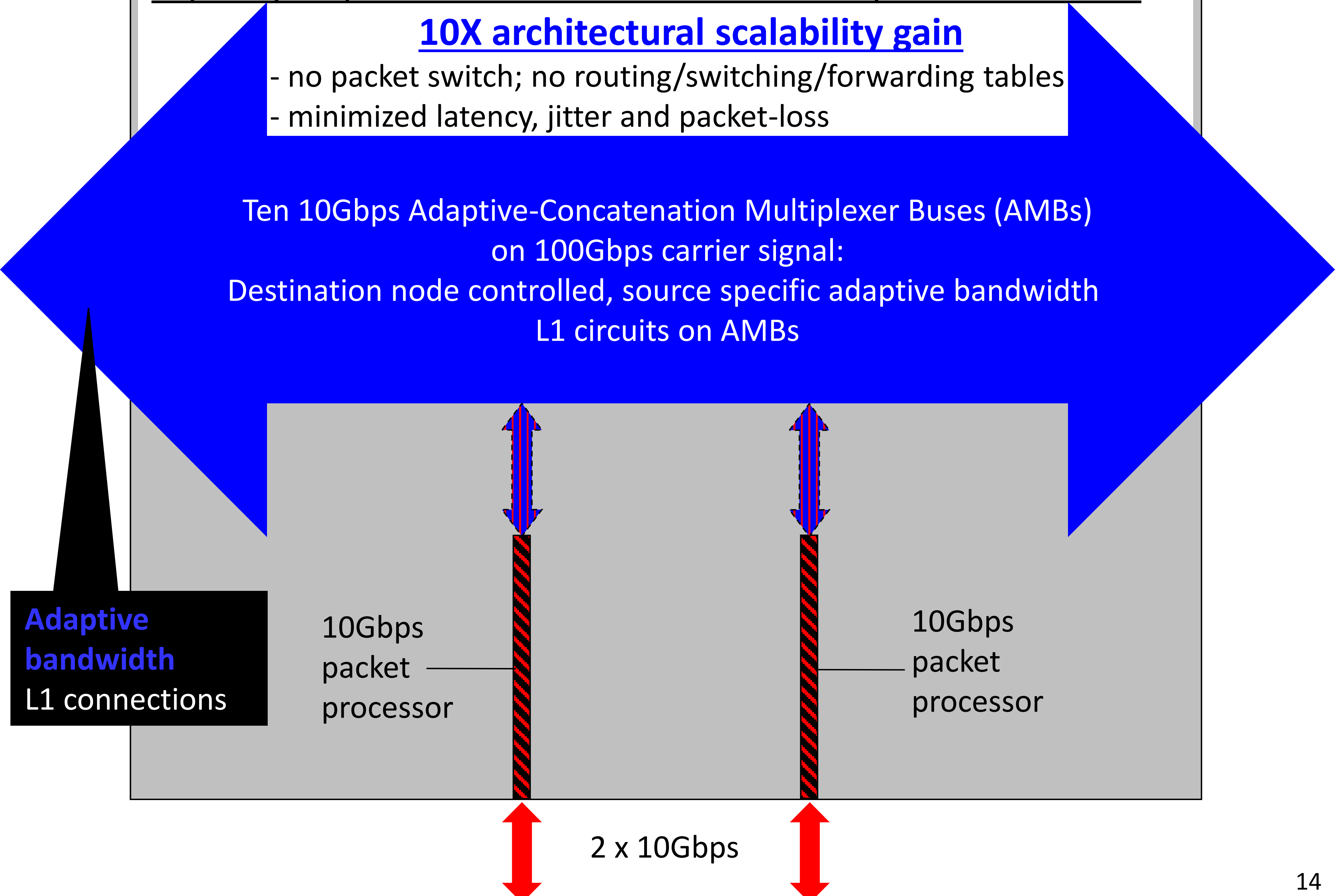
BACKUP SLIDES

C. 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: **2x100+2x10=220Gbps** packet processing+switching capacity required



AMB interface unit: **2x10Gbps = 20Gbps** of packet forwarding capacity required for same access and transport bandwidth:



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