Impact of Adaptive Layer 1 for Packet Switching Network Cost and QoS

TRLabs Next Generation Internet Workshop

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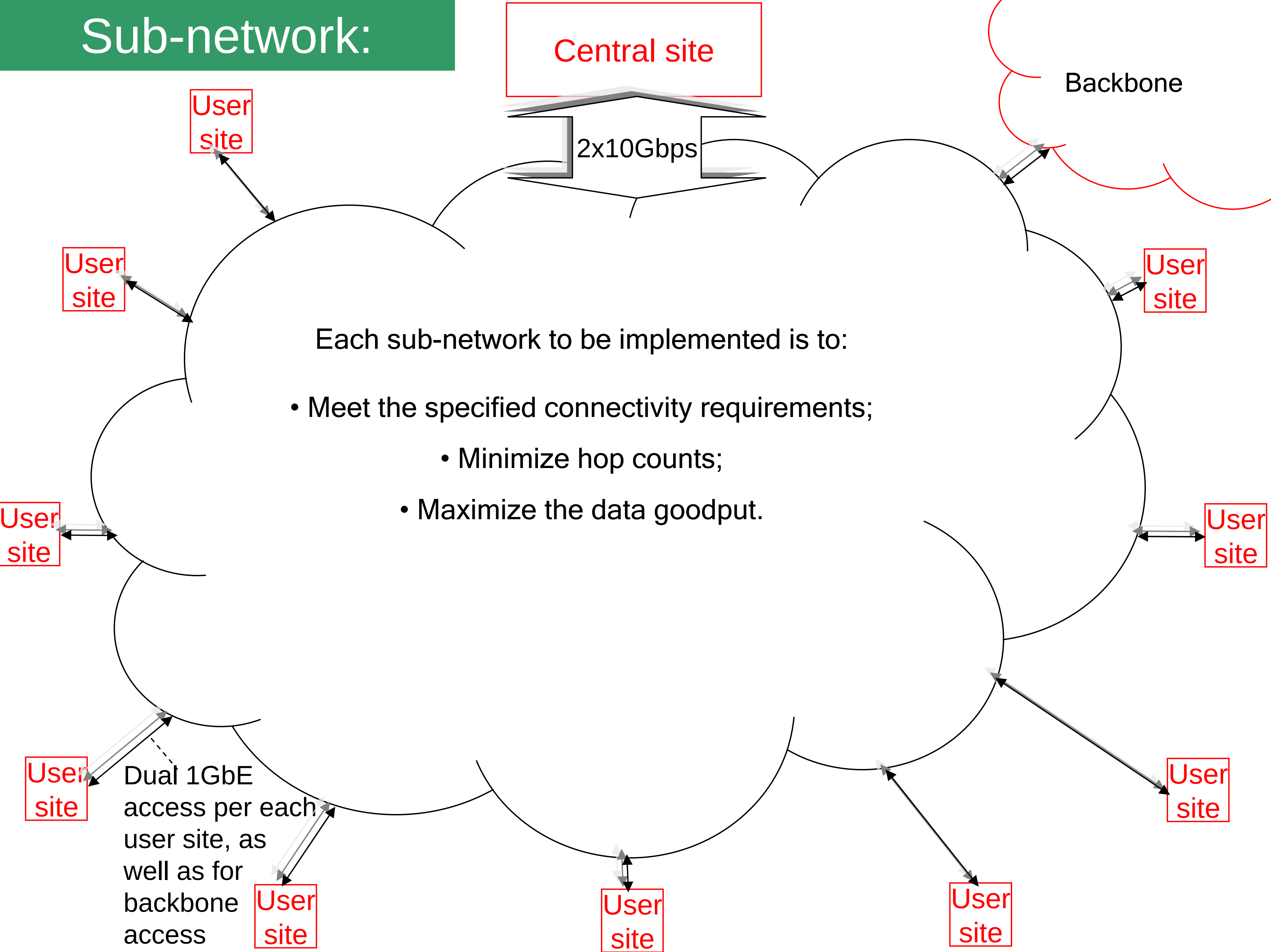
Network case study outline - *Based on typical campus/research network connectivity requirements*

- One hundred GbE access sites (1+1 protected)
- Ten sub-networks, each with:
  - Ten 2xGbE user sites
  - 2x10Gbps central site
  - 2xGbE access to backbone
- Backbone network:
  - Interconnects the ten sub-networks
  - 2x10Gbps central site
  - 2xGbE access e.g. international research network backbone
- One 10Gbps fiber/wavelength ring per a sub/backbone network

Network case study specifications

- Each user site must be able to get:
  - As much as possible of its full 1+1=2Gbps of **burstable** bandwidth to/from any other user site or central site within the ten-subnetwork cluster as long as that traffic flow does not block other valid traffic;
  - At least its equal division of network bandwidth when **fair sharing** of network capacity is needed under a condition of excess demand by several source-destination flows for the shared capacity.
- The backbone network is similar to any one of the ten user-access subnetworks, though the “user sites” for the backbone network are the subnetworks themselves.

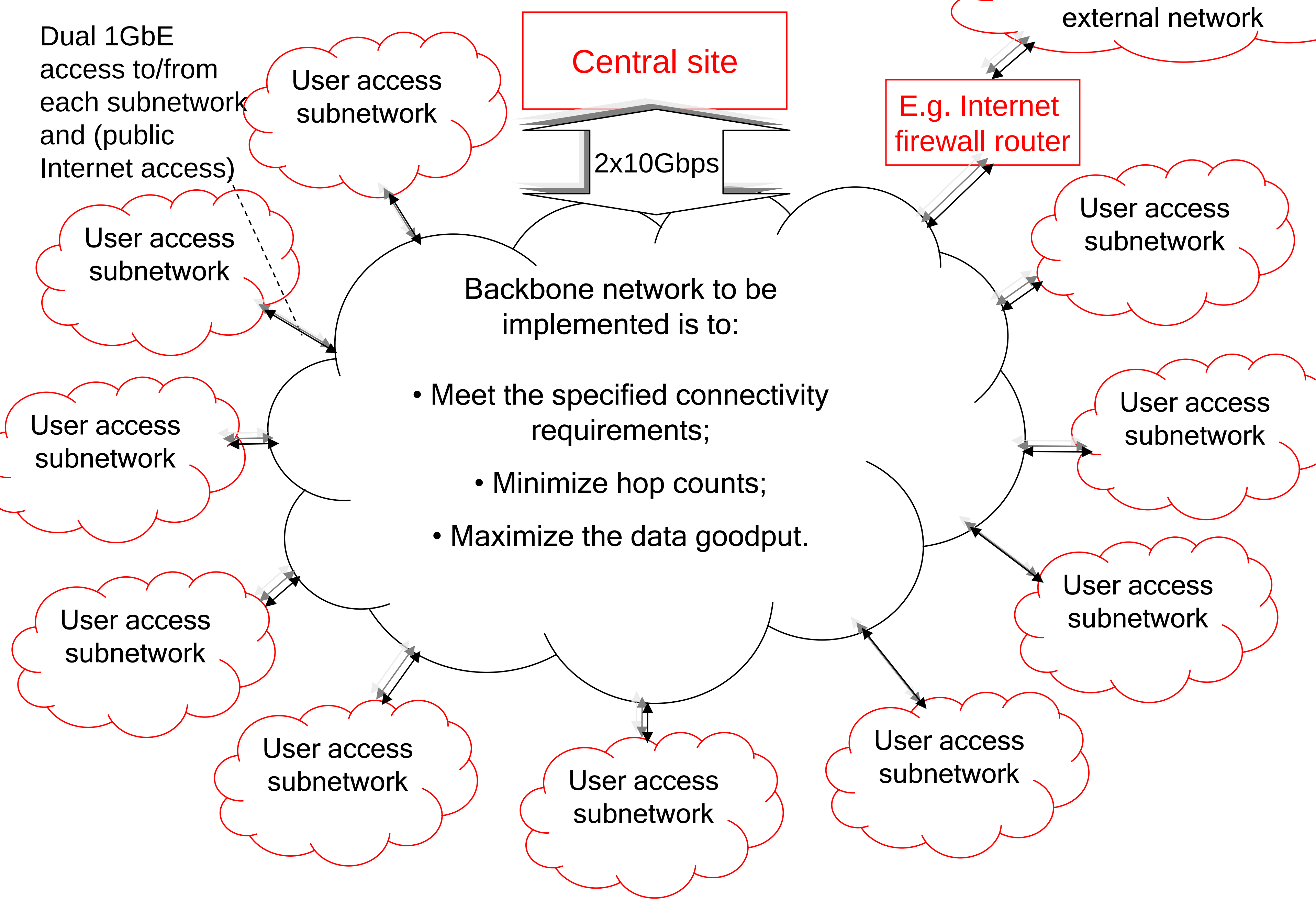
Sub-network:



Each sub-network to be implemented is to:

- Meet the specified connectivity requirements;
- Minimize hop counts;
- Maximize the data goodput.

Backbone network:

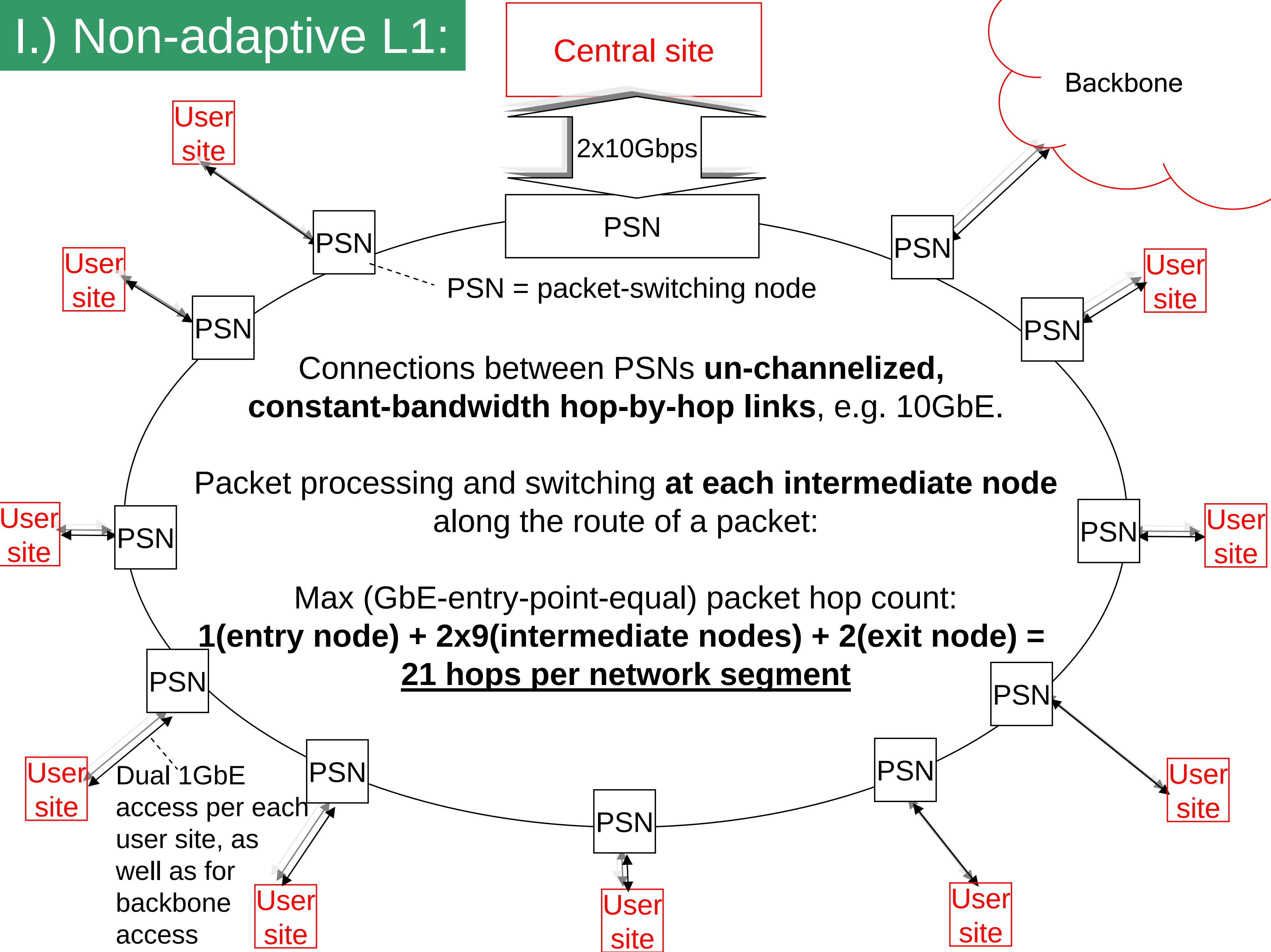


Comparison network alternatives

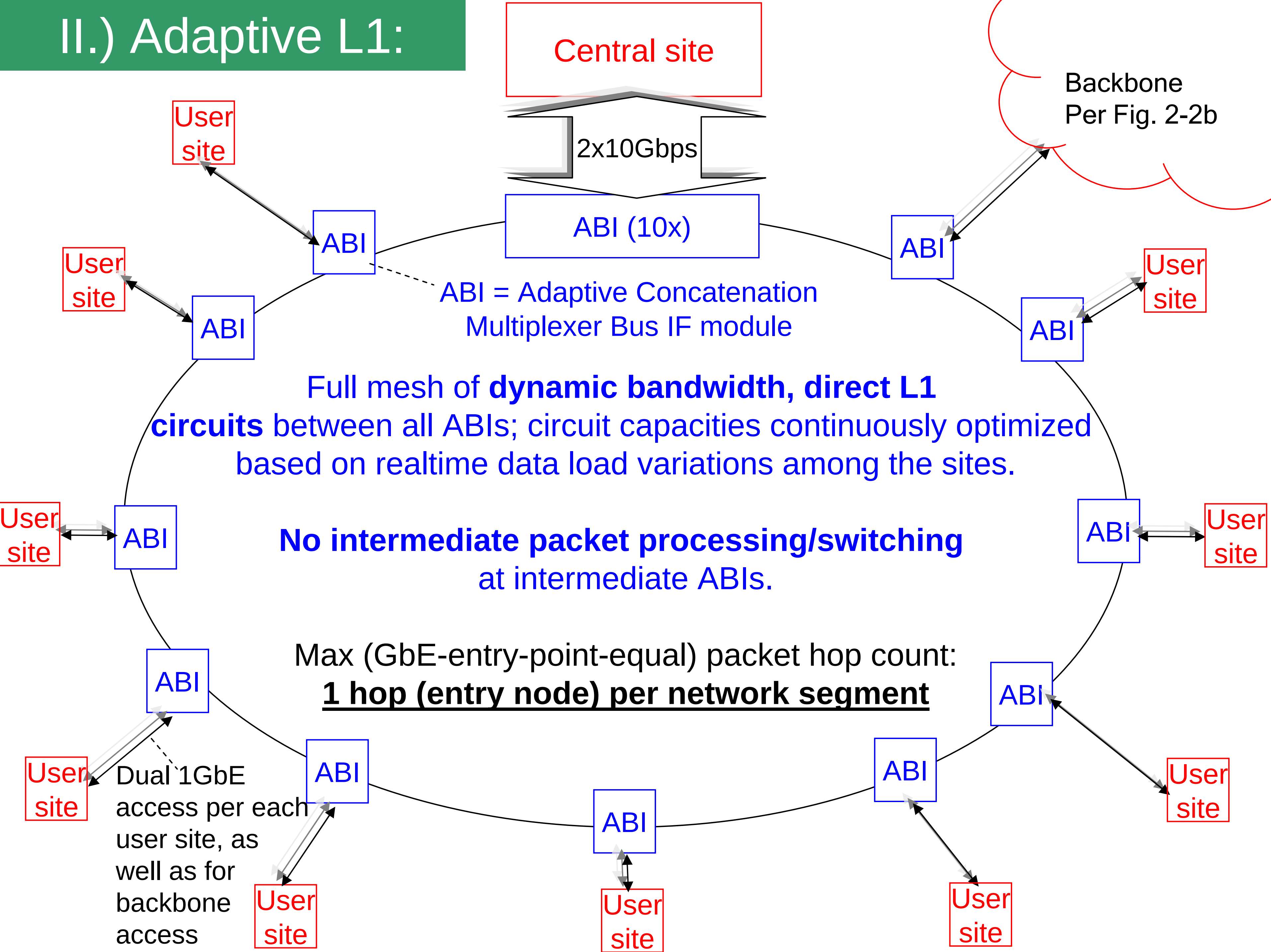
- The connectivity that the subnetworks and the backbone network segments need to provide are equal
- Therefore, the comparison implementations for only one such segment (either subnetwork or backbone) need to be analyzed
- The comparison implementations:
  I. **Non-Adaptive Layer 1** based, e.g. regular 1/10GbE, PBB etc. L2/L3 packet-switched network
  II. **Adaptive-bandwidth Layer 1**, e.g. STS-X Adaptive-Concatenation based packet transport (US patent appl:s 11/692925, 10/382729)

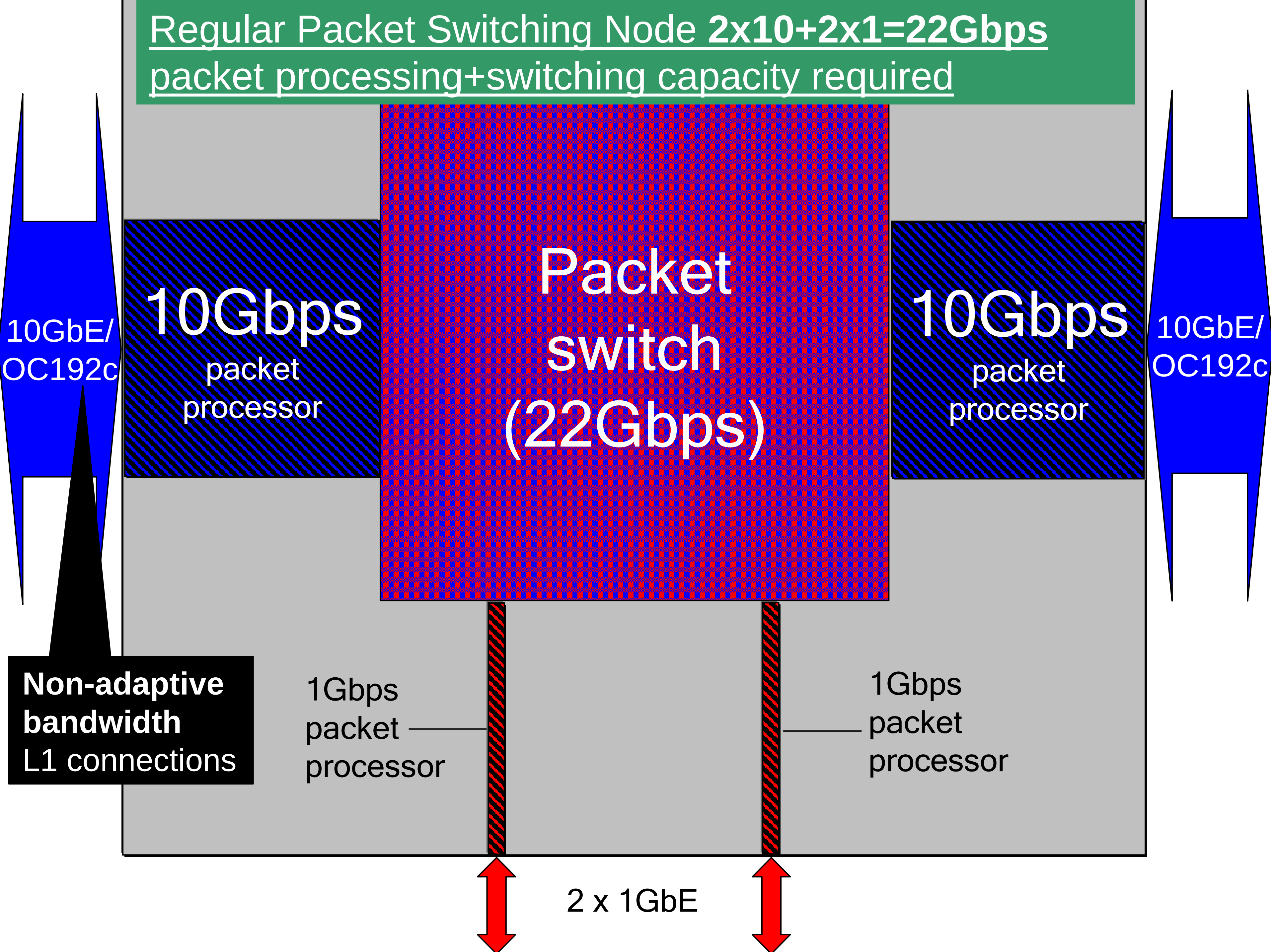
Comparison network quality criteria

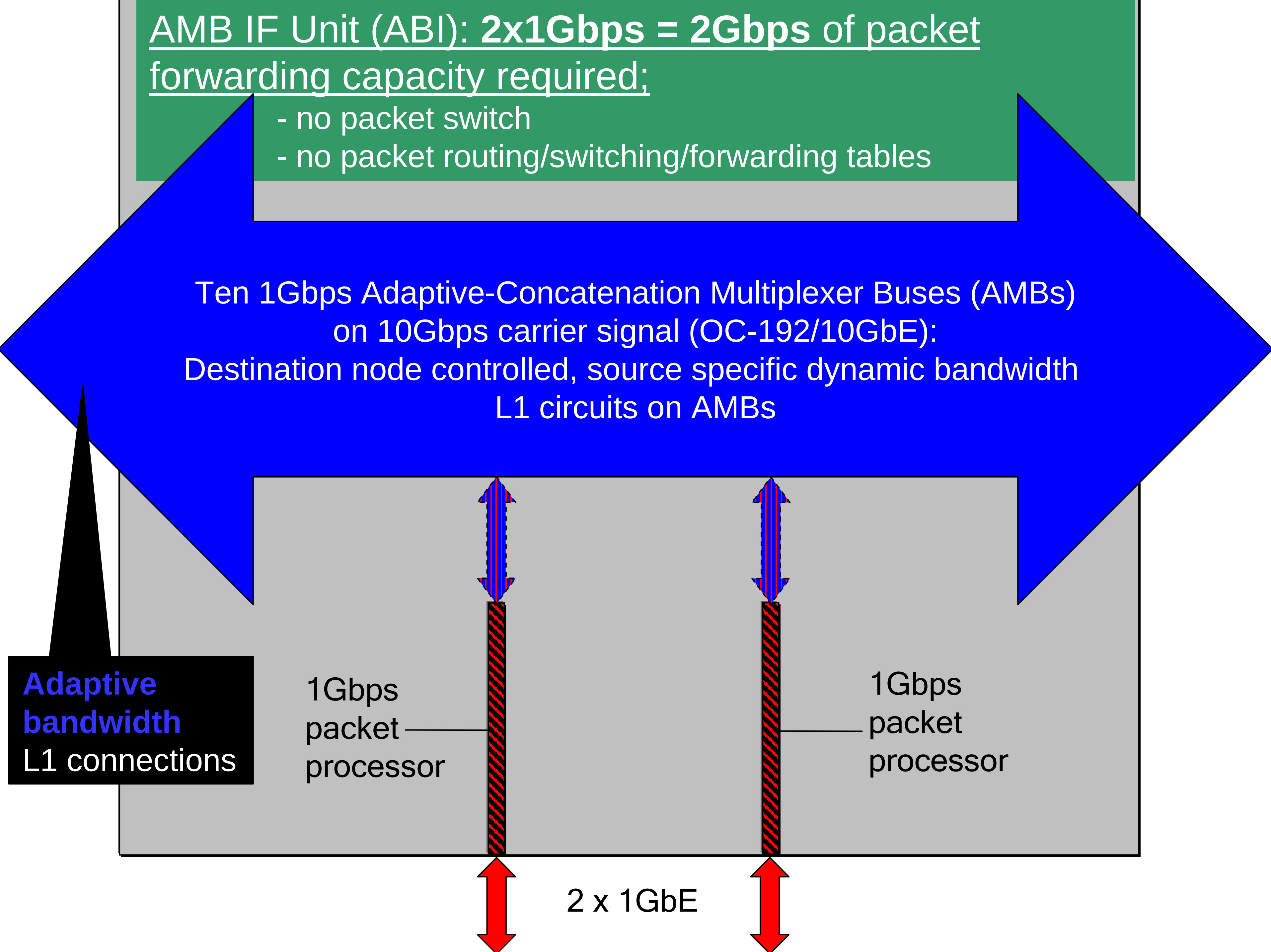
1) To minimize packet hop counts, to maximize the on-time data delivery capacity ("goodput") and user-experience performance:
   - Minimizing packet hop counts essential to provide quality service
     - Each packet hop increases delay, jitter and packet loss probability
   - Measured as the maximum hop count across the network
     - Worst case performance needs to kept above the minimum tolerated threshold
   - Hop counts quantified in 1Gbps-equal packet-switched access points.
2) To minimize the equipment cost:
   - Measured as the total packet processing+switching capacity required
     - Network bandwidth is fixed for this study
3) To minimize network operations and administration costs -- quantified as:
   - The amount of interaction required between the user group's and the service provider's administrative domains to set up, maintain the network
     - When inter-domain interaction requirements are minimized, also the domain-internal administrative burden can be minimized


I.) Non-adaptive L1:
Central site
2x10Gbps
PSN
Backbone
User site
PSN
PSN = packet-switching node
Connections between PSNs un-channelized, constant-bandwidth hop-by-hop links, e.g. 10GbE.
Packet processing and switching at each intermediate node along the route of a packet:
Max (GbE-entry-point-equal) packet hop count:
1(entry node) + 2x9(intermediate nodes) + 2(exit node) = 21 hops per network segment
Dual 1GbE access per each user site, as well as for backbone access

II.) Adaptive L1:




Regular Packet Switching Node **2x10+2x1=22Gbps**
packet processing+switching capacity required
10GbE/
OC192c
10Gbps
packet
processor
Packet
switch
(22Gbps)
10Gbps
packet
processor
10GbE/
OC192c
Non-adaptive
bandwidth
L1 connections
1Gbps
packet
processor
1Gbps
packet
processor
2 x 1GbE


AMB IF Unit (ABI): 2x1Gbps = 2Gbps of packet forwarding capacity required;
- no packet switch
- no packet routing/switching/forwarding tables
Ten 1Gbps Adaptive-Concatenation Multiplexer Buses (AMBs) on 10Gbps carrier signal (OC-192/10GbE): Destination node controlled, source specific dynamic bandwidth L1 circuits on AMBs
Adaptive bandwidth L1 connections
1Gbps packet processor
1Gbps packet processor
2 x 1GbE

Evaluation of I.) Non-adaptive and II.) Adaptive L1 alternatives per the quality criteria

Criteria *(to be minimized)*	I.) Non-Adaptive	II.) Adaptive L1	Gain of Adaptive L1
1) Max hop counts	21x3 = 63	1x3 = 3	(63-3)/3 = 2000%
2) Packet processing capacity	22Gbps/node	2Gbps/node	(22-2)/2= 1000%
3) Inter-domain network admin. interactions	✓ L2/3 address exchange ✓ TE/QoS policing ✓ Multicast group mgmt.	None (not even L2 addresses needed at core network when using techniques per US patent #7,254,138)	Substantial

Impact of 20 times higher max packet hop count of Non-adaptive-L1 vs. Adaptive-L1 network

- In this study, each packet hop is a 1Gbps entry to 10Gbps link
  - Oversubscription potential 10% of transport link capacity
  - At full network load, 10% of packets dropped per hop (90% gets through)
- Worst case throughputs across network:
  I. Non-adaptive (63 hops): 0.9^{63} = 0.1%
  II. Adaptive L1 (3 hops): 0.9^{3} = 73%

➔ Adaptive L1 provides $0.9^{(3-63)}$ = 556 times higher minimum throughput for the 100 user-site network case.

Conclusions:
Adaptive L1 vs. Non-adaptive L1 Cost and QoS

- Adaptive L1:
  - Reduces equipment (packet processing and switching) costs by a factor of 10
  - Eliminates inter-domain administrative transactions
- Worst case performance at 10% packet loss per hop for the 100 user-site network:
  - Adaptive L1 supports packet-switched service with circuit-like QoS (required by realtime services e.g. voice, video) for 0.9^3 = 73% of access link capacities
  - Non-adaptive L1 networks (e.g. Ethernet/PBB based) get only 0.9^{63} = 0.1% of packets through at all (though not with QoS required by realtime services)
- Performance differences between non-adaptive vs. adaptive L1 networks become *exponentially* amplified (due to hop count factor) as the node count increases
  - Particularly important regarding Future Internet architectures!

Thank you!

For more info contact:

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