

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

TRLabs Next Generation Internet  
Workshop

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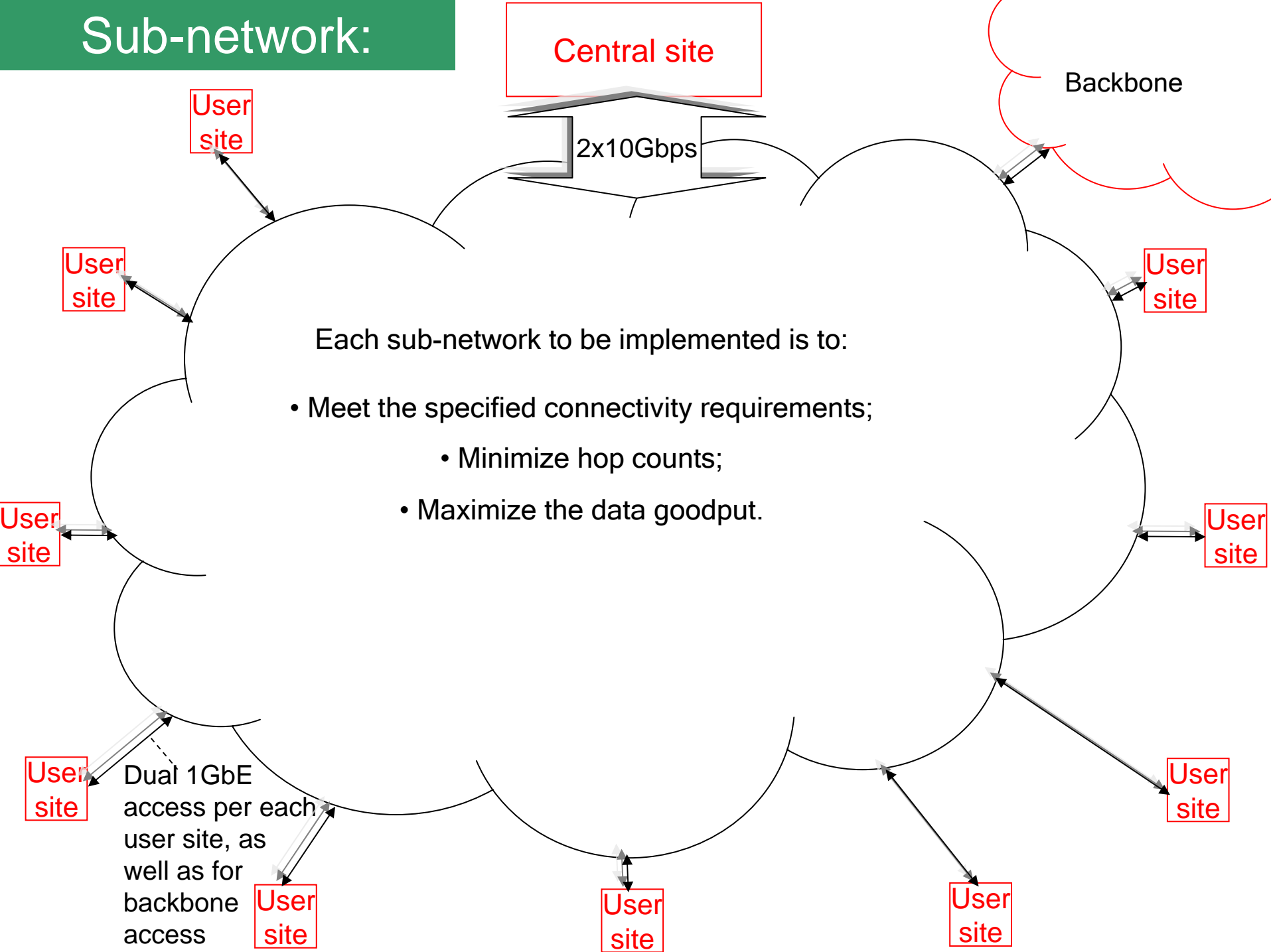
## Network case study outline - *Based on typical campus/research network connectivity requirements*

- 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:



Central site

2x10Gbps

Backbone

User site

User site

User site

Each sub-network to be implemented is to:

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

User site

User site

User site

Dual 1GbE access per each user site, as well as for backbone access

User site

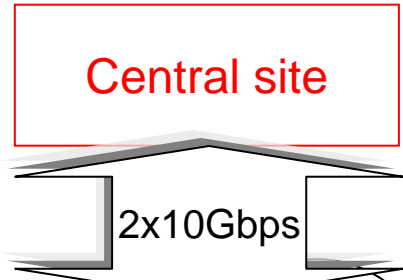
User site

User site

User site

# Backbone network:

Dual 1GbE access to/from each subnetwork and (public Internet access)



E.g. Internet firewall router

Internet or another external network

User access subnetwork

User access subnetwork

Backbone network to be implemented is to:

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

User access subnetwork

User access subnetwork

User access subnetwork

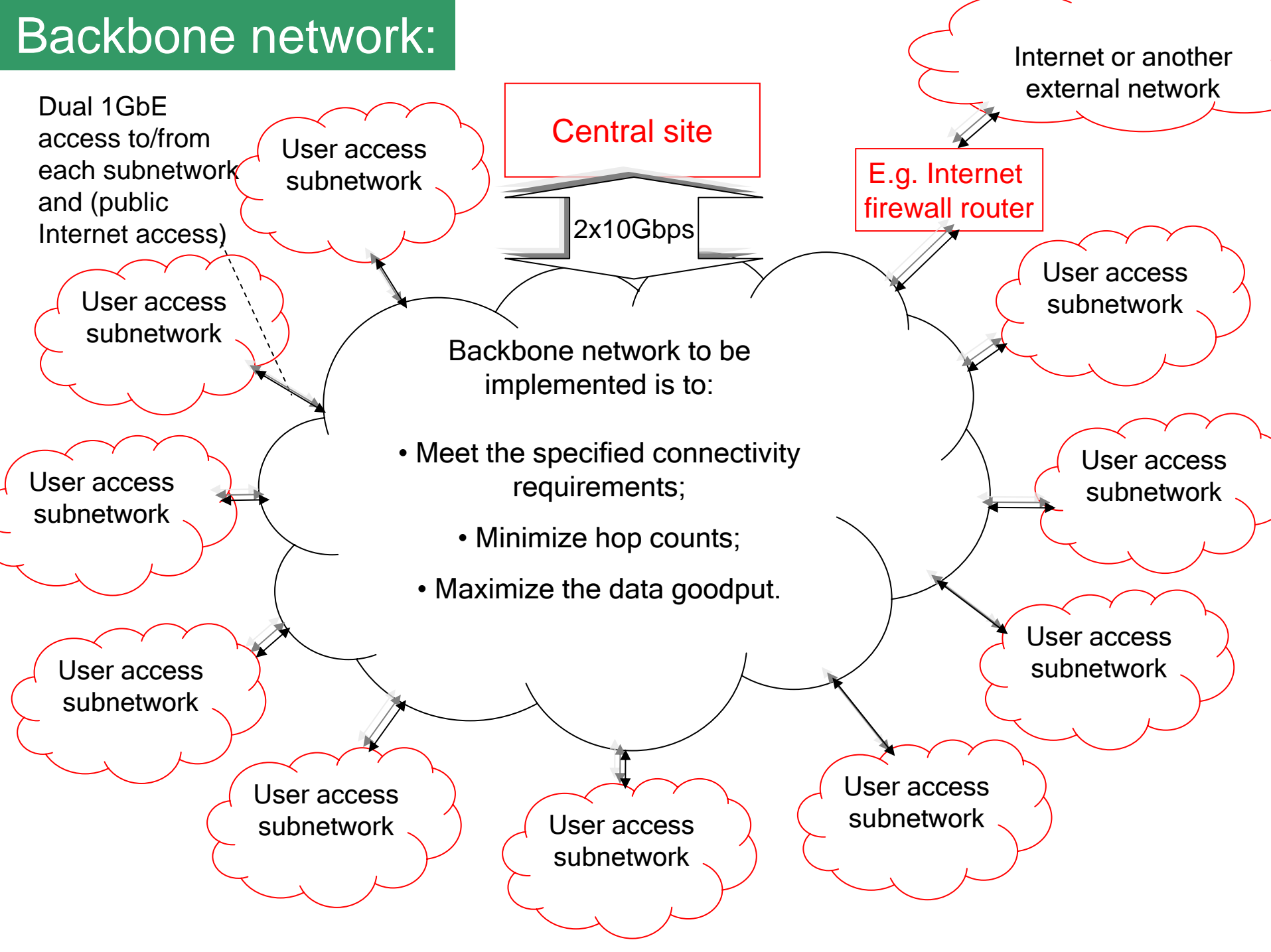
User access subnetwork

User access subnetwork

User access subnetwork

User access subnetwork

User access subnetwork



# Comparison network alternatives

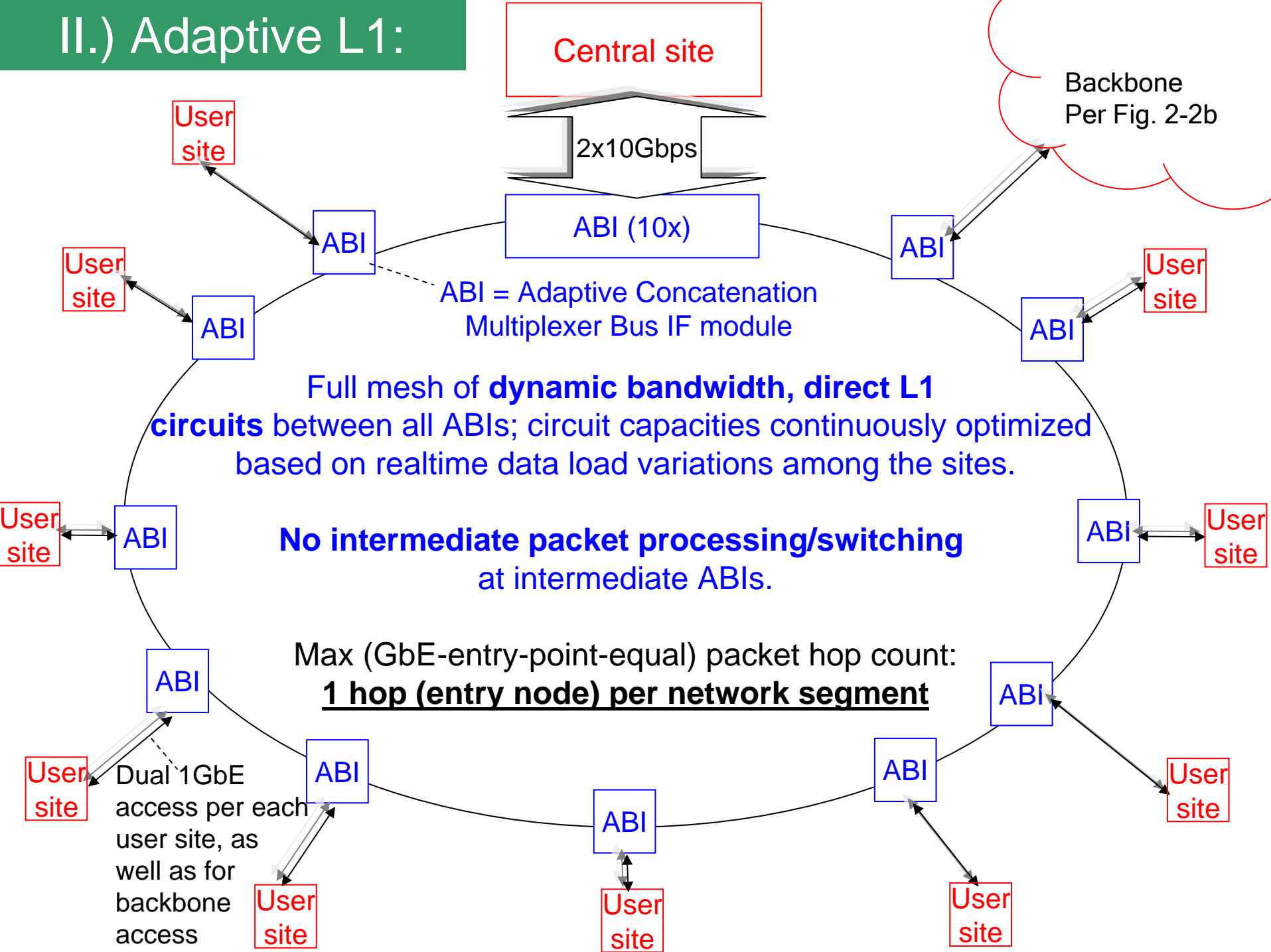
- The connectivity that the subnetworks and the backbone network segments need to provide are equal
- Therefore, the comparison implementations for only one such segment (either subnetwork or backbone) need to be analyzed
- The comparison implementations:
  - I. Non-Adaptive Layer 1 based, e.g. regular 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

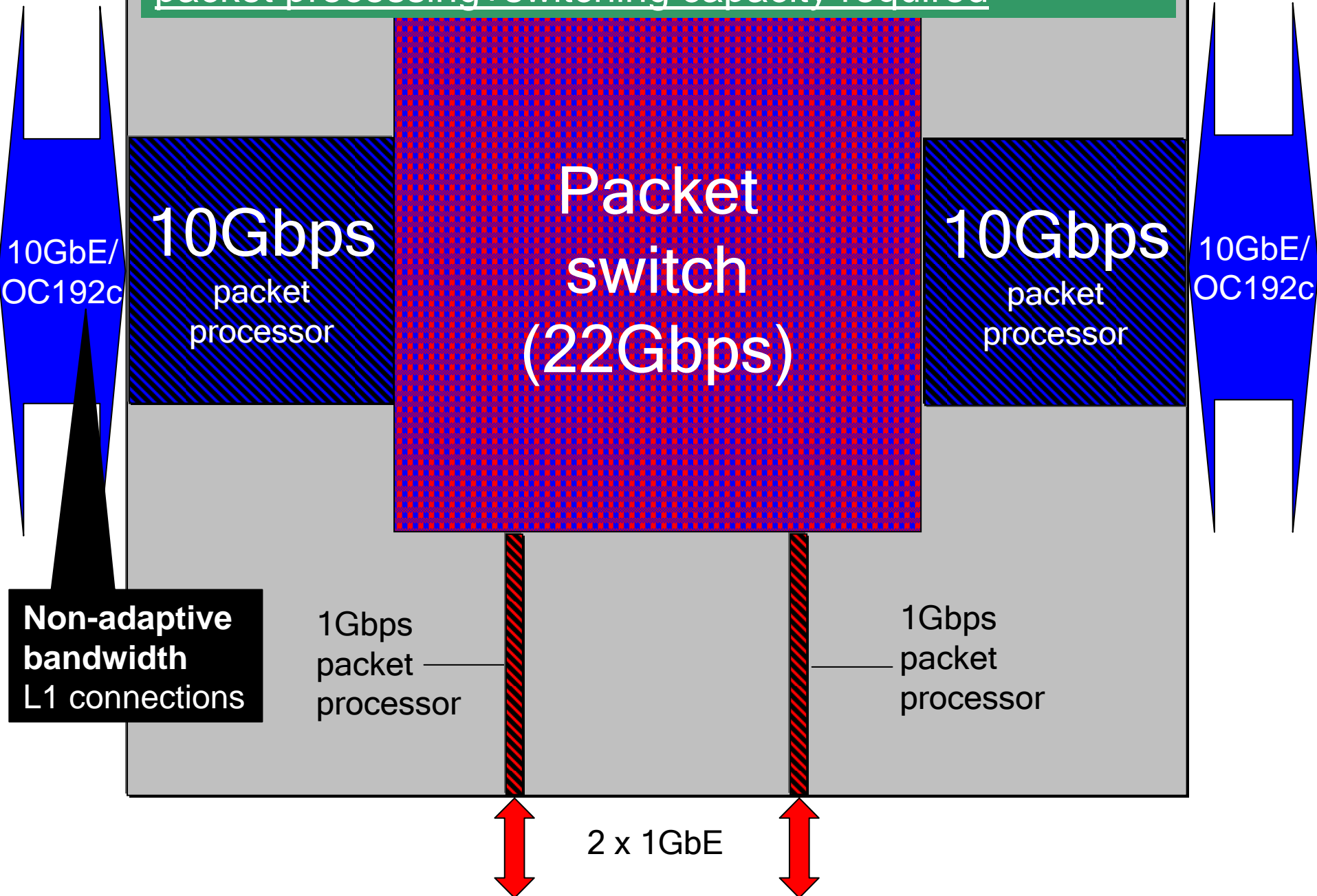
- 1) To minimize packet hop counts, to maximize the on-time data delivery capacity (“goodput”) and user-experience performance:
  - Minimizing packet hop counts essential to provide quality service
    - Each packet hop increases delay, jitter and packet loss probability
  - Measured as the maximum hop count across the network
    - Worst case performance needs to be 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



## II.) Adaptive L1:



Regular Packet Switching Node  $2 \times 10 + 2 \times 1 = 22 \text{ Gbps}$   
packet processing+switching capacity required



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

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

# 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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