What makes an exchange open?

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www.glif.is
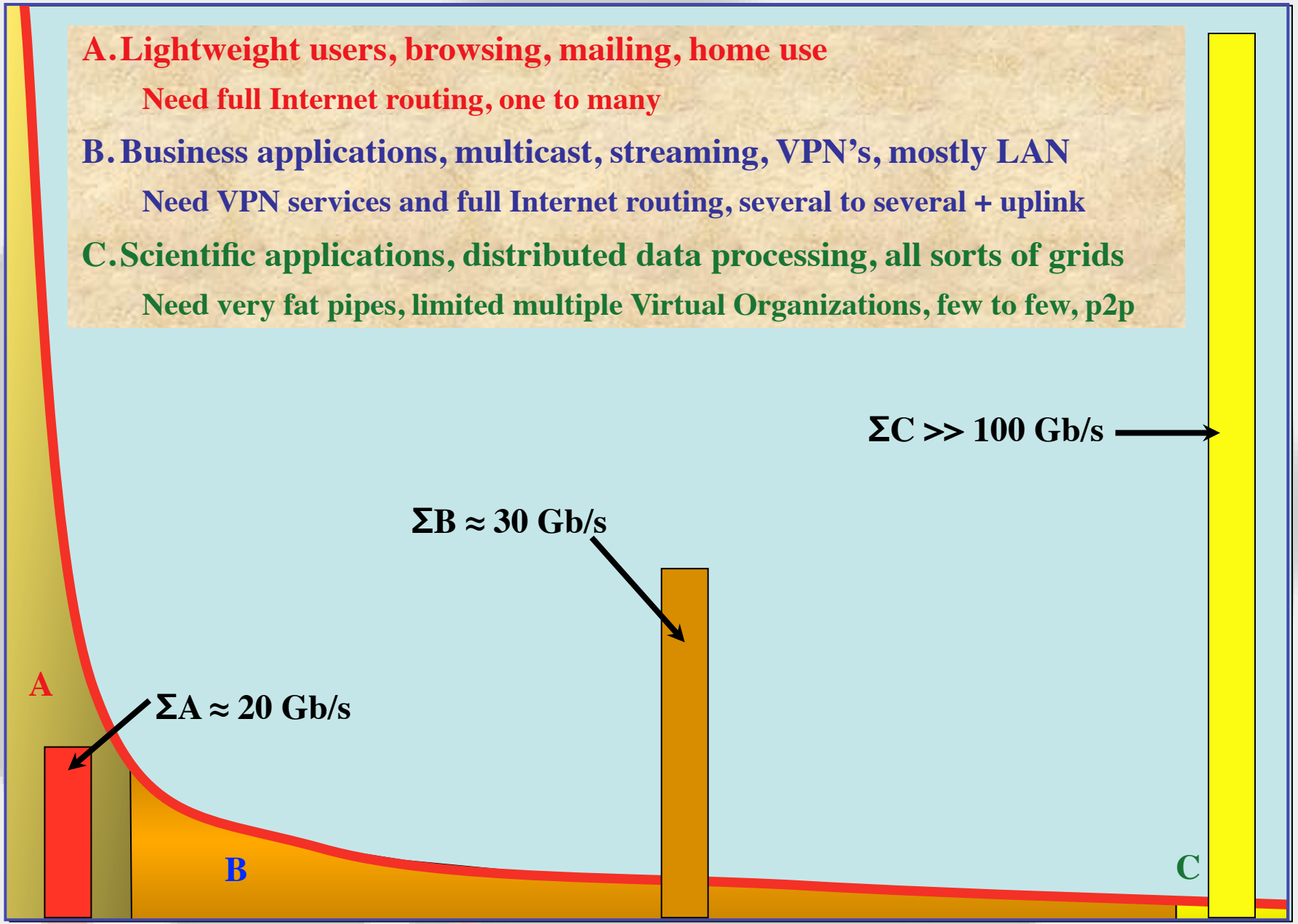
So what?

- **Costs of optical equipment 10% of switching 10 % of full routing equipment for same throughput**
  - **10G routerblade -> 100-500 k$, 10G switch port -> 10-20 k$, MEMS port -> 0.7 k$**
  - **DWDM lasers for long reach expensive, 10-50k$**
- **Bottom line: look for a hybrid architecture which serves all classes in a cost effective way (map A -> L3 , B -> L2 , C -> L1)**
- **Give each packet in the network the service it needs, but no more !**

L1 -> 0.7 k$/port

L2 -> 5-15 k$/port

L3 -> 100-500 k$/port

How low can you go?

Application Endpoint A

Application Endpoint B

Local Ethernet

MEMS

15454 6500 HDXc

POS

Regional dark fiber

Trans-Oceanic

Router

Ethernet

SONET

DWDM

Fiber

NetherLight

UKLight

StarLight

GLIF
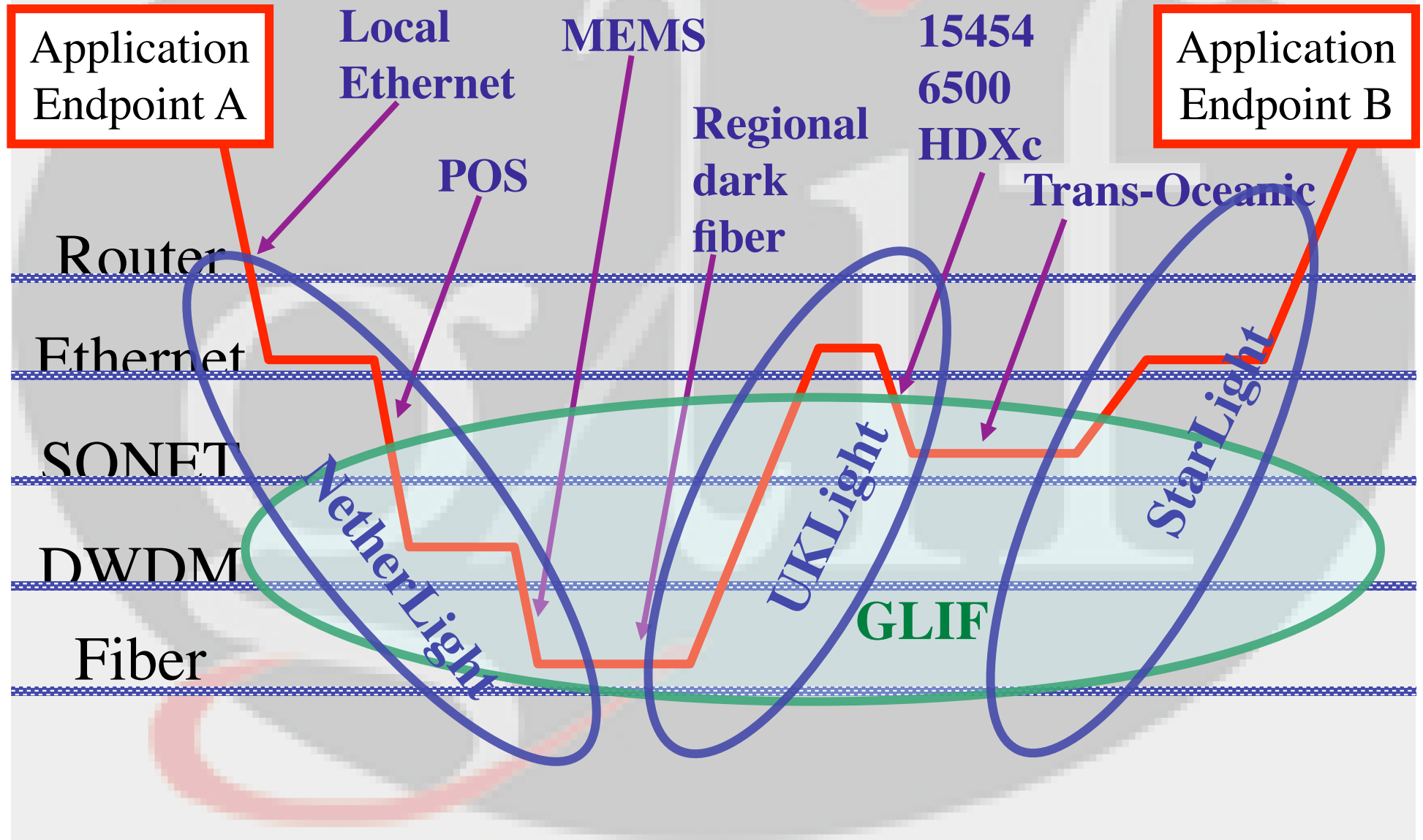
Services

SCALE / CLASS	2 Metro	20 National/ regional	200 World
A	Switching/ routing	Routing	ROUTER$
B	Switches + E-WANPHY VPN's	Switches + E-WANPHY (G)MPLS	ROUTER$
C	dark fiber DWDM MEMS switch	DWDM, TDM / SONET Lambda switching	Lambdas, VLAN's SONET Ethernet

Service Matrix

From \ To	WDM (multiple λ)	Single λ, any bitstream	SONET/ SDH	1 Gb/s Ethernet	LAN PHY Ethernet	WAN PHY Ethernet	VLAN tagged Ethernet	IP over Ethernet
WDM (multiple λ)	cross-connect multicast, regenerate, multicast	WDM demux	WDM demux*	WDM demux *	WDM demux *	WDM demux *	WDM demux *	WDM demux *
Single λ, any bitstream	WDM mux	cross-connect multicast, regenerate, multicast	N/A *	N/A *	N/A *	N/A *	N/A *	N/A *
SONET/SDH	WDM mux	N/A *	SONET switch, +	TDM demux *	TDM demux[6]	SONET switch	TDM demux *	TDM demux *
1 Gb/s Ethernet	WDM mux	N/A *	TDM mux	aggregate, Ethernet conversion +	aggregate, eth. convert	aggregate, Ethernet conversion	aggregate, VLAN encap	L3 entry *
LAN PHY Ethernet	WDM mux	N/A*	TDM mux[6]	aggregate, Ethernet conversion	aggregate, Ethernet conversion +	Ethernet conversion	aggregate, VLAN encap	L3 entry *
WAN PHY Ethernet	WDM mux	N/A *	SONET switch	aggregate, Ethernet conversion	Ethernet conversion	aggregate, Ethernet conversion +	aggregate, VLAN encap	L3 entry *
VLAN tagged Ethernet	WDM mux	N/A *	TDM mux	aggregate, VLAN decap	aggregate, VLAN decap	aggregate, VLAN decap	Aggregate, VLAN decap & encap +	N/A
IP over Ethernet	WDM mux	N/A *	TDM mux	L3 exit *	L3 exit *	L3 exit *	N/A	Store & forward, L3 entry/exit+

Optical Exchange as Black Box

Optical Exchange

Switch

TDM

Store & Forward

DWDM mux/demux

Optical Cross Connect

TeraByte Email Service

Ref: gridnets paper by Freek Dijkstra, Cees de Laat
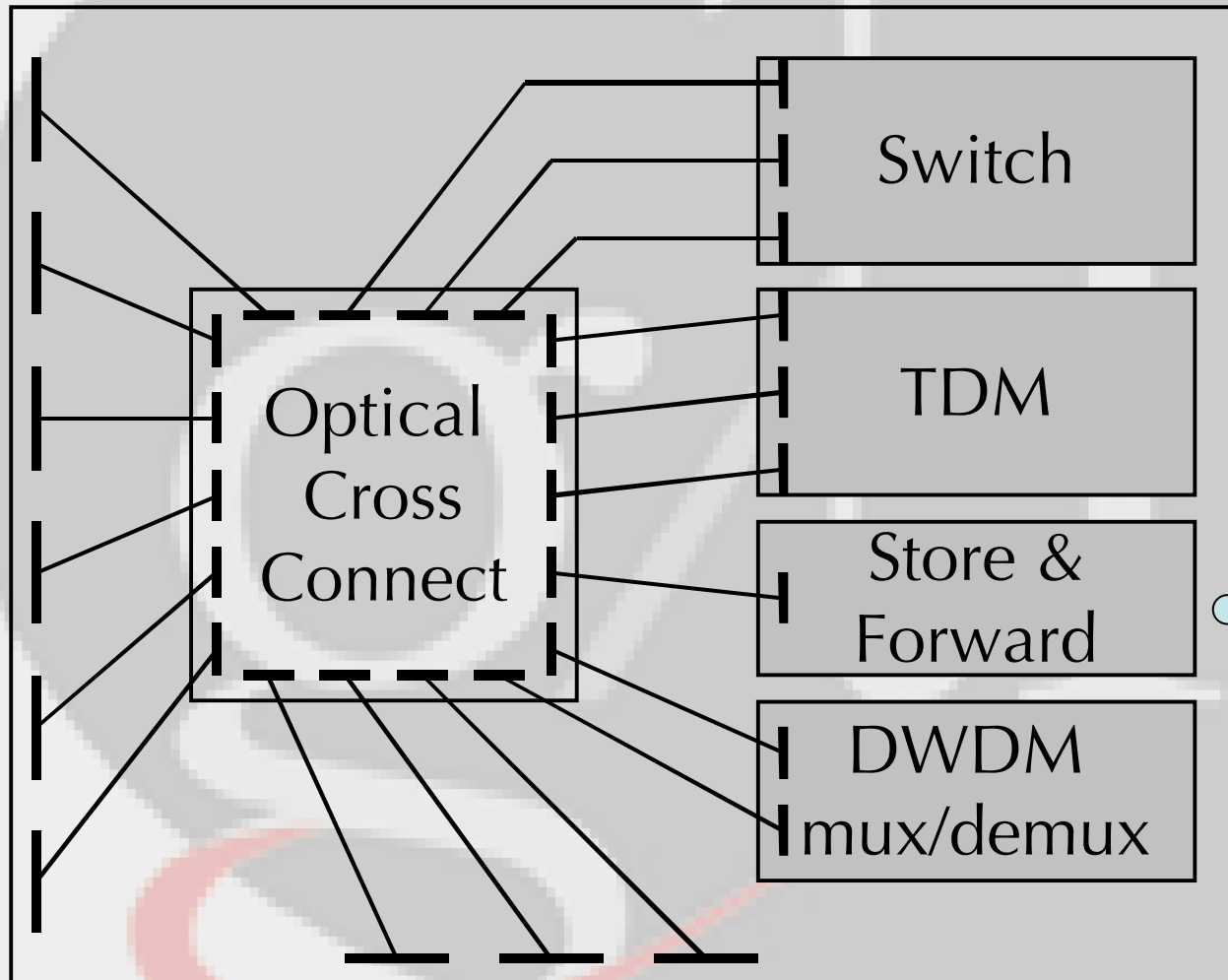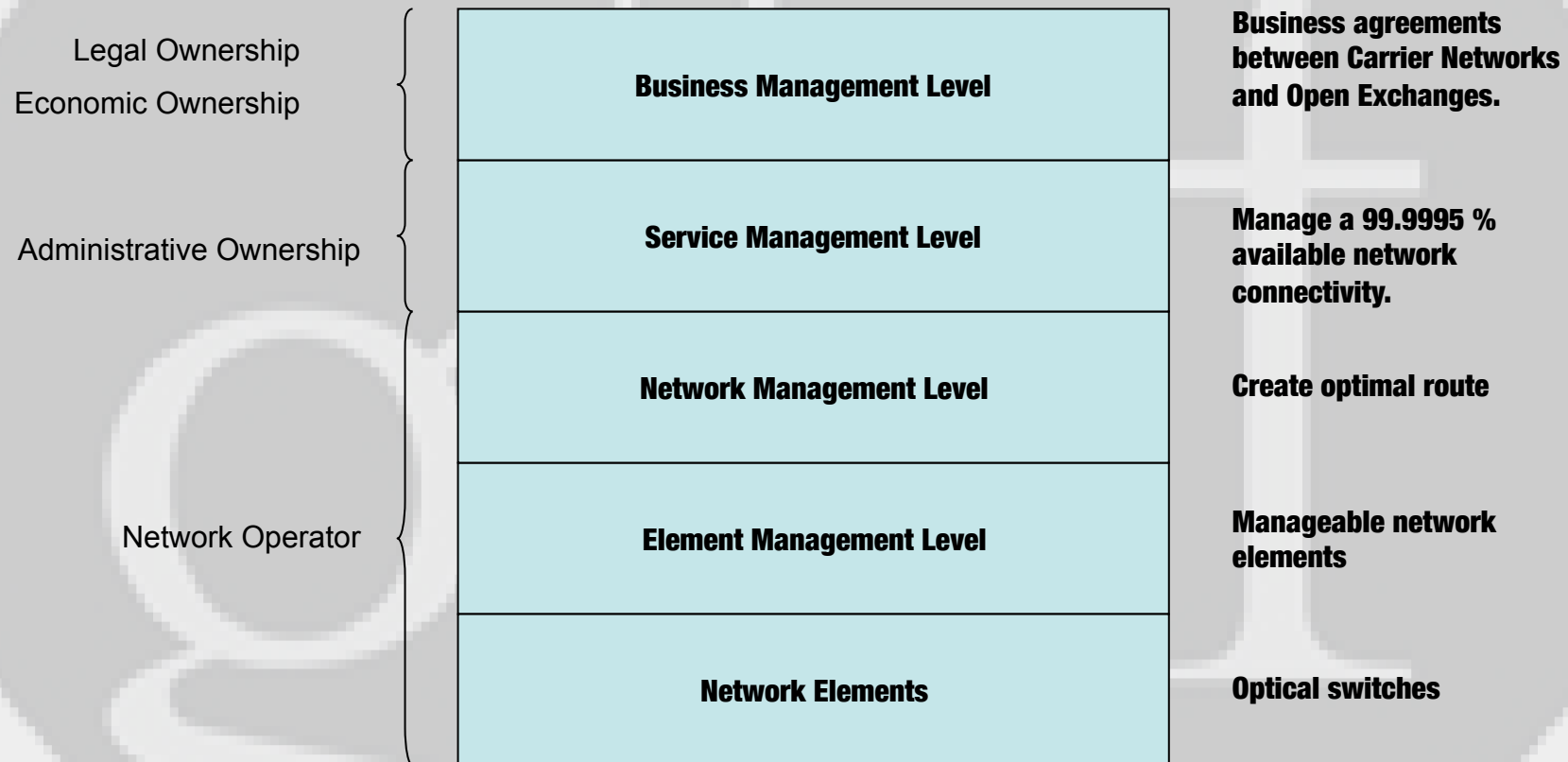
Ownership of resources

- **Legal Owner:**
  - Organization that legally owns a resource.
  - A legal owner may sell the right to economically use the resource.
- **Economic Owner:**
  - Acquires economic resource usage right a from legal resource owner.
  - A contract details terms by which a resource may be used.
  - Economic owners may outsource resource management to an Administrative Owner by means of a service level agreement.
- **Administrative Owner:**
  - Technically implements the terms of a service level agreement
  - Signals requests to other AO's and handles responses.
  - Collects accounting information.
- **Relationship between owners:**
  - Legal, economic and administrative owners may or may not be independent organizations.
  - Economic owners may acquire resources from different legal owners.
  - Administrative owners may serve different economic owners.
  - Economic owners may establish contracts with other economic owners to create more elaborate services. Technical details are delegated and implemented by Administrative Owners.

ISO Telecommunications Management Networks (TMN) reference model

Legal Ownership	**Business Management Level**	**Business agreements between Carrier Networks and Open Exchanges.**
Economic Ownership		
Administrative Ownership	**Service Management Level**	**Manage a 99.9995 % available network connectivity.**
	Network Management Level	**Create optimal route**
Network Operator	**Element Management Level**	**Manageable network elements**
	Network Elements	**Optical switches**

TMN is based on the OSI management framework and uses an object–oriented approach, with managed information in network resources modeled as attributes in managed objects. TMN is defined in ITU–T M.3000 series recommendations

Optical Network Stakeholders
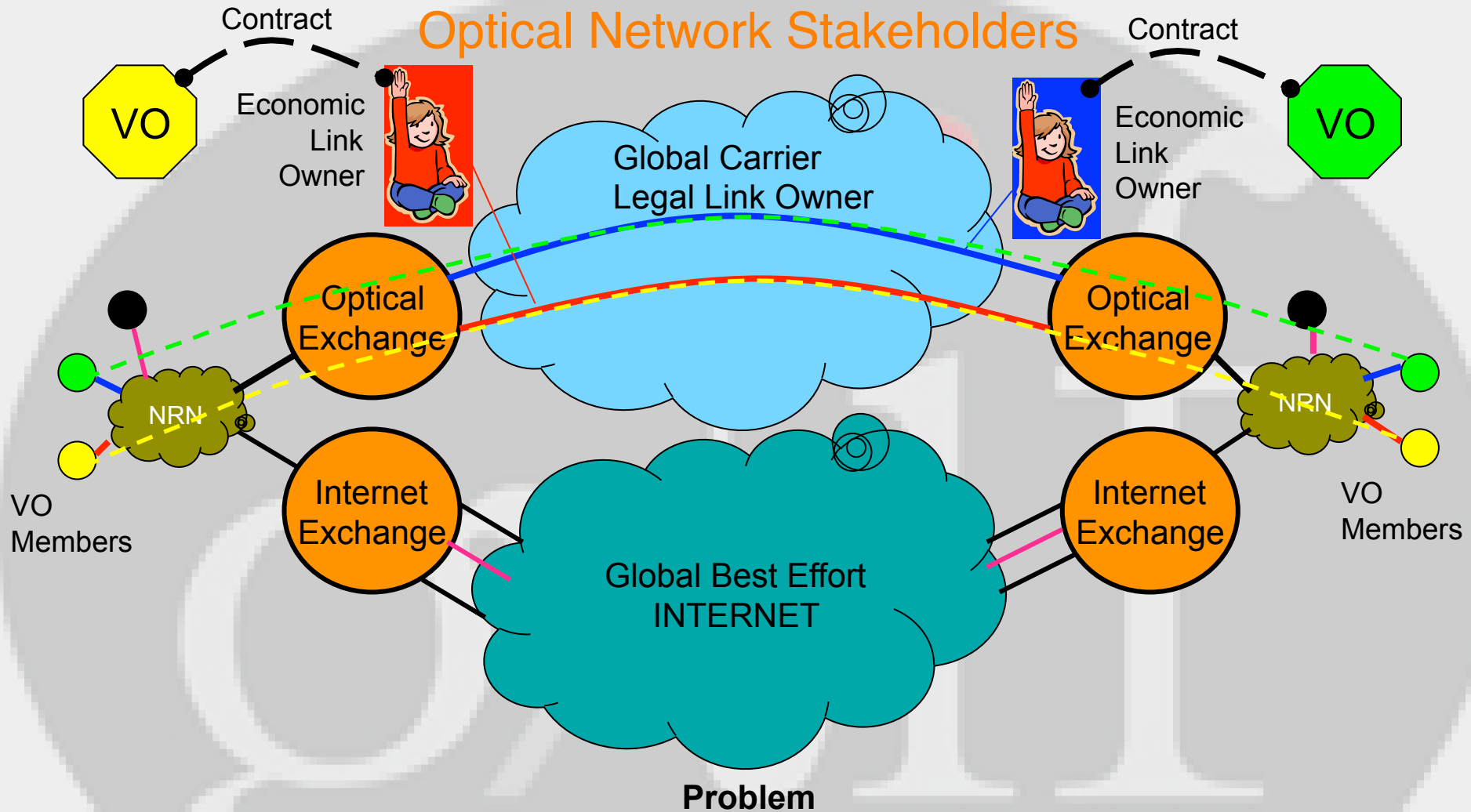
In order to enable a dynamic, cost effective VO business operation, Economic Link Owners Red and Blue need to create and have the ability to implement link usage contracts with VO's leading to the creation of **Optical Private Network (OPN)** between VO members.

Role definitions

- **Legal Link Owner (LLO):** Sells the right to use a link to an ELO's

- **Economic Link Owner (ELO):** Acquires the right to use a link and creates agreements with Economic VO's about the usage of its links.ELO's will terminate a link at an optical exchange based on a contract with an EPO.

- **Administrative Link Owner (ALO):** Translates the ELO defined business rules governing link access to technical rules that are subsequently pushed to the APO for enforcement (optical link fibers have no electronic control).

- **Legal Port Owner (LPO):** Owns optical switch-ports. Usage rights are sold to EPO's. Multiple LPO's may be present within an Optical Exchange.

- **Economic Port Owner (EPO):** Acquires the usage right from one or more LPO's for one or more ports on the Optical Exchange. EPO's establishes contracts to allow peering with own or other EPO ports on behalf of ELO's.

- **Administrative Port Owner (APO):** an entity that accepts peering policies from ALO's. Peering policies are based on the agreements between ELO and a VO. Creates connections with own ports or other ports from different APO's based on requests with credentials from VO's members or its proxy .

Possible roles and objectives

- **VO:**
  - Administrative entity that administers VO memberships
  - Administers technical implementations of contracts with ELO's regarding link usage rights.
  - Technically delegates ELO link usage rights to VO members.

- **VO Member:**
  - needs on-demand high-volumes traffic exchanges with their peers via one ore more links owned by and ELO.
  - is connected via a NRN to an Optical Exchange.
  - sends connection requests to NRN containing delegated VO rights

- **National Research Network:**
  - Operates a hybrid network infrastructure that allows re-direction of VO member traffic destined to ELO links.
  - Is LLO and ELO and ALO.
  - Non-ELO traffic is directed towards the regular Internet.
  - May re-advertise link availability obtained from Optical Exchange.
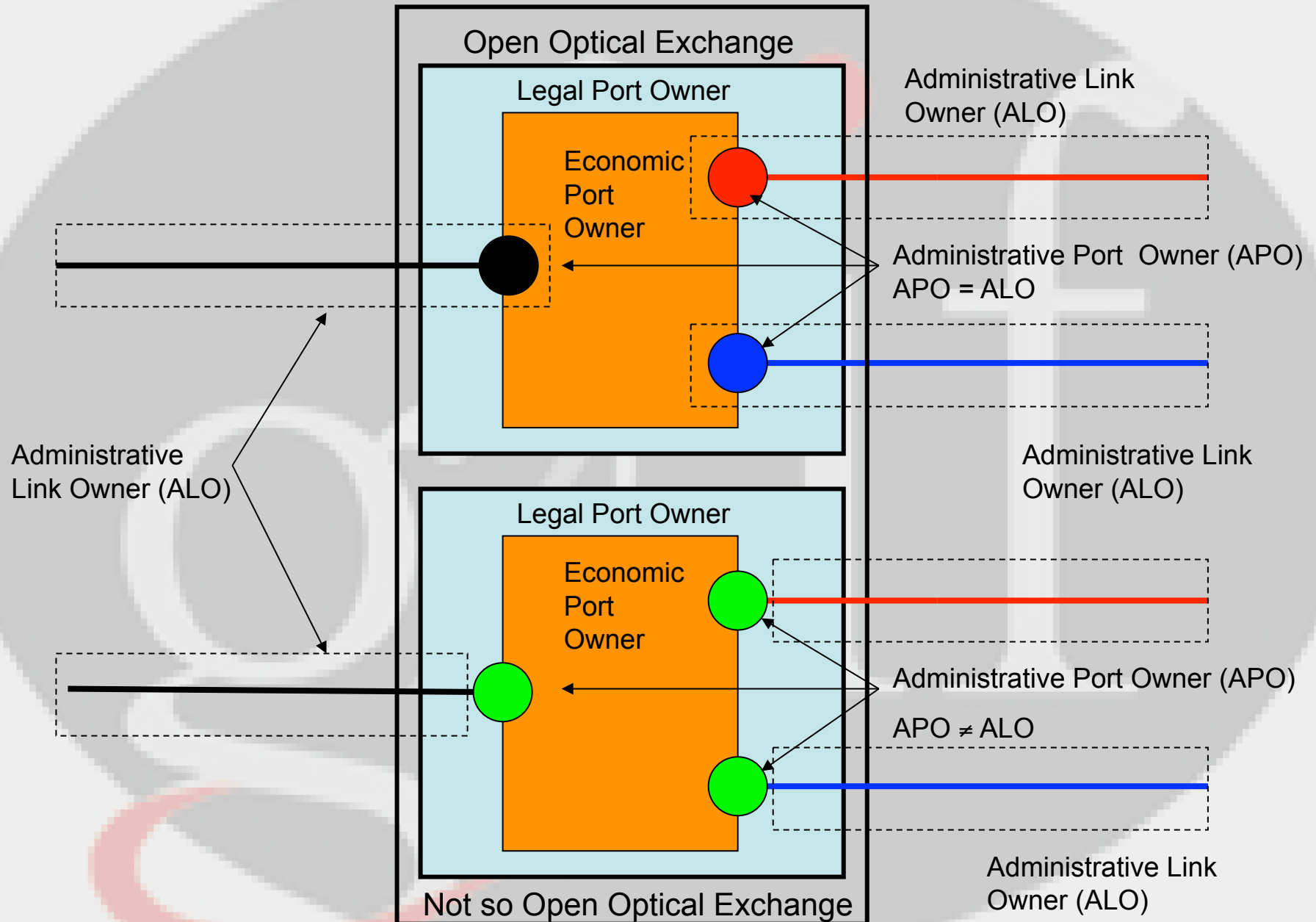 - Acts as proxy for VO member connection requests for ELO links.

Possible roles and objectives

- **Optical Exchange:**
    - Legal: Organization that facilitates LPO's and allow LLO's to terminate their links.
    - Economic: Sells housing, rack space, termination facilities etc.
    - Administrative: administers assets. Advertises topology info to other Optical Exchanges & NRNs ?

- **Open Optical Exchange: (**Part of) an optical exchange where ALO's also play the role of an APO.

Optical Exchange Stakeholders

Open Optical Exchange

Legal Port Owner

Economic Port Owner

Administrative Link Owner (ALO)

Administrative Port Owner (APO)
APO = ALO

Administrative Link Owner (ALO)

Legal Port Owner

Economic Port Owner

Administrative Link Owner (ALO)

Administrative Link Owner (ALO)

Administrative Port Owner (APO)

APO ≠ ALO

Not so Open Optical Exchange

Administrative Link Owner (ALO)

Possible Business Model - WORK IN PROGRESS

- **Economic VO (EVO):** ELO and VO detail agreement on link access.
- **Administrative VO (AVO):** Issues link access right credentials to its members. VO administers link usage and bills VO members accordingly.
- **VO Member:** obtains link access credentials from AVO. Dynamically creates on demand connection by sending request + credentials to NRN, possibly based on info advertised by NRN.
- **NRN:** Recieves request from VO member and forwards request to its APO
- **LLO:** has a simple 7x24 contract with ELO (business as usual).
- **ALO:** provides access control- and accounting services to ELO's.
- **Open Optical Exchange:** Hosts ALO's and offers aggregates link views to NRN's.
- **NRN:** Has contract with Business Partner. Offers path view & selection services. Offers guaranteed forwarding services to ELOs. May charge for ELO link usage and put surcharge for own link usage. Has contract with ELO to provide billing service.

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