The GÉANT Network: Ready for the Future

(Or: Infra to the Next Level)

Internet 2 TechEX Minneapolis -20th of September 2023

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CNOO GÉANT

The Eternal Challenge: Traffic Growth

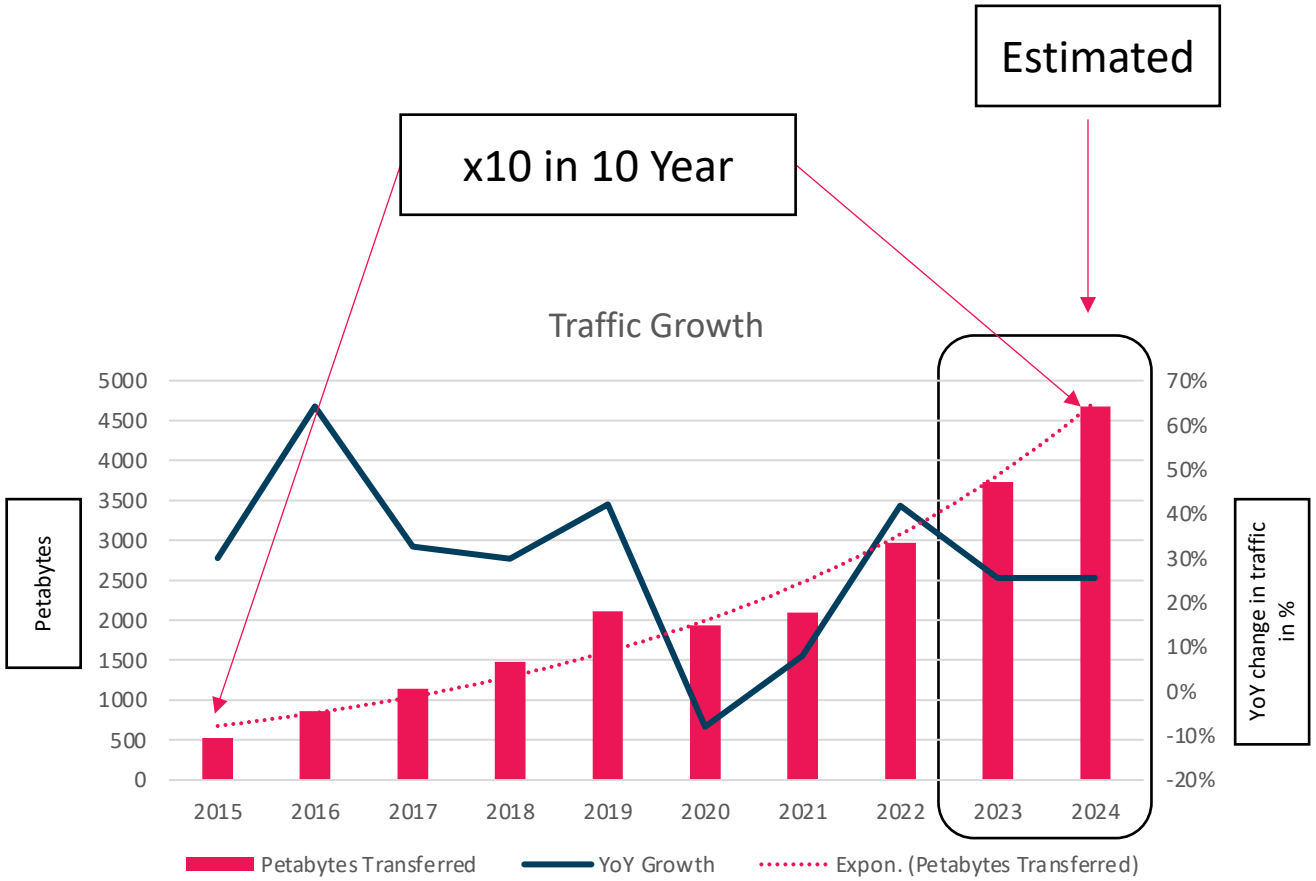
Long-term Backbone Traffic Growth

(GÉANT: largely driven by science instruments)

- **Total: 2010 –2022:** growth of over **30% YoY**
- **2015–2019**: Traffic growth of **40% YoY**
- **2015–2022:** Traffic growth of **27% YoY**

Total Backbone Trunk Capacity

Feb **2019**	**2.7 Tbps**
Dec **2022**	**9.4 Tbps**
*Dec **2032…***	***94 Tbps***



GÉANT and the "Grand Plan" – what is happening?

- ***Investing*** **in infrastructure:**
  - **Control**
    - Technology and services => **ability to deliver all services required, in an appropriate way, for a long time**
    - Financial => sustainable, and affordable
  - **Digital Divide** – research and education anywhere in/from/with Europe

- **Several *projects*:**
  - **GN4-3N**: Fiber and Spectrum Infra *(2019-2023)*
  - **EAP:** Eastern Access Partnership *(2015-2025)*
  - **GN5-1/2**: Renewal of the Router Layer *(2023-2024)*
  - **GN5-ic1:** Global Connectivity *(2022-2025)*

In parallel to Infrastructure:

Develop Capabilities and services

Infrastructure Project 1: GN4-3N (2019-2022/2023)

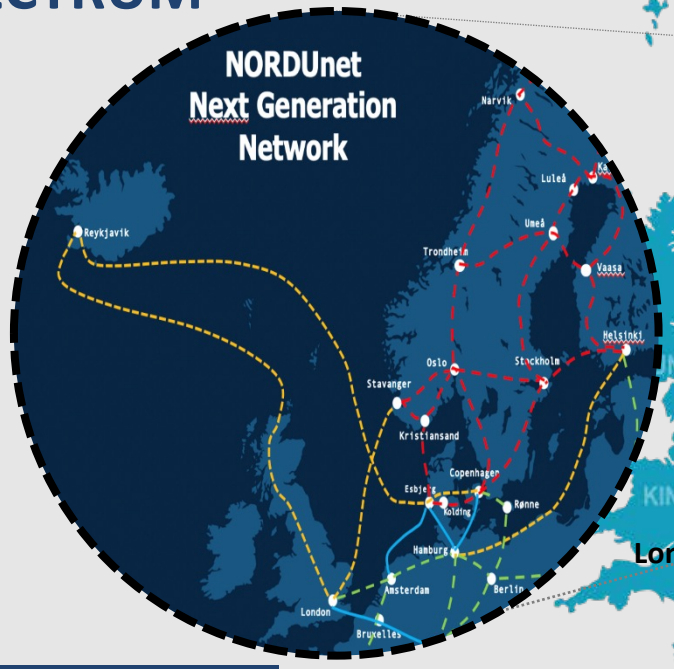
- Build GÉANT network on a **fibre footprint infrastructure, guaranteed in the long term**
- **Bridge the digital divide** for all NRENs
- Monitor impact of extension of GÉANT backbone
  Make it financially sustainable

services to NREN members, partners, e-infrastructure projects, R&E community in general

Or: build the long term ability to serve the most demanding users, anywhere in Europe – together with the NRENs

GN4-3N: FIBRE AND SPECTRUM

FIBRE INFRASTRUCTURE AT START OF GN4-3N (2019)



Fibre Network at start of project

14 countries (+NORDUnet) on fibre

Short term contracts => higher maintenance costs, to be replaced

Other countries on (typically high cost) leased lines

Amsterdam
Hamburg
London
Frankfurt
Brussels
Prague
Bratislava
Vienna
Paris
Budapest
Geneva
Zagreb
Ljubljana
Milan
Marseille
Madrid

Commercial Dark Fibre	NREN Spectrum

GN4-3N: INITIAL AMBITION:

REFERENCE NETWORK IN GN4-3N PROPOSAL

Estimated investment cost for this network: 48 M€

24 countries integrated in this infra

Other partners – depending on budget:
Additional dark fibre (DF) /spectrum projects
or
Standard leased capacity (minimally 10GE, might be 100GE by end of project)

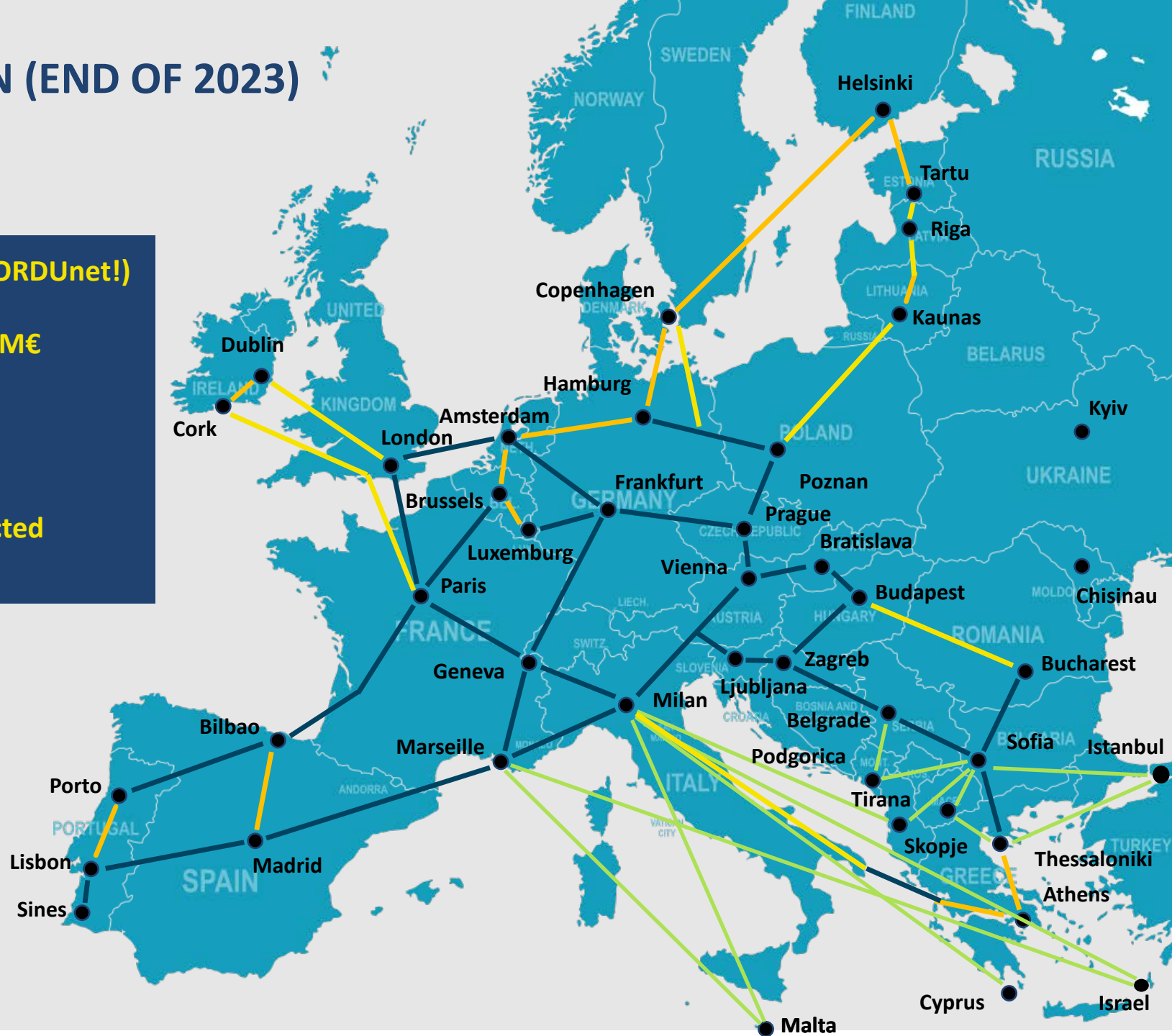
GN4-3N: CURRENT EXPECTATION (END OF 2023)

30 countries integrated in this infra (and add NORDUnet!)

Estimated investment cost for this network: 49 M€

Infrastructure ensured for 15 to 21 years

Considerable NREN contributions
Spectrum more accessible/available than expected



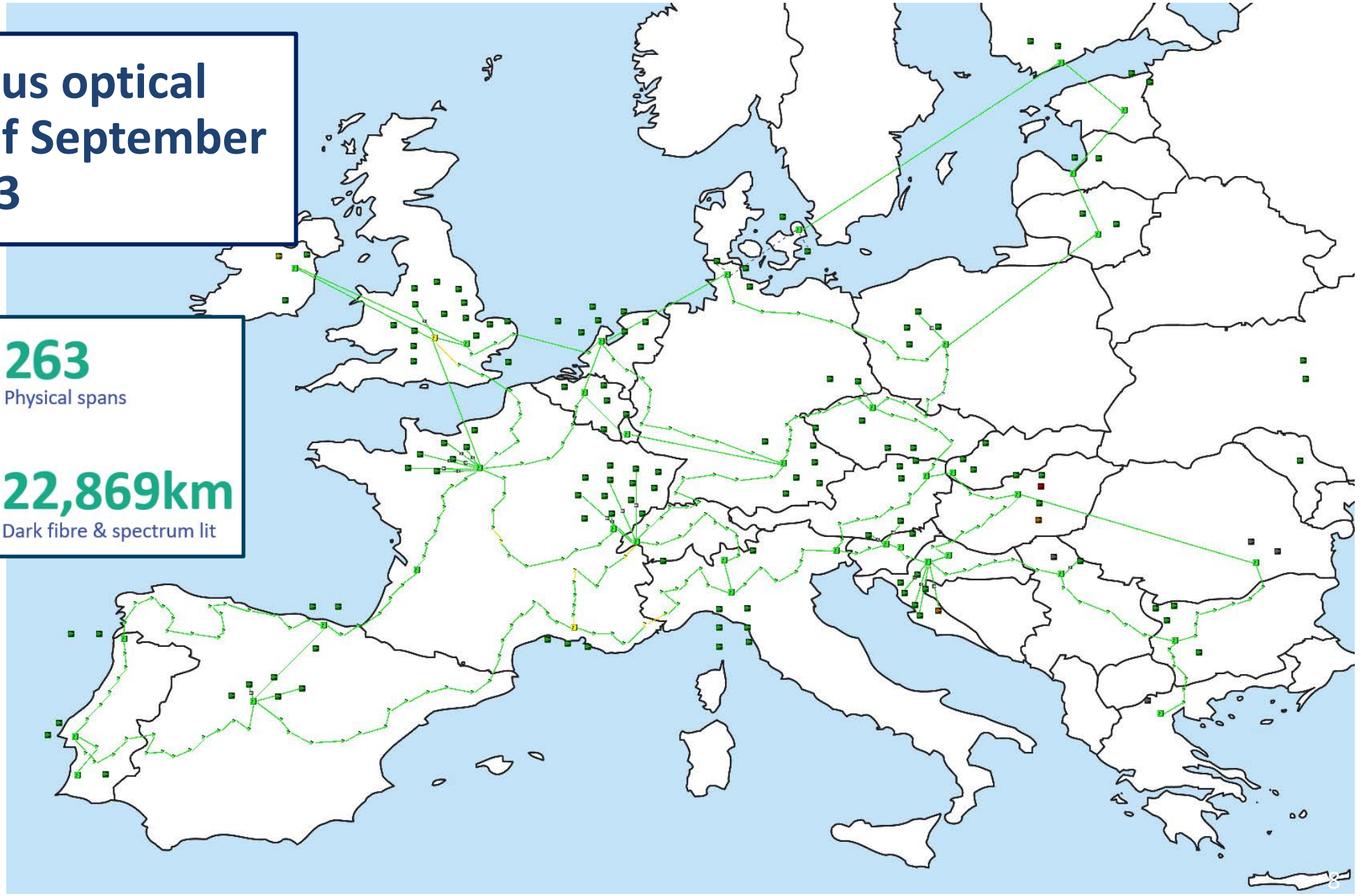
It’s real: Status optical network 14th of September 2023

28
Countries connected to GN4-3N network
(includes new 100G leased services)

263
Physical spans

368
New Infinera nodes

22,869km
Dark fibre & spectrum lit



Infrastructure Project 2: EaPConnect (https://eapconnect.eu/)

RENAM: Moldova

GRENA: Georgia

URAN: Ukraine

AZSciencenet: Azerbaijan

Asnet-AM: Armenia

CONNECT **INTEGRATE** **STRENGTHEN**

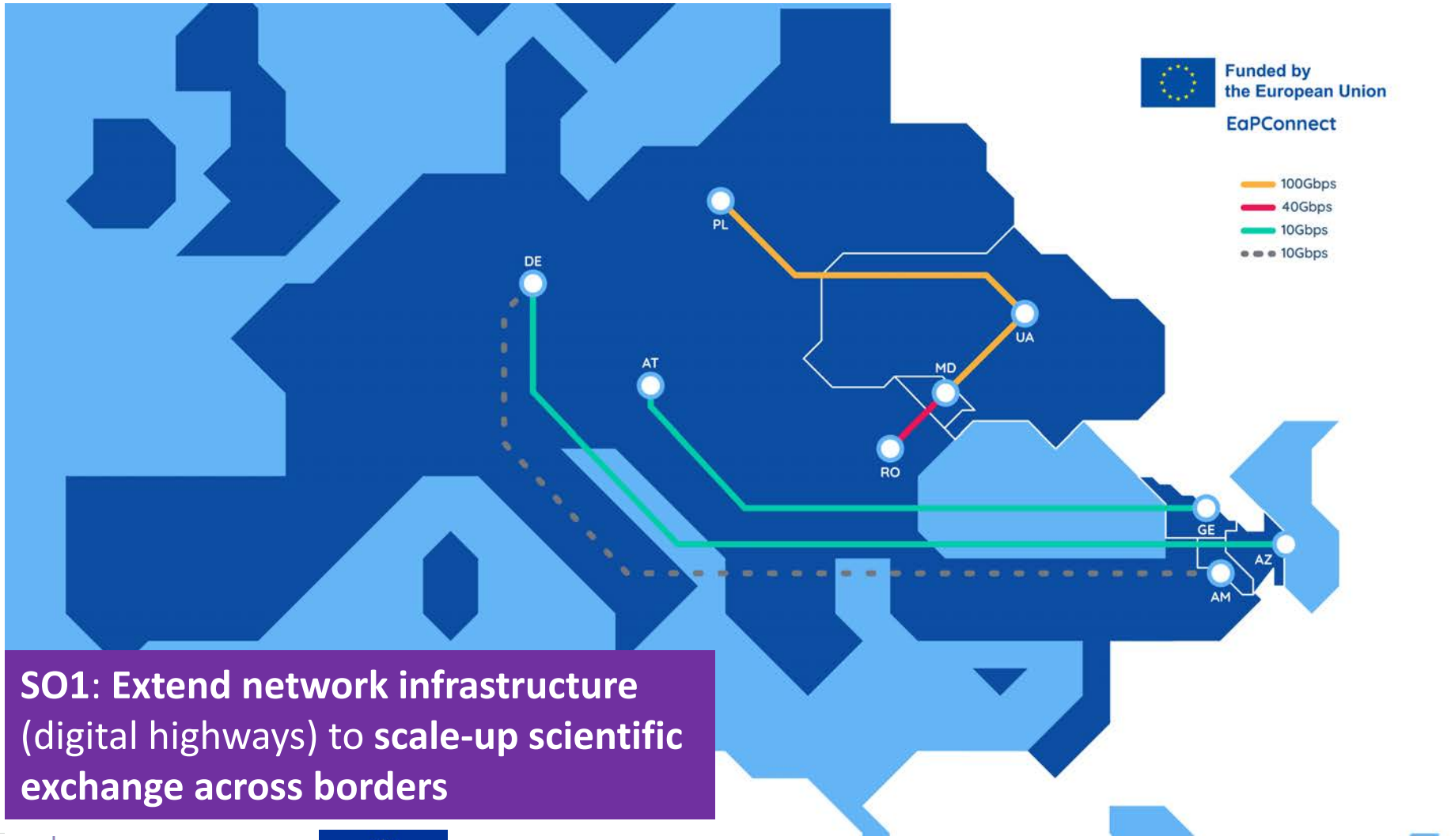
SO1: **Extend network infrastructure** (digital highways) to **scale-up scientific exchange across borders**

SO2: Increase the **use of services** implemented under EaPConnect and offer new services to enhance international cooperation in R&E.

SO3: Strengthen EaP **NRENs' position** in the national R&E ecosystems

1st Phase: 2015-2021
2nd Phase: 2020-2025
Total funding: 24.5 M€

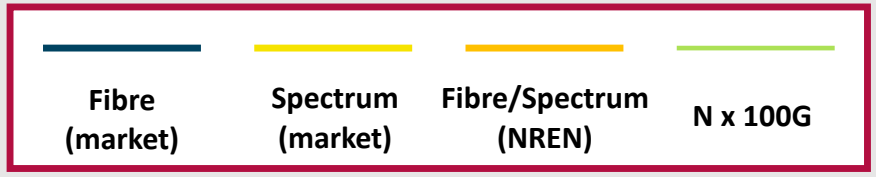
Infrastructure Project2: EaPConnect (https://eapconnect.eu/)



SO1: **Extend network infrastructure** (digital highways) to **scale-up scientific exchange across borders**

EASTERN ACCESS:
INTEGRATION IN THE NETWORK

32 countries integrated in this infra (and add NORDUnet!)



Project 3: GN5-1 (2023-2024): Network Technology and Services

Building on the fibre and spectrum infra:

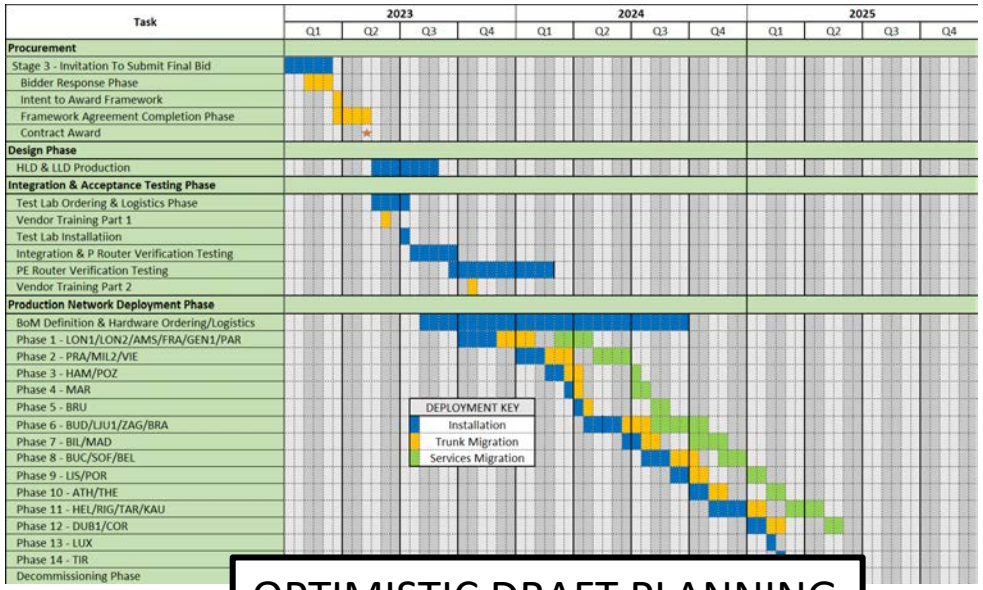
Optical Based Services

- **Spectrum**: capabilities and services
- **400G and beyond:** technology – pluggables?

Main Infra: Router Renewal: 2023-2025

- GÉANT IP Layer _needs_ renewal
- Ready for the future: 400G/800G/beyond

Capabilities: Automation



OPTIMISTIC DRAFT PLANNING

Spectrum and Dark Fibre

Dark fibre: enormous amount of capacity, long term.

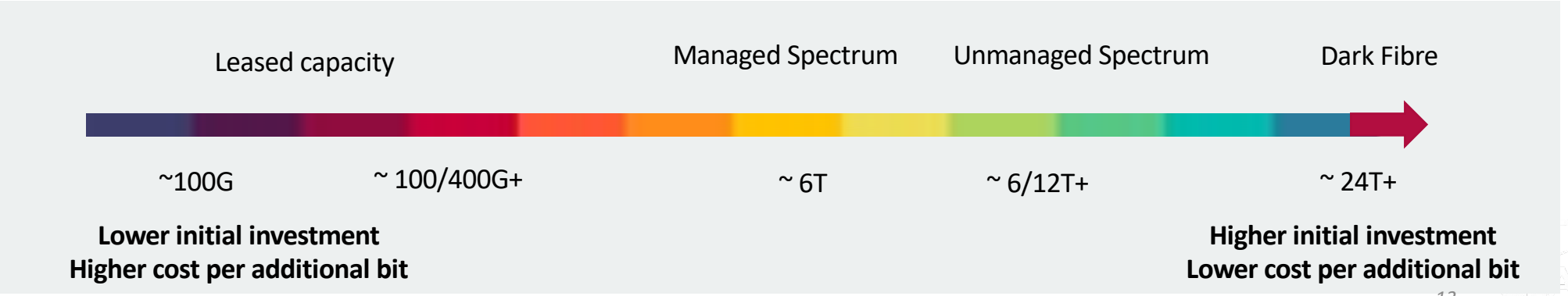
Spectrum: long-term investment *without the high cost of a full dark fibre pair*

Both allow for upgrades in line with technology evolution, at marginal cost, own control

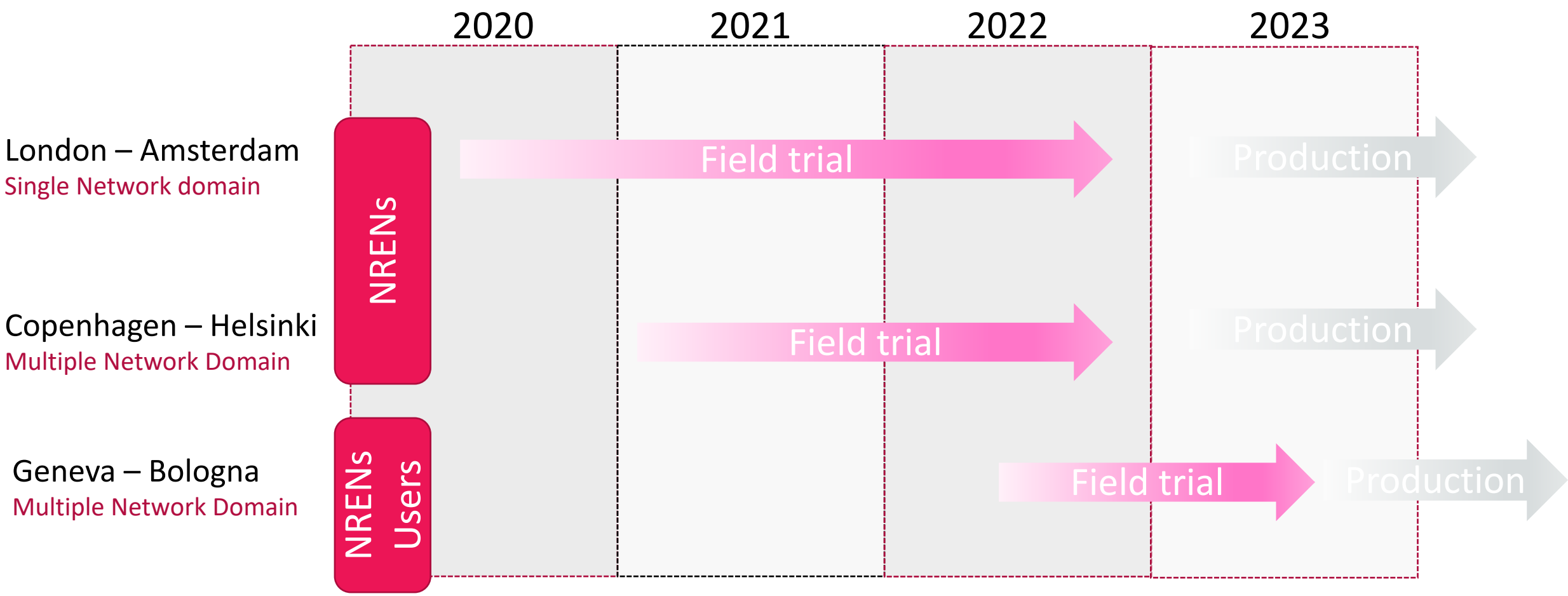
Network providers are now offering spectrum – FlexGrid used in GÉANT network

GÉANT to provide spectrum on its own fibres to members/partners

- (where that makes sense, wavelength still the standard optical service)



Spectrum Service Field trials



GN5-1: IP/MPLS renewal: ZR+ optics

- New packet equipment to support ZR+ optics => affects the way we procure optics in the future
- The reach for ZR+ optics on real-world fibre with good margins is expected to be around 750km with 400G
- The price of ZR+ 0dBM optics is expected to be in the range of 8k, resulting in up to 50% cost reduction over transponder options

Specification	Data rate	Modulation	FEC/coding gain	Target reach (fibre dependent)
OIF 400ZR	400G	DP-16QAM	OFEC/11.6dB	120km
OpenZR+	400G	DP-16QAM	OFEC/11.6dB	1400km
	300G	DP-8QAM	OFEC/11.6dB	2500km
	200G	DP-QPSK	OFEC/11.6dB	3000km
	100G	DP-QPSK	OFEC/11.6dB	8000km

Table: Max reach of ZR and ZR+ optics from Open ZR+ MSA

Guy Roberts' blog: https://connect.geant.org/2022/12/19/are-400g-zr-and-400g-xr-ready-for-geants-ip-backbone

Check with our Dark Fibre

- Most routes in GEANT are suitable for ZR+ 0dBm
- Green routes are highly suitable
- Yellow routes are possible, but may be spectral density issues

Route	fibre length (km)		Route	fibre length (km)		Route	fibre length (km)
AMS-FRA	672		BIL-PAR	1,120		LJU-LJU	4
AMS-LON1	476		BIL-POR	1,067		UDI-LJU	176
FRA-GEN1	831		LIS-POR	366		RIG-SIA	150
FRA-PRA	668		LIS-MAD	897		ZAG1-ZAG2	10
GEN1-GEN2	5		HAM-POZ	692		BEL1-BEL2	27
GEN1-MIL1	714		POZ-PRA	748		BUC-SOF	611
GEN2-MAR	700		BRA-BUD	249		PAR-BRU	524
GEN2-PAR	788		BRA-VIE	111		LIS-SUN	172
LON1-LON2	70		BUD-ZAG	456			
LON2-PAR	626		LJU-MIL1	678			
MAD-MAR	1,400		LJU-ZAG	197			
MAR-MIL2	770		BEL-SOF	458			
MIL1-MIL2	23		BEL-ZAG	546			
MIL2-VIE	1,080		SOF-THES	512			
PRA-VIE	451		DUB1-DUB2	24			

Many fibers good to go

ALTERNATIVE WITH DCI STILL EXISTS

Future: Next generation of pluggables

- CIM8: Coherent Interconnect Module 8: 1.2T pluggable coherent solution
- Available now from Acacia, not clear what equipment provider take up will be – first in DCI equipment
- Probabilistic shaping (and Nyquist carriers?)

- 800G ZR+ is in the process of being standardized
- Form factor unknown, but target of compatibility with 400G ZR+ is being targeted
- 400G XR optics are similar performance to ZR+, but with multipoint capabilities

Guy Roberts' blog: https://connect.geant.org/2022/12/19/are-400g-zr-and-400g-xr-ready-for-geants-ip-backbone

Renewal of GÉANT IP-MPLS router layer

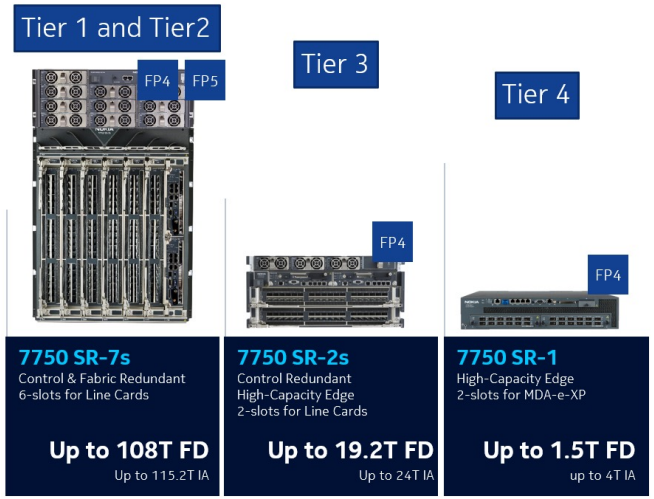
- **After 11 years of Juniper MX platform => time for renewal**

- **<u>Procuring for:</u>**
  - **A new platform:**
    - Move to standard 400 Gbps, ready for 800 Gbps and “Terabits” (“future proof”)
    - Flexible, Tbps architecture, energy use, software quality
  - **A Partner/Channel**: Implementation, maintenance and support, on European scale
  - **Appropriate Cost**: Investment + Install + Maintenance and Support (TCO based on 7 years)

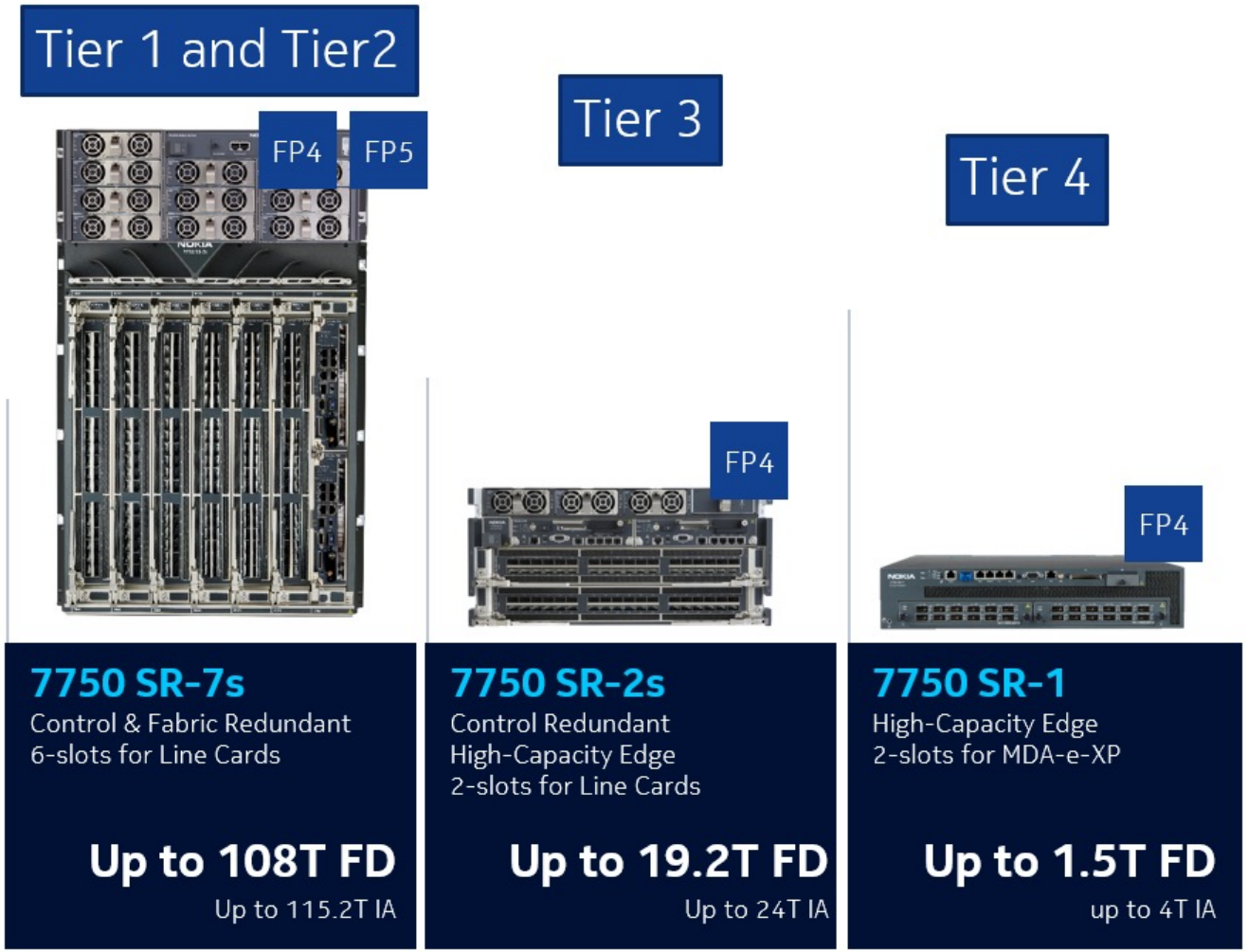
- **<u>Contract:</u> framework -** maximum running time 12 years (10 years + 2 x 1 year)

IP-MPLS router layer – Procurement and Outcome:

- **Competitive Dialogue approach - and it was a competitive process**
- **Selection concluded June 2023**
- **Platform: Nokia** has a solid, leading edge solution (7750 SR-s series)
- **Integration Partner: Nomios** (used to be called Infradata):
  - Mid-sized integrator, Dutch headquarters, European coverage, offices in FR, BE, DE, IE, PL, UK, US (San Francisco)
- **Cost:** Investment well within budget, Annual Maintenance and Support promises considerable reduction



In the network - tiers



Architecting for simplicity:

Most likely simplifying even further by “upgrading” Tier 4 to Tier 3

Cards re-useable between all nodes, one OS,…

Building Capabilities:
GAP – Geant Automation Platform

- **Based on open-source components: WorkFlowOrchestrator + Ansible**
- **Enforce the concept of "Database is King" (Single source of truth)**
  - OSS/BSS and network are finally in sync
  - Network is an instance of an intent
  - Fundamental change in the way we work
- **Support migration from Juniper to Nokia with minimal changes:**
  - Ready for Phase1 (P+PE routers – No User services yet)
  - Working on Phase2 (User services migration)
- **Capability will support future service development and service quality**
- **More info on docs.gap.geant.org (WiP)**

GAP – a shared effort

M-shaped team to build and support…

- Software Engineers
- Network Engineers
- DevOps

…but also **collaboration** with other organizations:

- SURF and ESnet (who wrote it and already use it, thanks!)
- i2CAT, GRnet, CARnet (who are helping building GAP)
- Present in GNA automation WG

… and total transparency with our **community:**

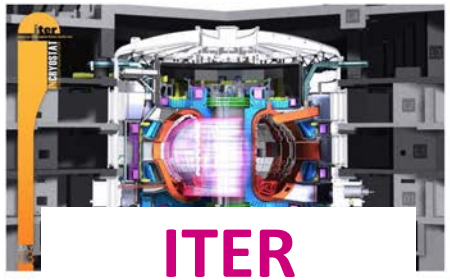
- All the code publicly available
- Documentation

Global Research – Global Traffic

LHC

- 200 sites across the globe
- 50% of GÉANT global traffic
- High Luminosity HLC from 2029

Map courtesy of Google.com



ITER

Fusion Research

- Several PBs of data per year
- To be copied from France to multiple locations globally

Astronomy

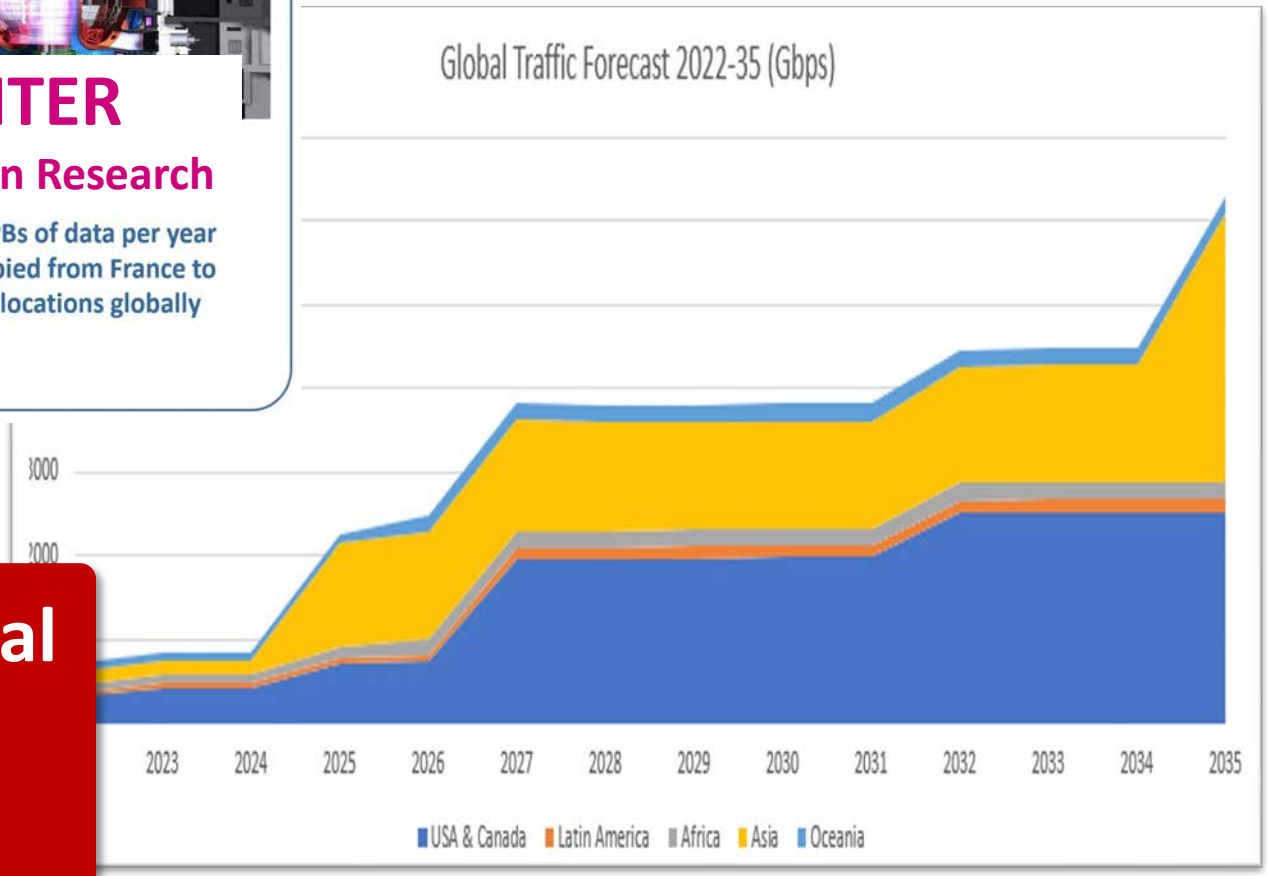
- Square Kilometre Array
  - Detectors in 100 Gbps capacities required
- Chile:
  - Cherenkov Telescope Array
  - ESO – Very Large Telescope

Earth Observation

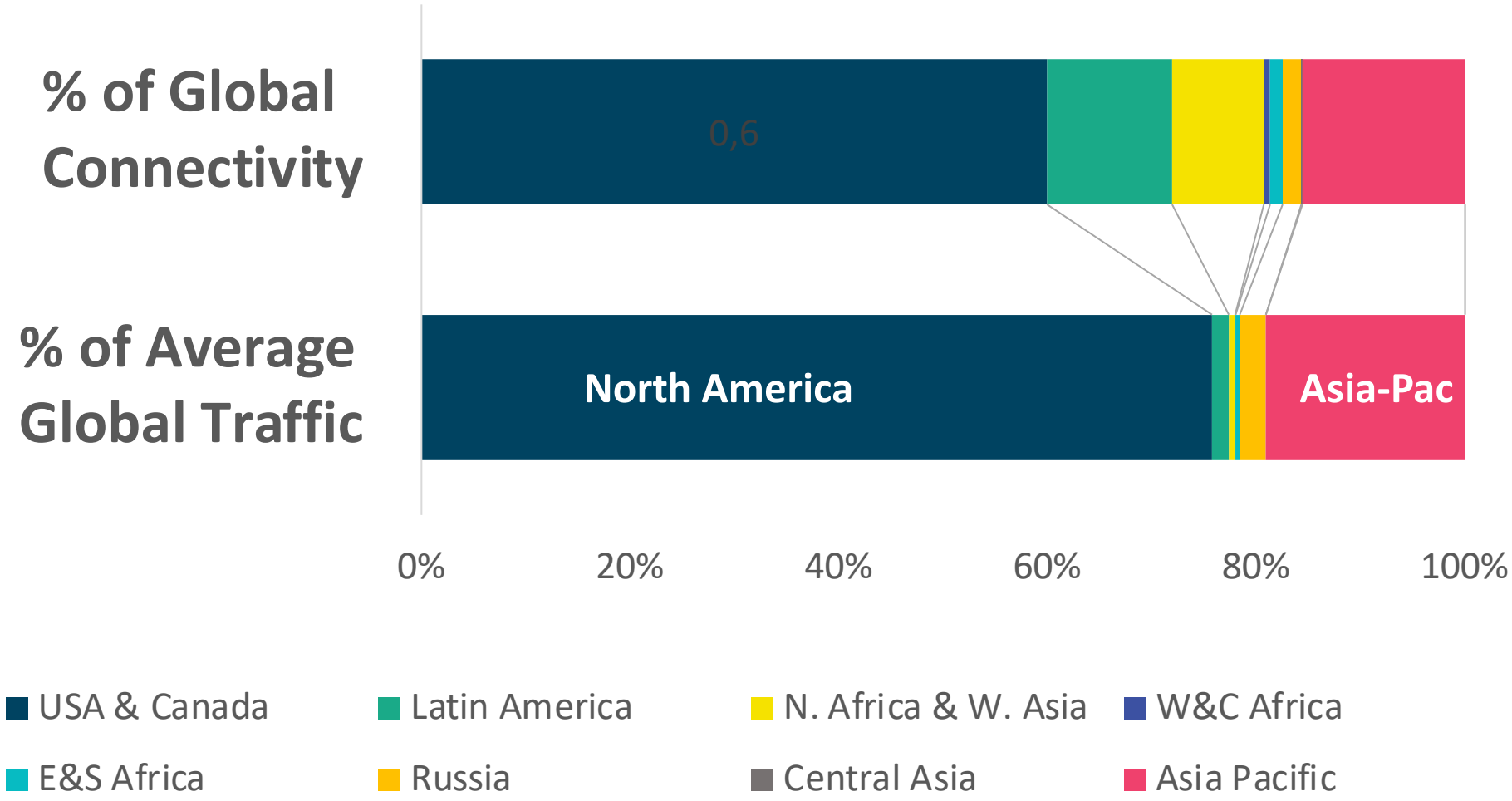
- Copernicus

Estimated annual growth

35%



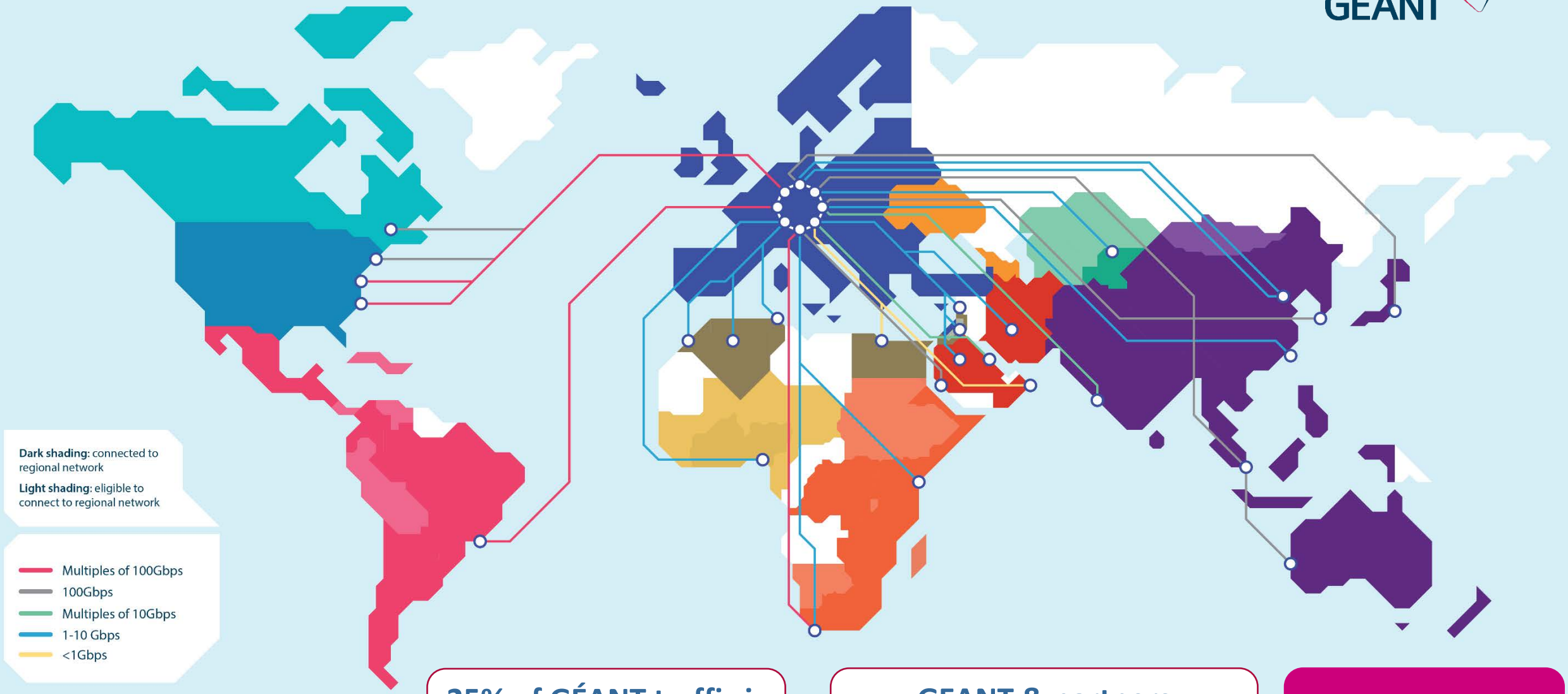
GÉANT's Global Challenge: Connectivity and Traffic (@31 Dec 22)



GÉANT's Intercontinental Traffic:

- 75% North America
- 19% Asia-Pacific region

Current NREN connectivity into Europe



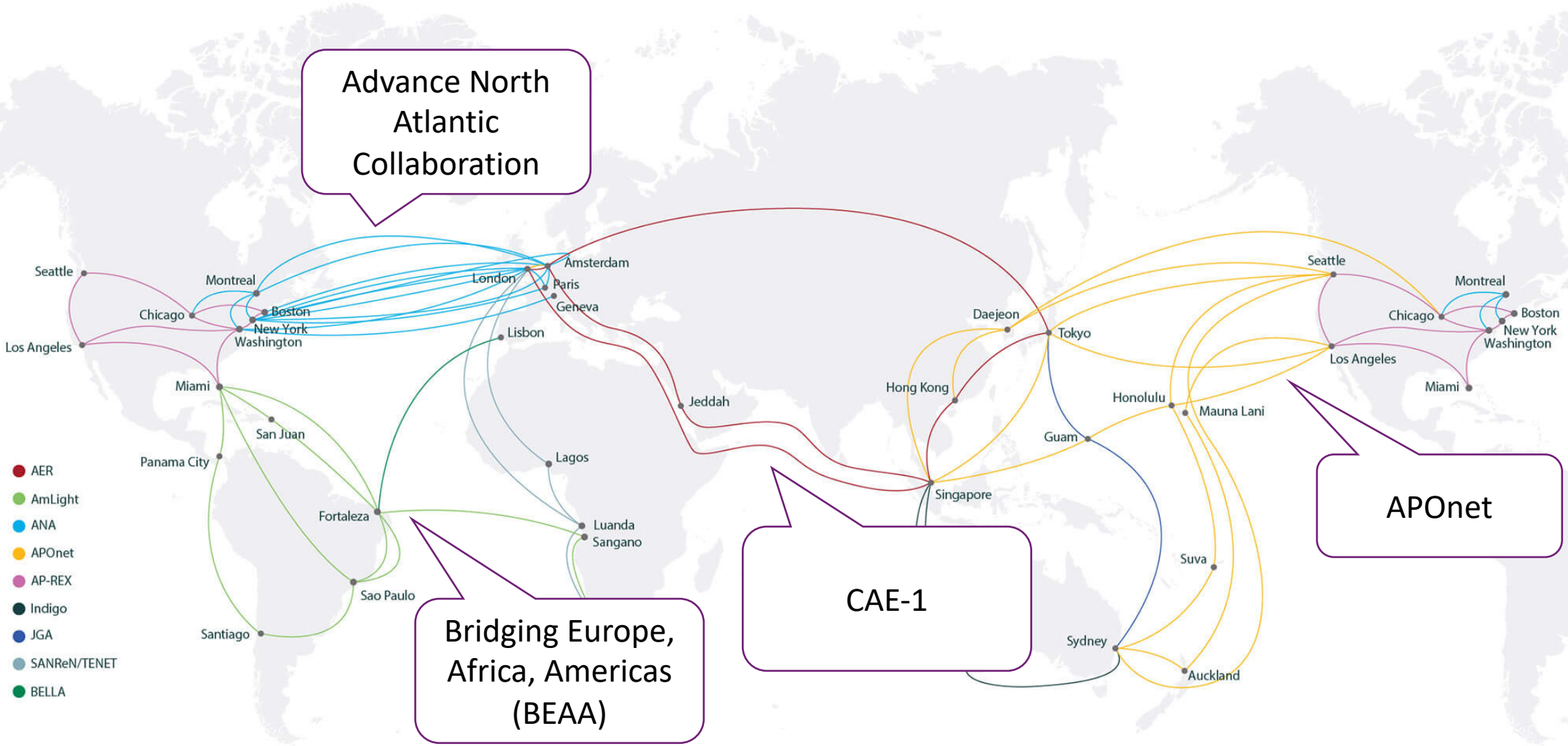
January 2023

25% of GÉANT traffic is intercontinental

GEANT & partners ~ 1.9 Tbps (2022)

35% growth

Global Research – Global Network



Investments: An example: BELLA and EllaLink

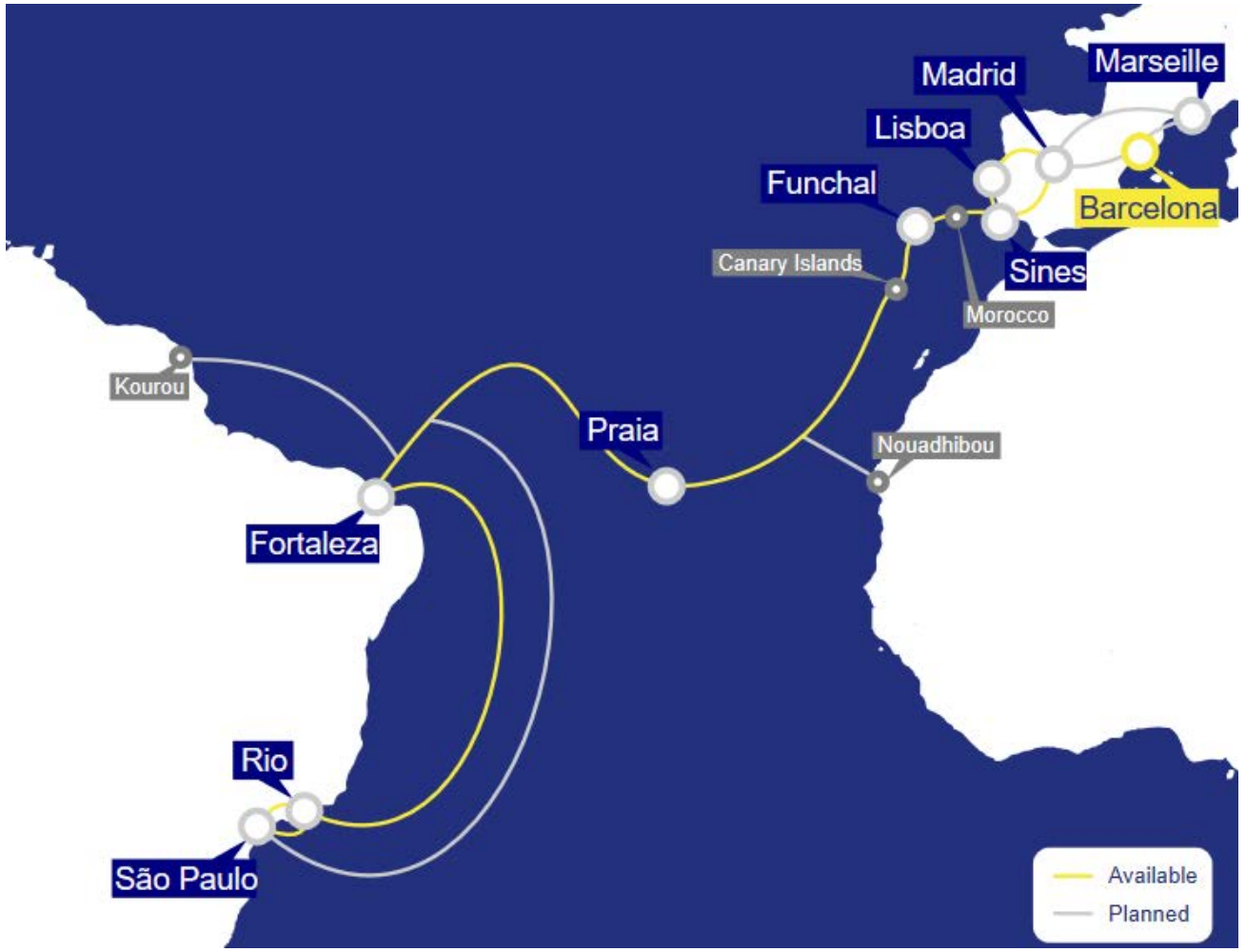
First-ever direct GÉANT-RedCLARA interconnection

Transatlantic R&E connectivity needs met for next 25 years

- Spectrum available for use by European & Latin American NRENs
- Supports Copernicus traffic with dedicated wave

Capacities for specific R&E collaborations

GÉANT-RedCLARA latency reduced up to 2/3



Source: https://ella.link

BELLA Establishes Connectivity on EllaLink

- Over 10 years in the making

Over 2 years for manufacture and deployment

Final Splice: 400km NE Mid-Atlantic ridge in early March 2021

BELLA connectivity went live in August 2021

EllaLink Inauguration
Sines, Portugal - 1 June 2021

GN5-IC1 (International Connectivity) Project

3 years GÉANT project - €15M funding

Two Main Objectives:

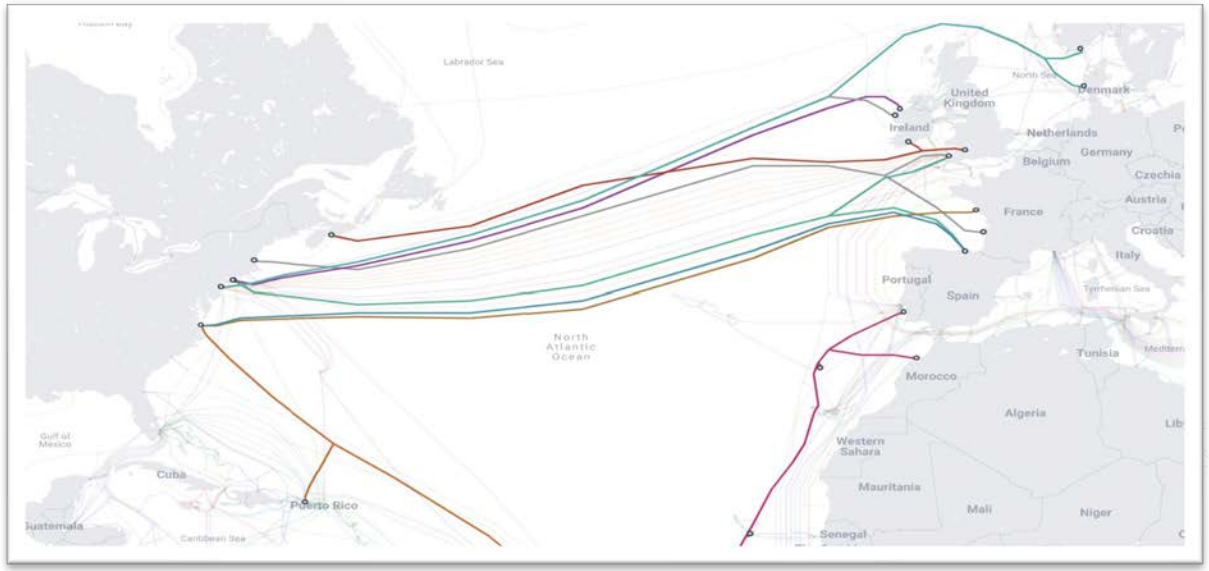
Objective 1: Procure connectivity to at least 2 world regions

Objective 2: Create intercontinental connectivity investment plan

GN5-IC1: Objective 1: Deliver Connectivity to at least two world regions

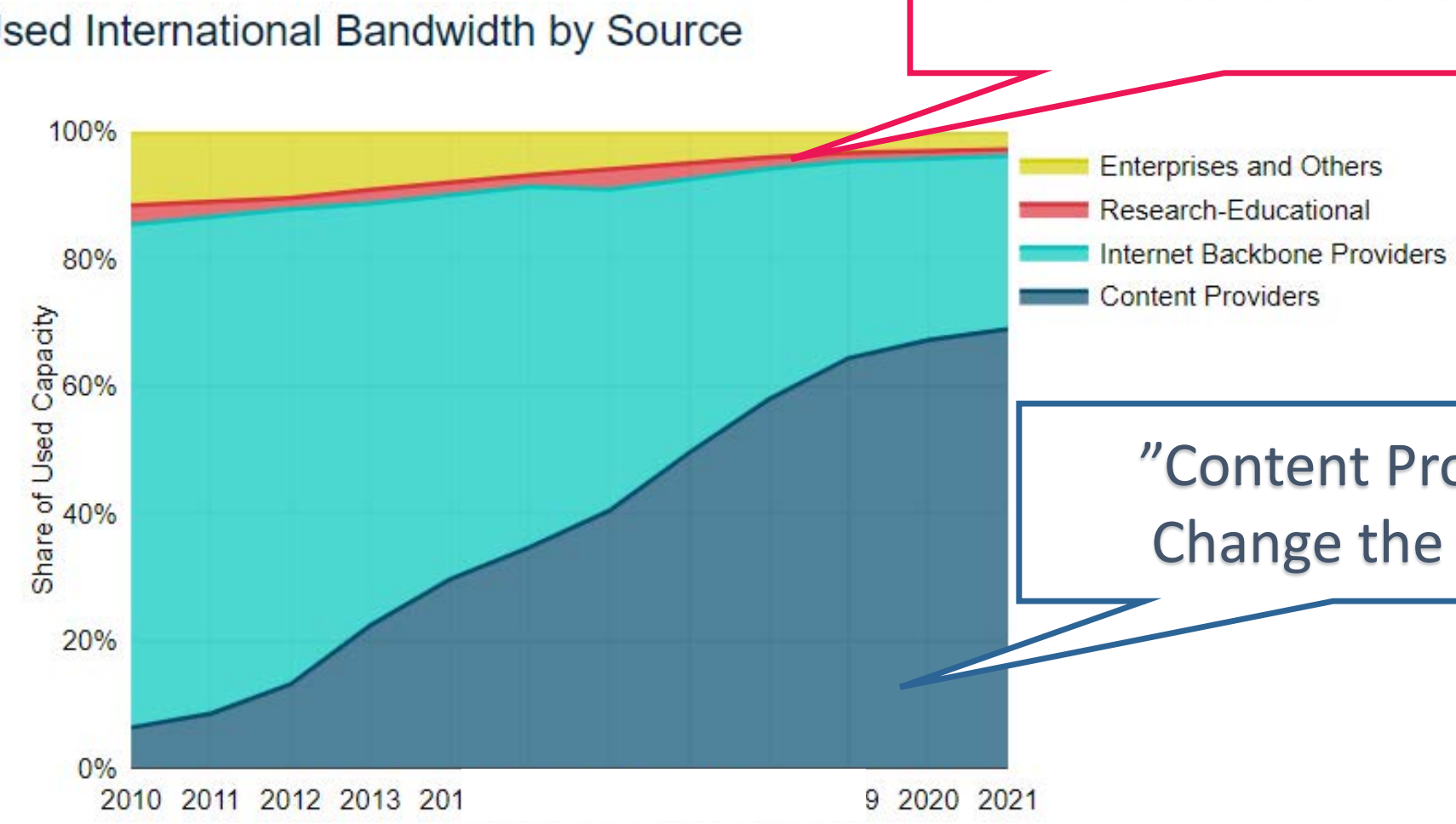
- **First region: Asia**
  - Marseille – Singapore: 100G
  - Connection to a hub
  - Collaborate with partners

- **Next region: North America**
  - **Ambition:** access to up to **4 systems**
  - **Spectrum!**
  - Collaborate with partners



Submarine cables – who is driving?

R&E makes it on the charts



”Content Providers”
Change the market

Source: TeleGeography

Download spreadsheet

GN5-IC1: Objective 2: Produce a Long-term Investment Plan

Network and User Needs

Infrastructure
Existing, Planned

Sustainability
Performance, resilience, security
Link ownership, partnerships, contract duration
Geopolitical risks

Reference topology

Preparing for IC2 and beyond

Concluding and summarising

- **GEANT is addressing long term challenges**

- **European Infrastructure radically changed**
  - Fibre/Spectrum project nearly finished
  - From 14 to 32 countries on fiber/spectrum (+ 5 x NORDUnet)
  - Packet layer renewal to follow soon, 800G ready

  - Automation and new services

  ⇒ Capacity and Capabilities on European footprint

- **International connectivity focus**
  - Long term investments in the next few years

  ⇒ (Access to) Capacity and Capabilities on global scale

Thank You

Any questions?

www.geant.org

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