International networking for LHC

Communication Systems group 40th years anniversary
1st November 2023
Edoardo Martelli

LHC Computing Model

Back in the late 1990s, it was already clear that the expected amount of LHC data would far exceed the computing capacity at CERN alone. Distributed computing was the sensible choice.

The first model proposed was MONARC (Models Of Networked Analysis at Regional Centres for LHC Experiments), on which the experiments originally based their computing models.

In September 2001, CERN Council approved the first phase of the LHC Computing Grid project, led by Les Robertson of CERN's IT department. From 2002 to 2005, staff at CERN and collaborating institutes around the world developed prototype equipment and techniques. From 2006, the LHC Computing Grid became the Worldwide LHC Computing Grid (WLCG) as global computing centres became connected to CERN to help store data and provide computing power.

WLCG Tier Structure

WLCG uses a tier structure with the CERN data centre as Tier-0. CERN sends out data to each of the 11 major data centres around the world that form the first level, or Tier-1.

Each Tier-1 site is then linked to a number of Tier-2 sites, usually located in the same geographical region.
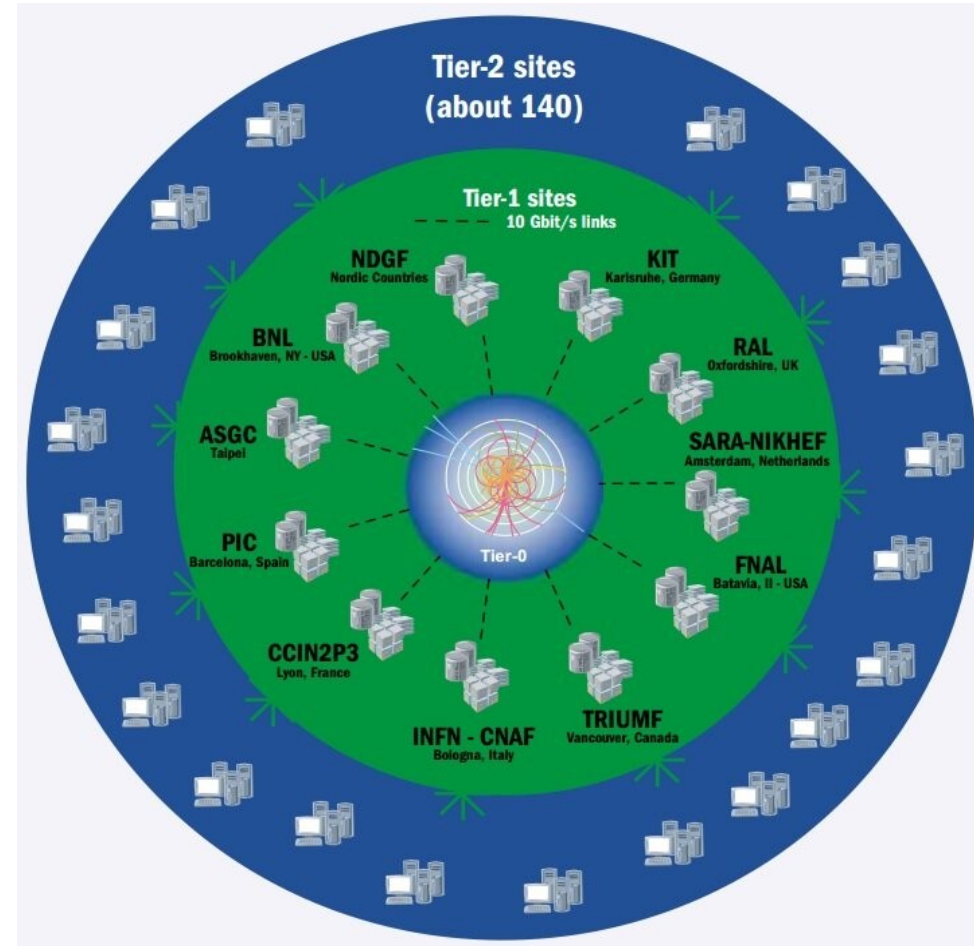
Datatag

DataTAG was one of the many projects that took care of prototyping the different components of the Computing Grid

DataTAG ran from 2002 to 2004 with the aim of testing high speed network devices and improve performance of data transfers over long distances.

DataTAG had a lab made of pair of routers provided by Cisco, Juniper and Alcatel. The routers were installed at CERN and at Starlight in Chicago. The two labs were connected by a transatlantic link, which started at 2.5Gbps and was later upgraded to 10Gbps

Elise Guyot, Olivier Martin and Edoardo Martelli, IT-CS members of DataTAG

Some DataTAG routers in the External Network area of the B513 computer centre

First WLCG router at CERN

Juniper was initially selected as the platform to connect the Tier0-Tier1 links because of being one of the first routers supporting 10Gbs interfaces.

It was quite soon replaced by cheaper Force10 routers and sold to the second-hand market

Martin Fluckiger (IT-CS-EN) install a linecard on a brand-new Juniper MX router.

The birth of LHCOPN

From the early 2005, the network teams of the Tier0 and Tier1s sites and the Research and Education Network providers (REN) started meeting regularly to design the architecture of the network to connect the 11 Tier1s to the Tier0.

They designed a network with a star topology with CERN Tier0 in the centre.
The network was called **LHC Optical Private Network, LHCOPN**. The world **Optical** was chosen because SURFnet wanted to highlight the use of innovative transmission technologies of the time. **Private Network** because the use of the link was reserved to the 12 sites only to transfer WLCG data.

The initial 11 Tier1 sites were: CA-TRIUMF, DE-KIT, ES-PIC, FR-IN2P3, IT-INFN-CNAF, NDGF, NL-T1, TW-ASGC, UK-RAL, US-BNL, US-FNAL.

LHCOPN

LHCOPN: LHC Optical Private Network

Will be used to move the data produced by the experiments to the Tier1 data centres all over the world.

Only the Tier0-Tier1s traffic will be carried by this network.

Every Tier1 will have a main dedicated 10Gbps link to CERN (lightpath) and a 10Gbps backup connection.

The lightpaths will be provided by Geant2 (Dante), Renater, USLHCnet (Caltech) and several NRENs [National Research and Education Network].
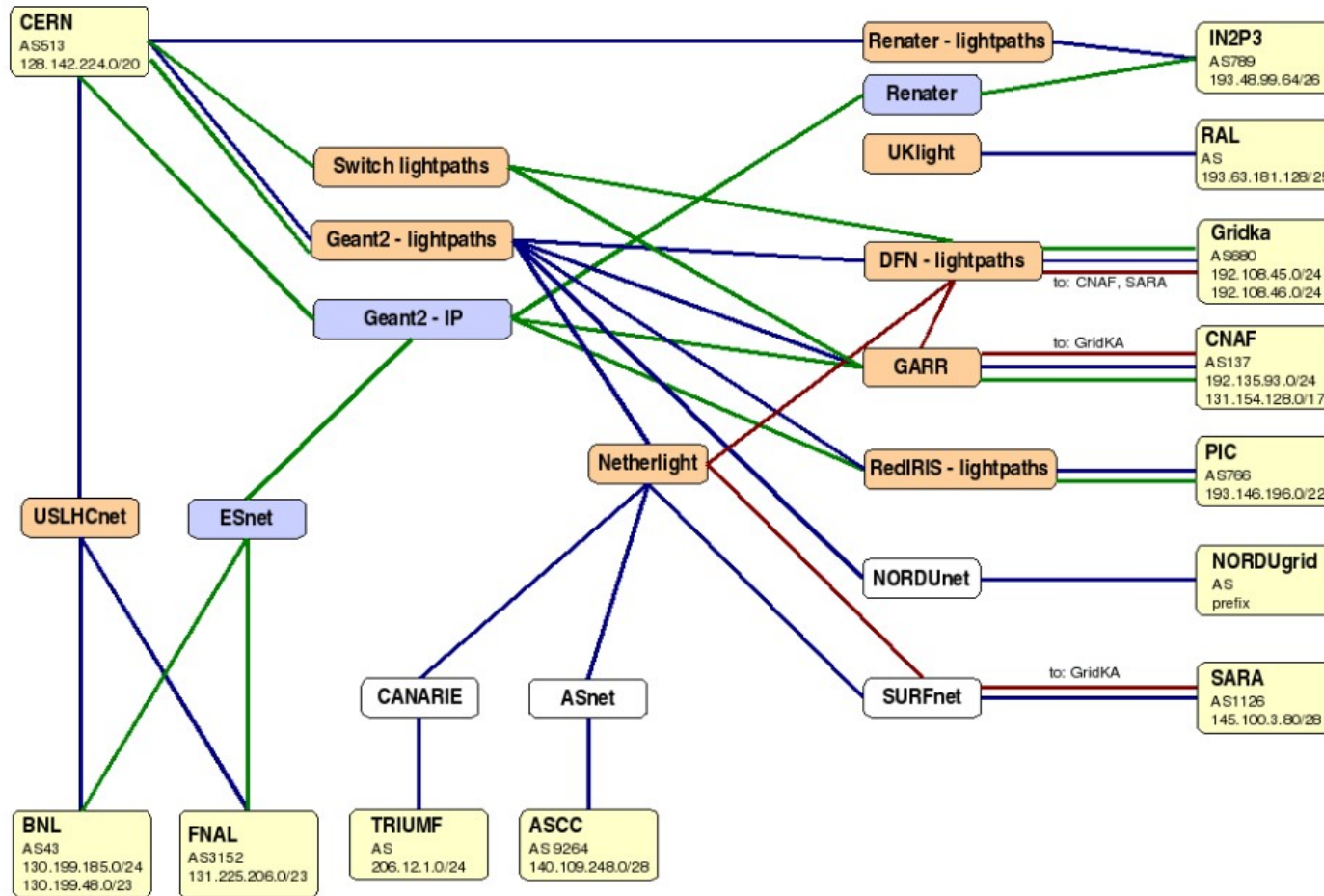
Slide from a presentation of LHCOPN to the IT-CS group meeting 7th of November 2005

LGC Network

The LCG network will interconnect the experiments and the server farms (CPUs, Disks, Tapes).

The backbone consists in eight Force10 E1200. They are being installed and configured in the Computer Center.

They will be interconnected with 10 times 10Gbps ethernet links. The core will be able to forward 1.2Tbps
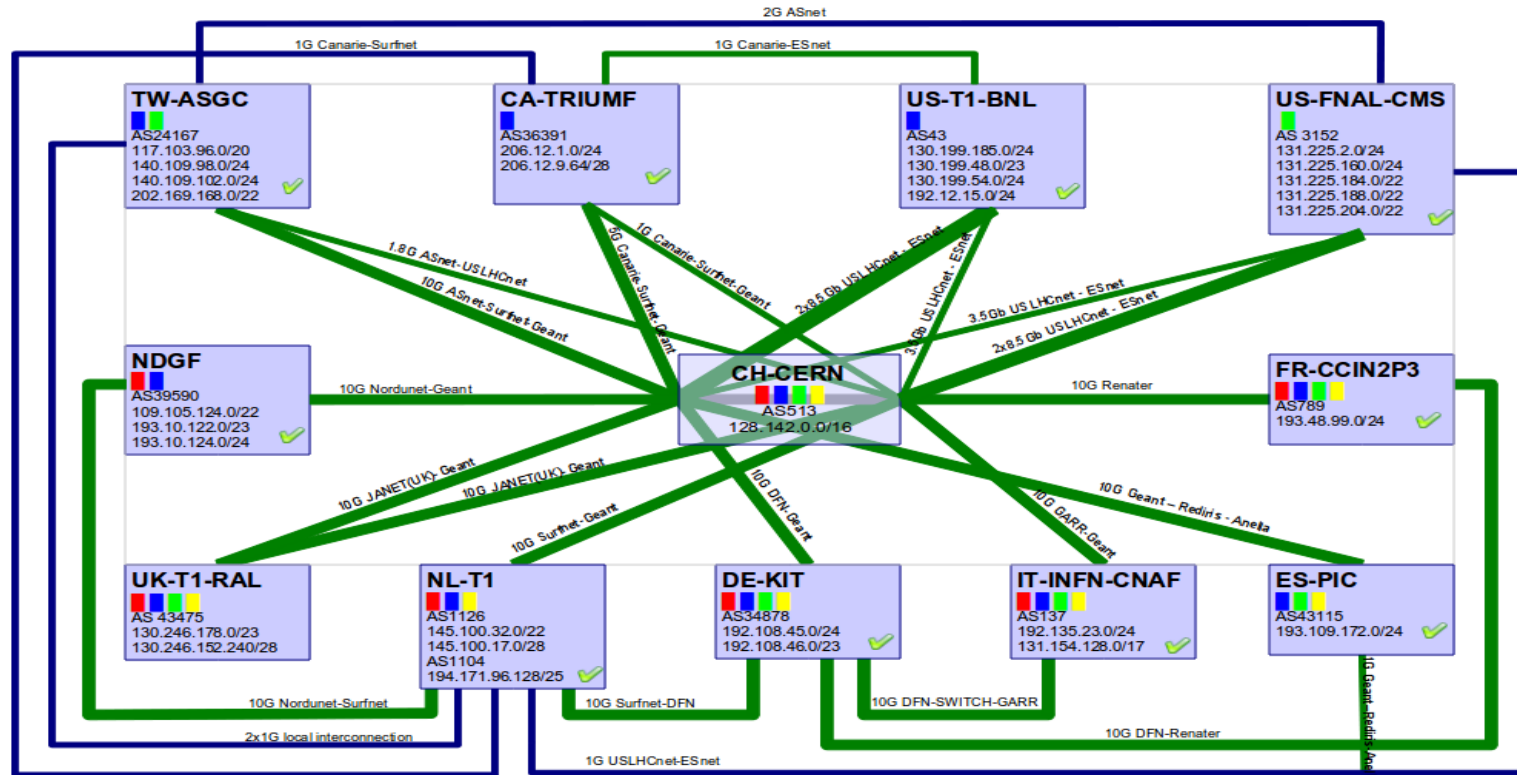

Slide from a presentation of LHCOPN to the IT-CS group meeting 7th of November 2005

LHCOPN logo

The LHCOPN logo was designed in 2009 by Rosy Mondardini, WLCG communication person
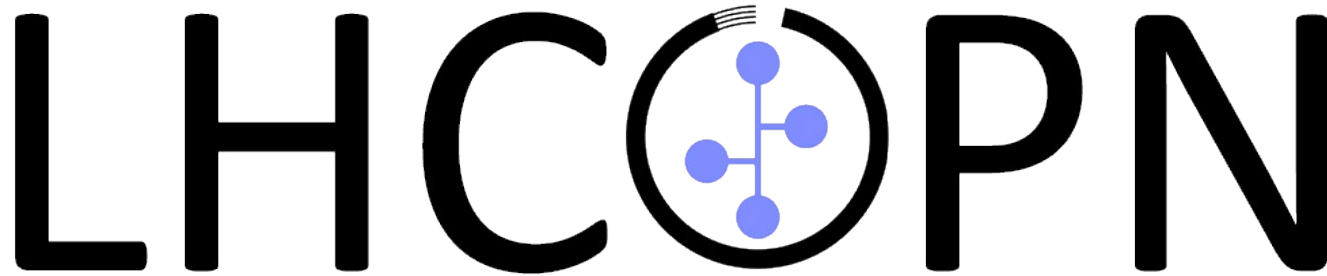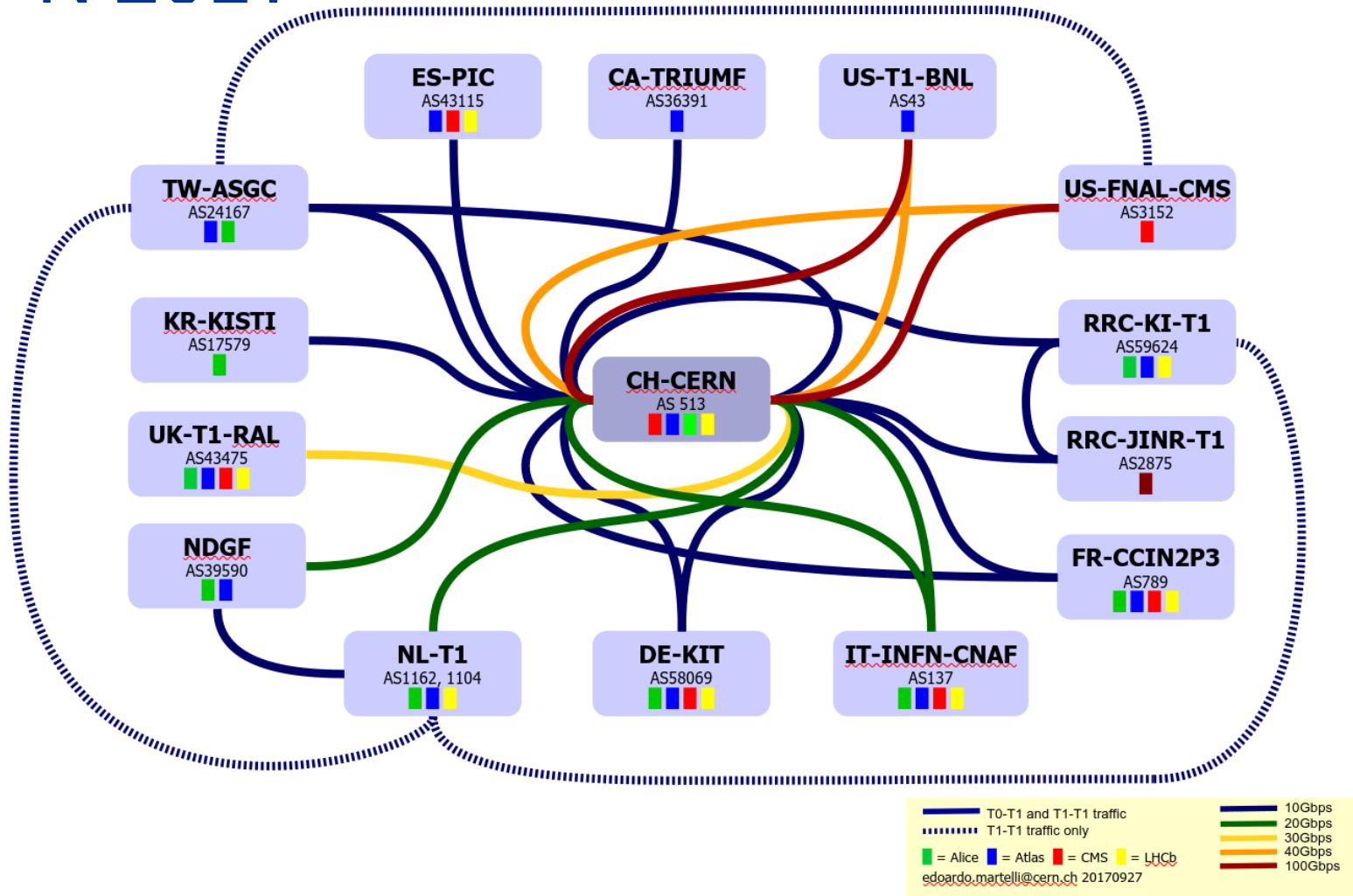
LHCOPN 2010

LHCOPN evolution

The topology later evolved in a star and a partial mesh, with direct links between some pairs of Tier1s.

In 2013 RU-KI and RU-JINR joined LHCOPN and in 2014 it was the time of KR-KISTI.
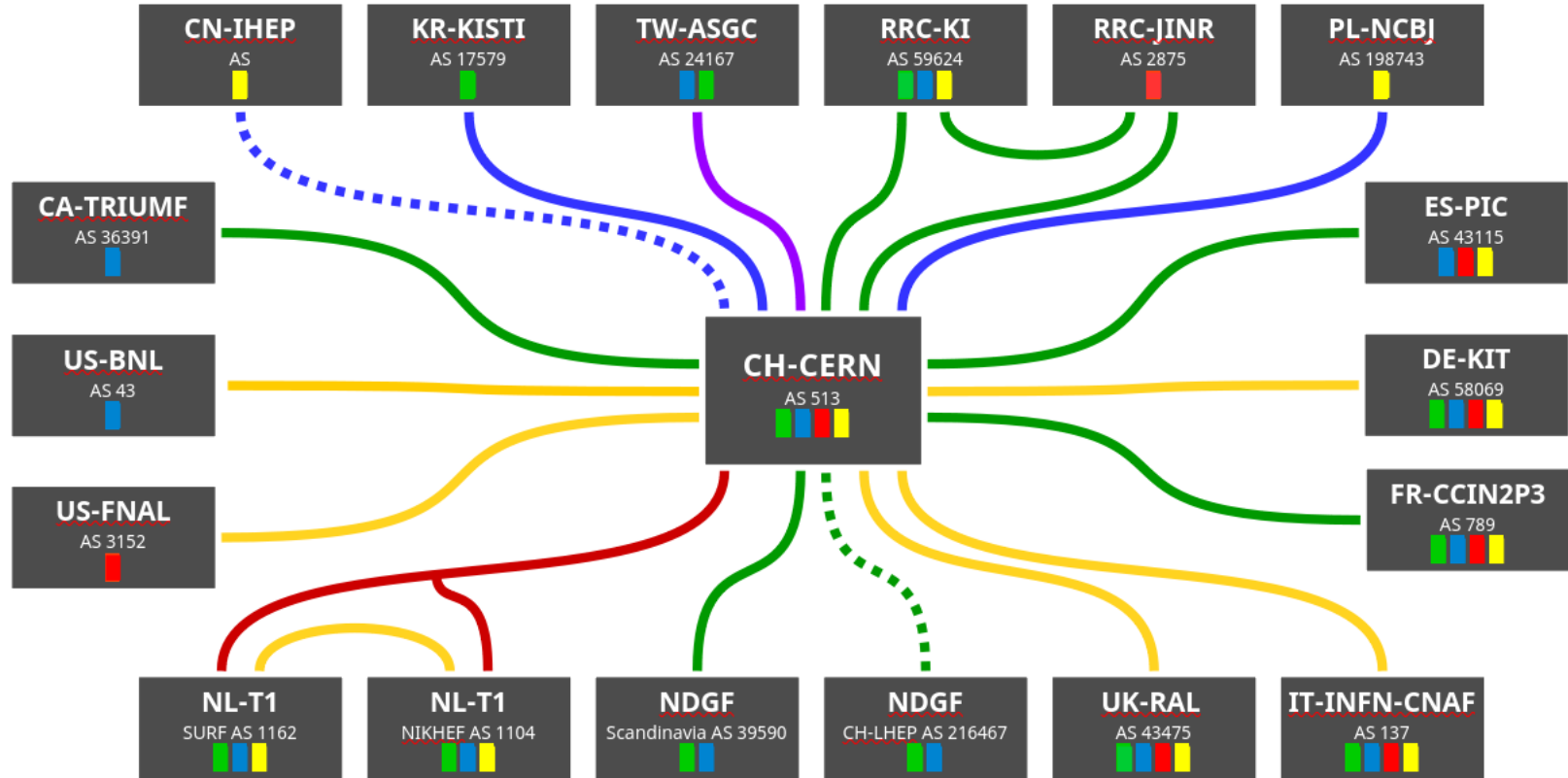
During the years the Tier1-Tier1 links were discontinued, replaced by LHCONE.

The membership of the network didn't change till 2023, when TW-ASGC announced the decision to discontinue the Tier1 role and disconnect from LHCOPN. At the same time three new sites have started the procedure to become Tier1 and are currently in the process to connect to LHCOPN: PL-NCBJ, CN-IHEP. CH-LHEP (part of NDGF)

LHCOPN 2017

LHC**OPN** 2023

CN-IHEP AS
KR-KISTI AS 17579
TW-ASGC AS 24167
RRC-KI AS 59624
RRC-JINR AS 2875
PL-NCBJ AS 198743

CA-TRIUMF AS 36391
US-BNL AS 43
US-FNAL AS 3152

CH-CERN AS 513

ES-PIC AS 43115
DE-KIT AS 58069
FR-CCIN2P3 AS 789

NL-T1 SURF AS 1162
NL-T1 NIKHEF AS 1104
NDGF Scandinavia AS 39590
NDGF CH-LHEP AS 216467
UK-RAL AS 43475
IT-INFN-CNAF AS 137

= Alice = Atlas = CMS = LHCb

10Gbps
20Gbps
100Gbps
200Gbps
400Gbps

edoardo.martelli@cern.ch 20231013

14

Evolving computing model

In 2010, during a successful Run1, the LHC experiment remarked that the network performed much better than expected, and better than other computing components.

They decided to evolve the computing model, such that the Tier2s were no longer bound to their closer Tier1

The LHCOPN community was involved to develop a network to better serve Tier1s and Tier2s

Computing model evolution
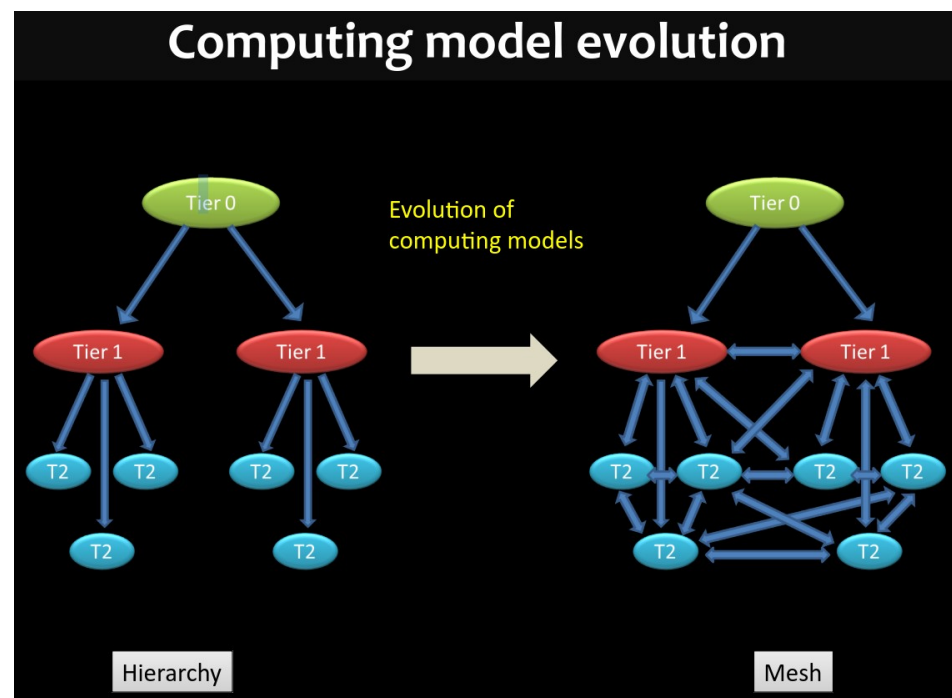
First community events

2010, June: <u>Transatlantic connectivity Workshop</u> at CERN
- Evolving computing models required better connectivity for Tier2s to reach any Tier1

2010, October 2010: <u>LHCOPN meeting</u> at CERN
- Tier2s connectivity WG mandate from LHCOPN community

2010. November-December: preparation of Tier2s connectivity proposals
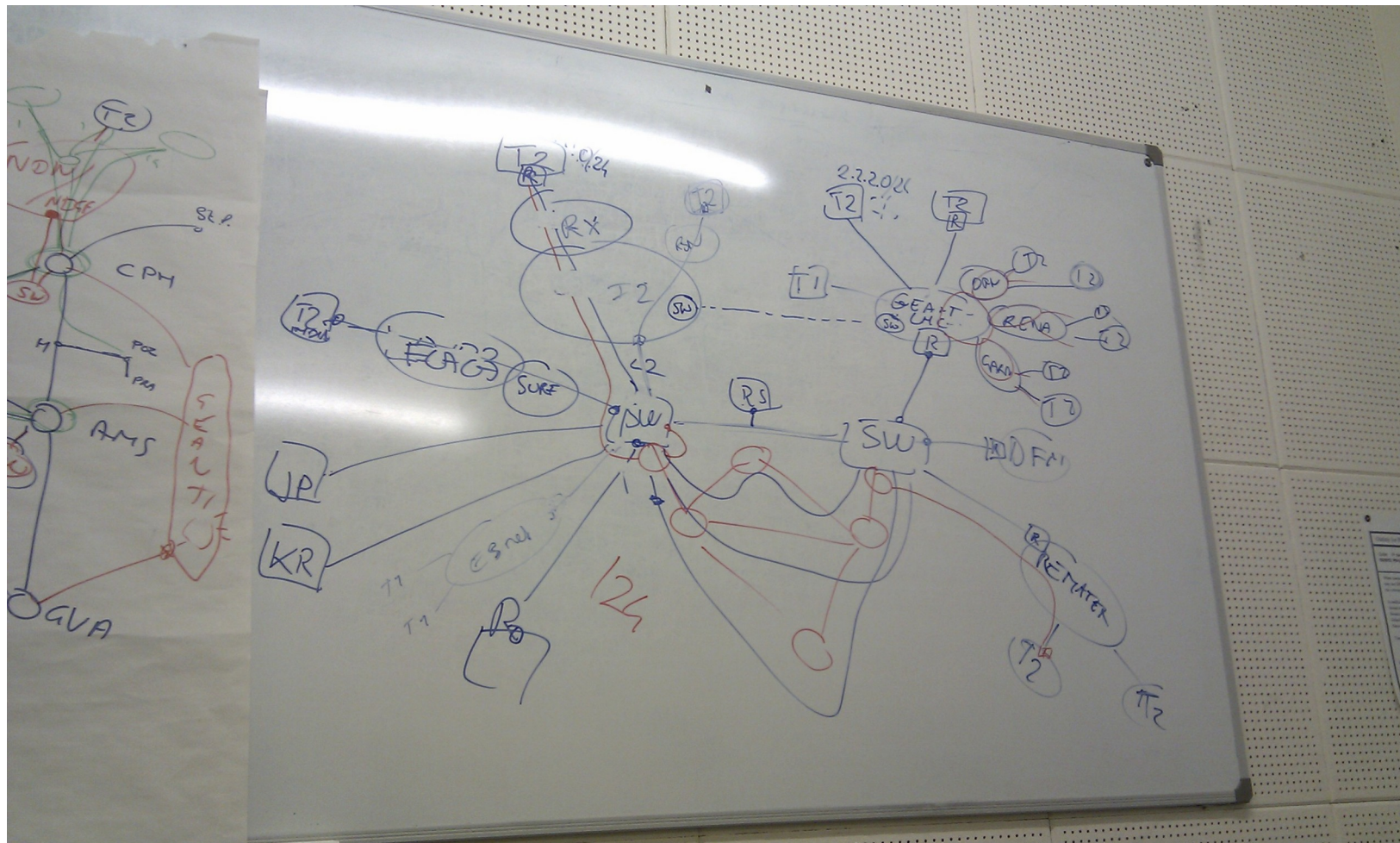- ESnet, GEANT, CERN+SURFnet work independently to prepare architecture proposals

Transatlantic connectivity workshop at CERN, 2010
David Foster IT-CS group leader) on the left, Artur Barczyk (Caltech) standing

Transatlantic connectivity workshop at CERN, 2010

LHCONE brain-storming, CERN October 2010

LHCONE architectures

2011 January: <u>Workshop on connectivity for Tier2s</u> at CERN
- First T2s connectivity Technical Meeting
- Two proposals: distributed IXP (L2VPN), Federated VRFs (L3VPN)

2011:
- GEANT, ESnet, CERN, Internet2, SURFnet, NORDUnet implement together a L2VPN prototype
- main issues: loops, unused transatlantic links

2011, December: <u>LHCONE architecture workshop</u> at SARA
- L2VPN turns out to be too complicated in a multi-domain network. Dropped.
- New design proposed: multidomain L3VPN
- It's a success. The main RENs implement their own LHCONE instance and peer together

First LHCONE meeting in Lyon, 2011

Three members of IT-CS:
- *David Foster (GL)*
- *John Shade*
- *Edoardo Martelli*

LHCONE L3VPN, January 2012
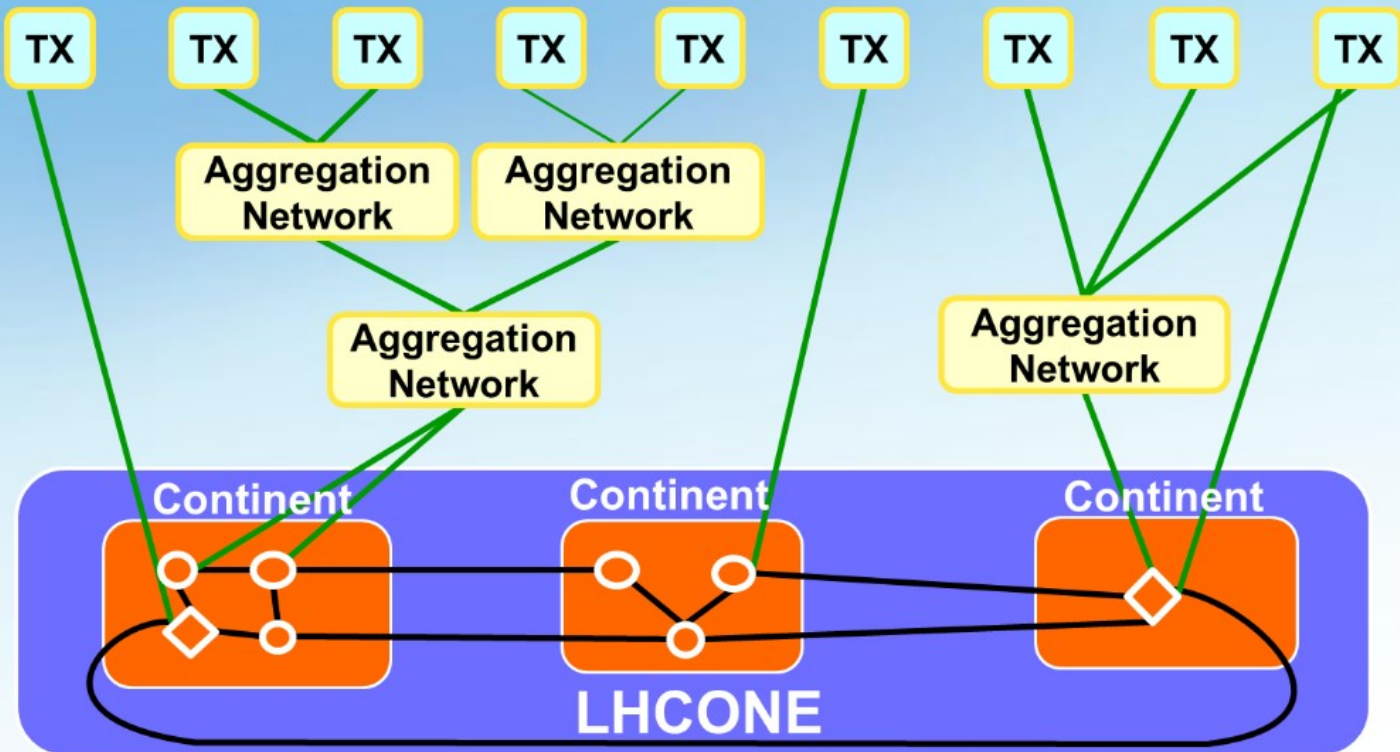
Layer3 VPN proposal presented during the workshop during the LHCONE meeting at the Internet2 offices in Washington DC

LHCONE evolution

2013, January: LHCONE extends to Asia
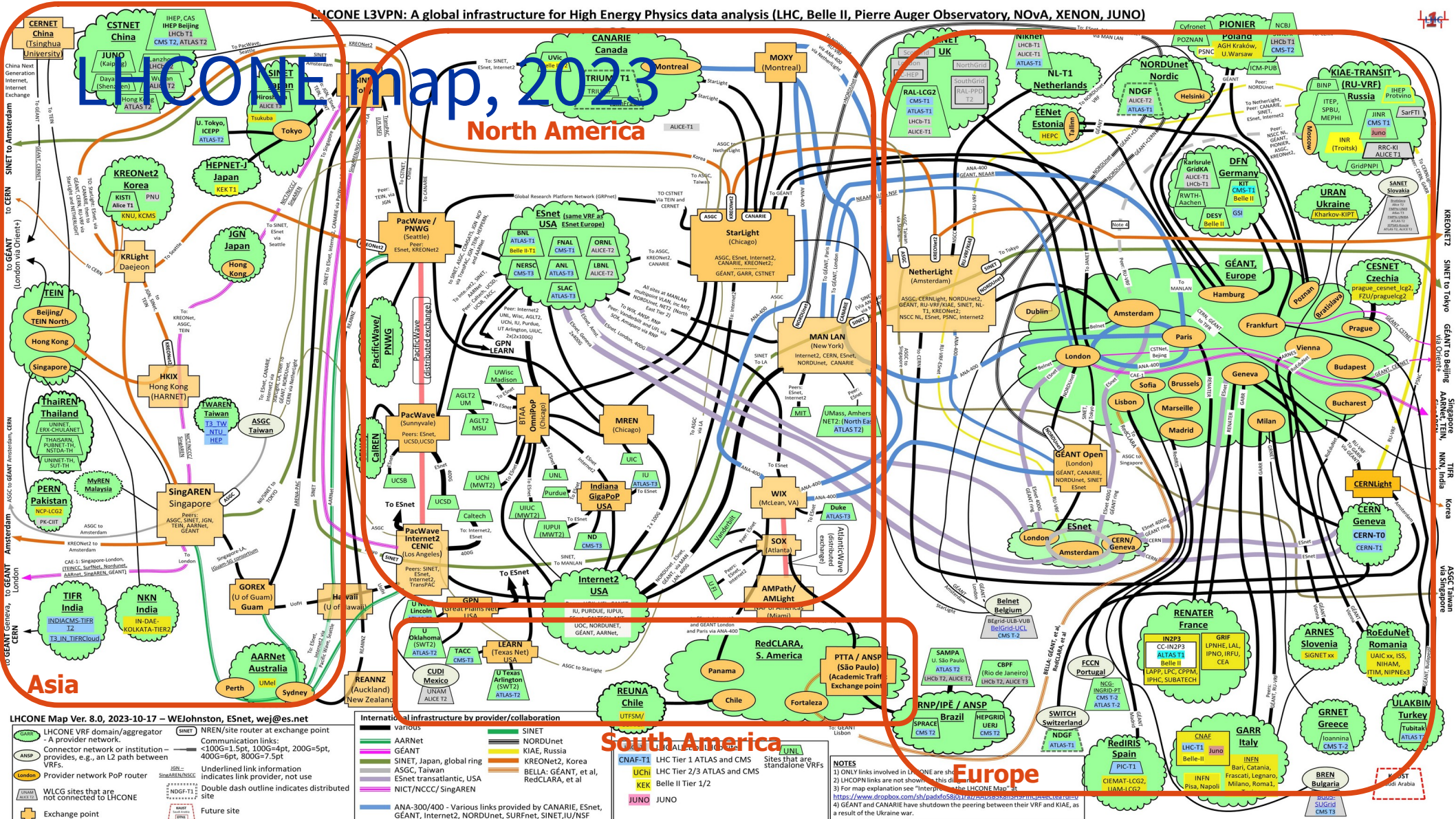- ASGC implement a VRF and reach the other VRFs via Netherlight (SURFnet)

2018, LHCONE extends to South America
- RNP implements the LHCONE VRF for the Brazilian Tier2s

Over the years, other High Energy Physics collaborations and experiment has joined LHCONE, mostly because many of their sites were already connected to LHCONE. As of today, these collaborations are part of LHCONE: BelleII, DUNE, JUNO, NOvA, Pierre Auger Observatory, US-ATLAS, US-CMS, XENON and obviously WLCG

LHCONE L3VPN: A global infrastructure for High Energy Physics data analysis (LHC, Belle II, Pierre Auger Observatory, NOvA, XENON, JUNO)

LHCONE logo

The LHCONE logo was designed around 2012 by Artur Barczyk, Caltech network architect

Questions?

edoardo.martelli@cern.ch