



U.S. DEPARTMENT OF
ENERGY



20 Years of LHCOPN

An ESnet Perspective



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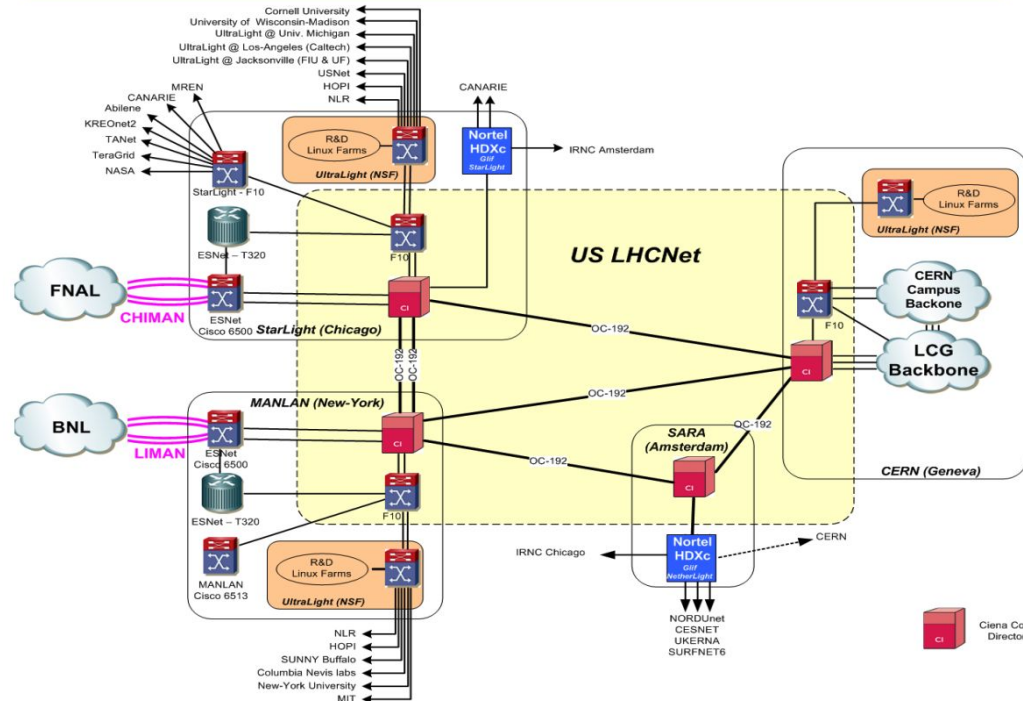
ESnet and LHCOPN - Science Driven

- ESnet has a long history of collaboration with Physics
 - HEPNET was one of two networks (with MFENET) that created ESnet in the 1980s
 - Physics has always been a leader in networking (in addition to other fields of technology)
- The story of ESnet and LHC is one of mission-driven collaboration and support
 - Science has needs at the forefront of technology and engineering
 - ESnet designs, builds, and operates a network to support science
 - Working together to make the science happen

Early US-CERN Connectivity via USLHCNet

- ESnet connected BNL and FNAL to USLHCnet
- USLHCNet carried traffic to CERN
- ESnet had no transatlantic circuits at this time

US-CERN backbone (“US LHCNet”) [ICFA SCIC]



Source: William Johnston

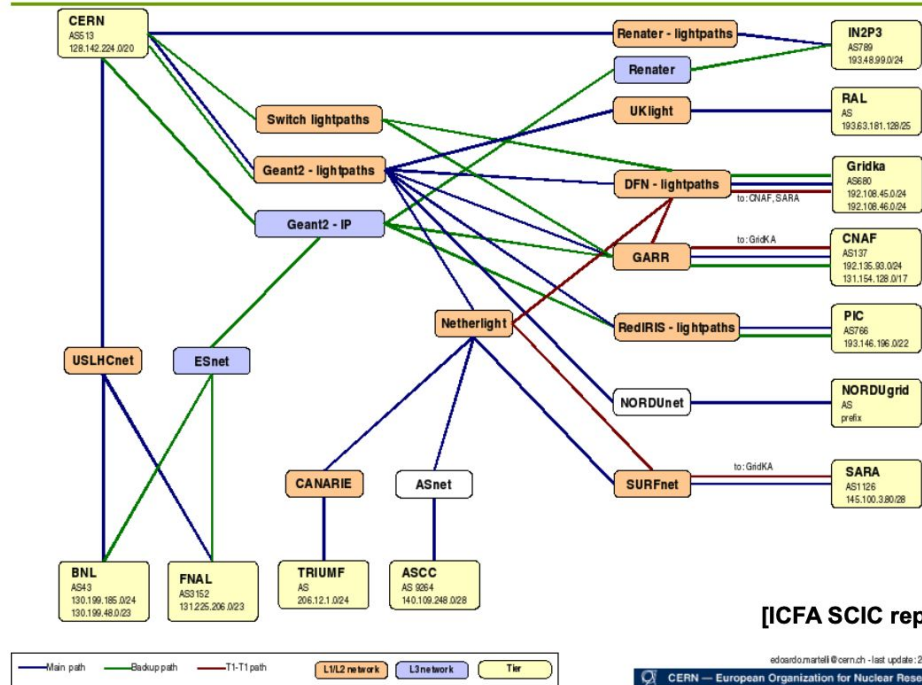
<https://www.es.net/assets/Uploads/LHC-Networking-Photonics-2007-02-26-v2.pdf>



Early CERN Connectivity via USLHCNet

- More abstract diagram
- Primary paths, secondary paths, etc.
- Notions of determinism, lack of shared fate, etc.
- ESnet architectural transition already underway at this time

Production:
LHC Optical Private Network (OPN) connecting CERN to TIER-1 centres



Source: William Johnston

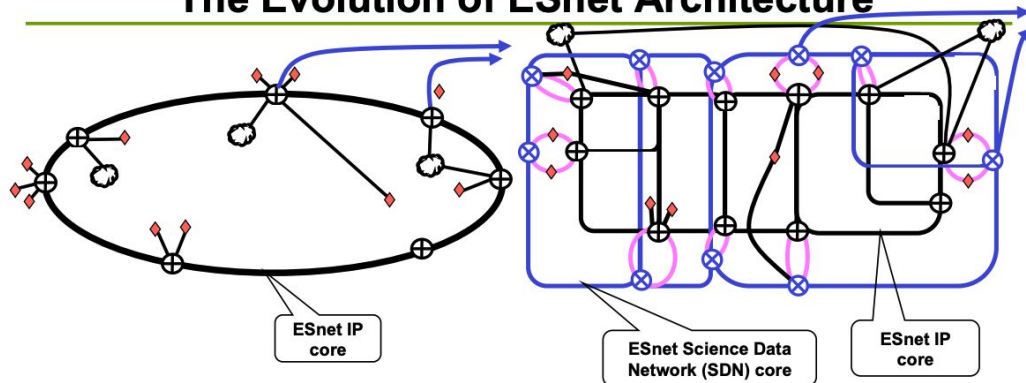
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ESnet Architecture Evolution

- Science requirements drive change
- Cooperation between ESnet, science collaborations, funding agencies
- Mission matters!

The Evolution of ESnet Architecture

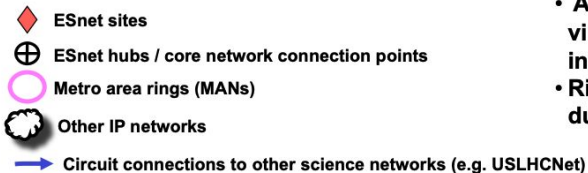


ESnet to 2005:

- A routed IP network with sites singly attached to a national core ring

ESnet from 2006-07:

- A routed IP network with sites dually connected on metro area rings or dually connected directly to core ring
- A switched network providing virtual circuit services for data-intensive science
- Rich topology offsets the lack of dual, independent national cores



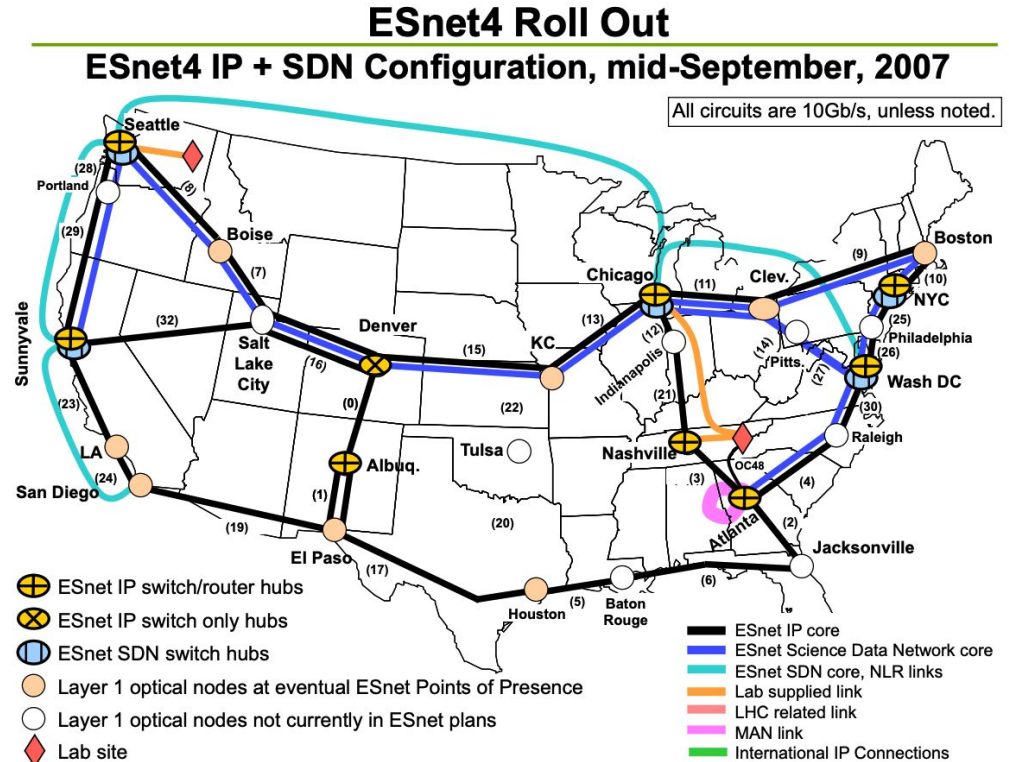
Source: William Johnston

<https://www.es.net/assets/Uploads/LHC-Networking-Photonics-2007-02-26-v2.pdf>



Upgraded Network

- Network diagram showing early architectural improvements
 - Richer footprint
 - Greater resilience
- Adding bandwidth is straightforward



Source: William Johnston

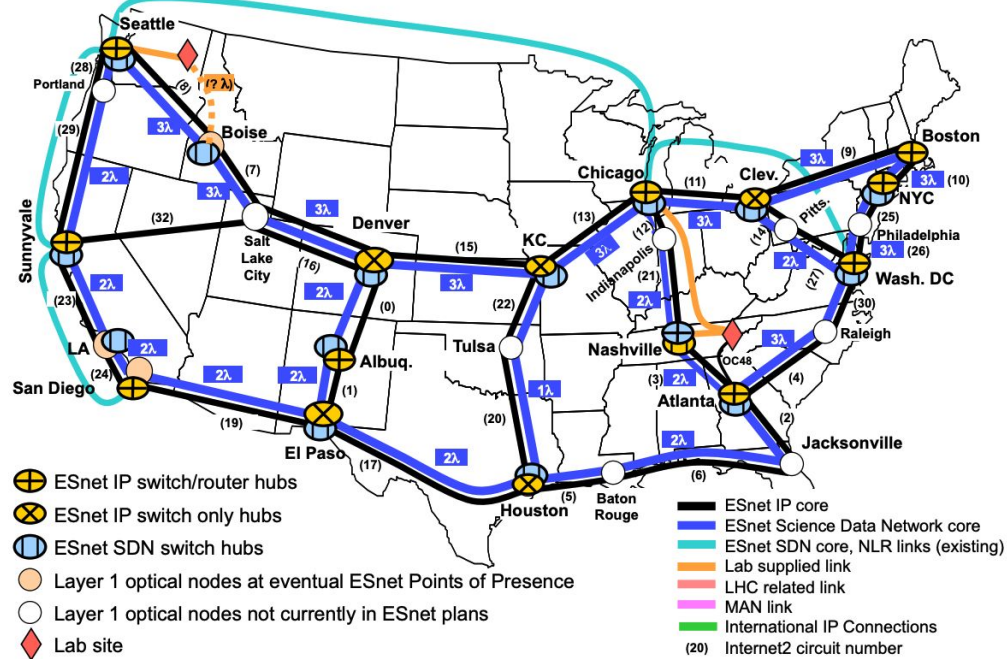
<https://www.es.net/assets/Uploads/LHC-Networking-Photonics-2007-02-26-v2.pdf>



Upgraded Network

- Significant additional capability with minimal operational pain
- OSCARS provisioned bandwidth on the blue paths

ESnet4 2009 Configuration
 (Some of the circuits may be allocated dynamically from a shared pool.)



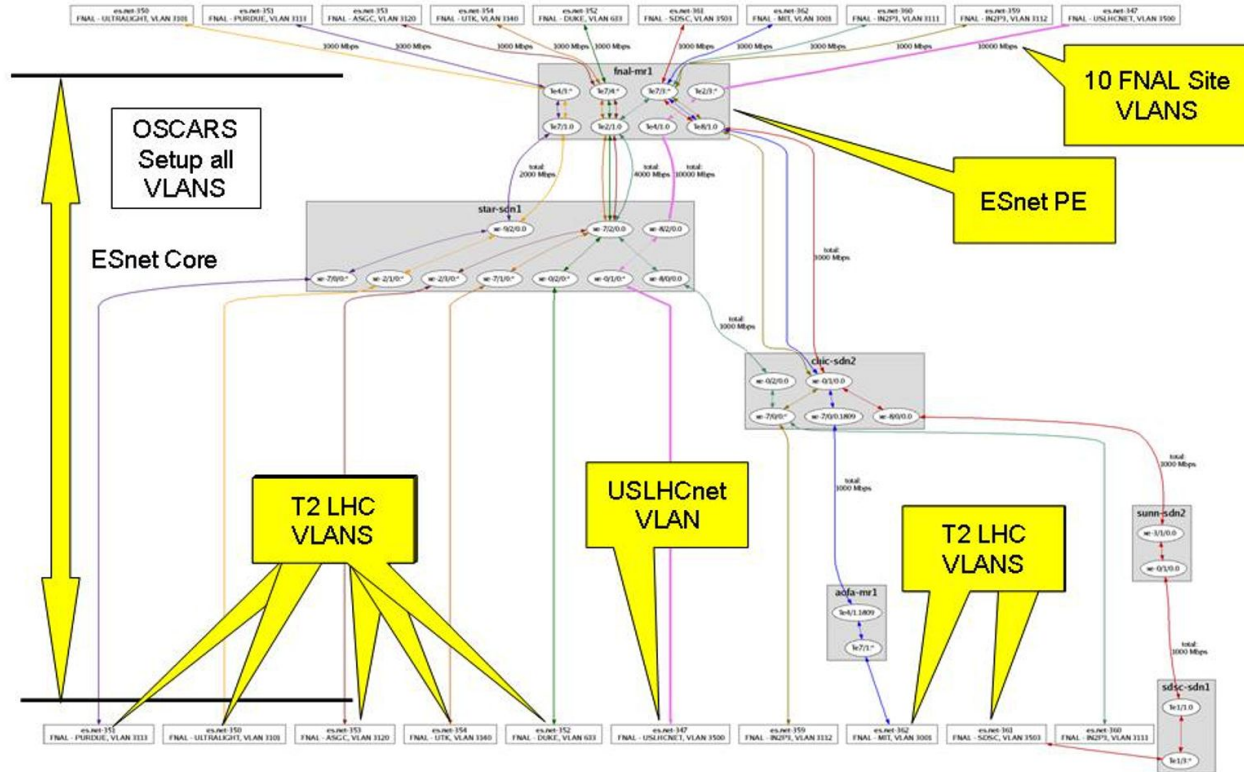
Source: William Johnston

<https://www.es.net/assets/Uploads/LHC-Networking-Photonics-2007-02-26-v2.pdf>



OSCARS Provisioning Example

- FNAL circuits
- Explicit paths eliminate shared fate
- Isolation protects different traffic classes
- Traffic failover scheme under the control of end sites (deterministic WAN behavior)

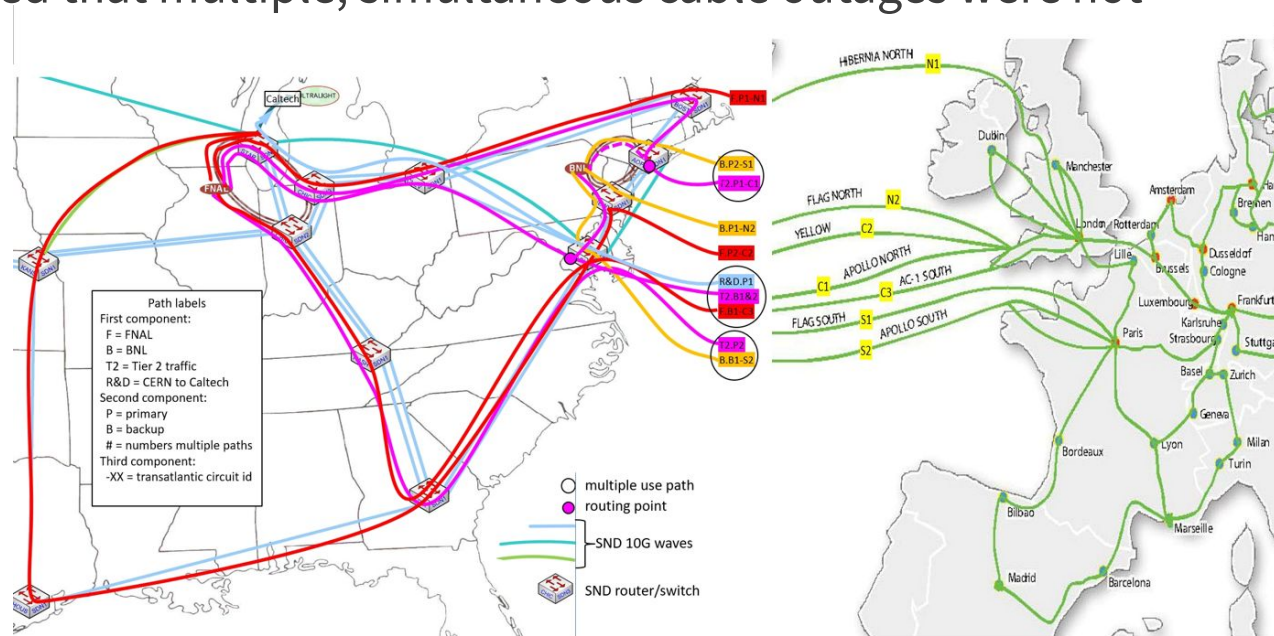


Source: William Johnston et al.

<https://www.es.net/assets/Uploads/The-Evolution-of-Research-and-Education-Networks-and-their-Essential-Role-in-Modern-Science.v5.pdf>

ESnet backbone extended to Europe (2010-2014)

- Architecture driven by an analysis of cable outages (kindly supplied by GÉANT) which showed that multiple, simultaneous cable outages were not uncommon.
- Multi-cable design to support a multiplicity of OSCARS paths
- Extremely high reliability and predictable behavior in the face of cable failure.



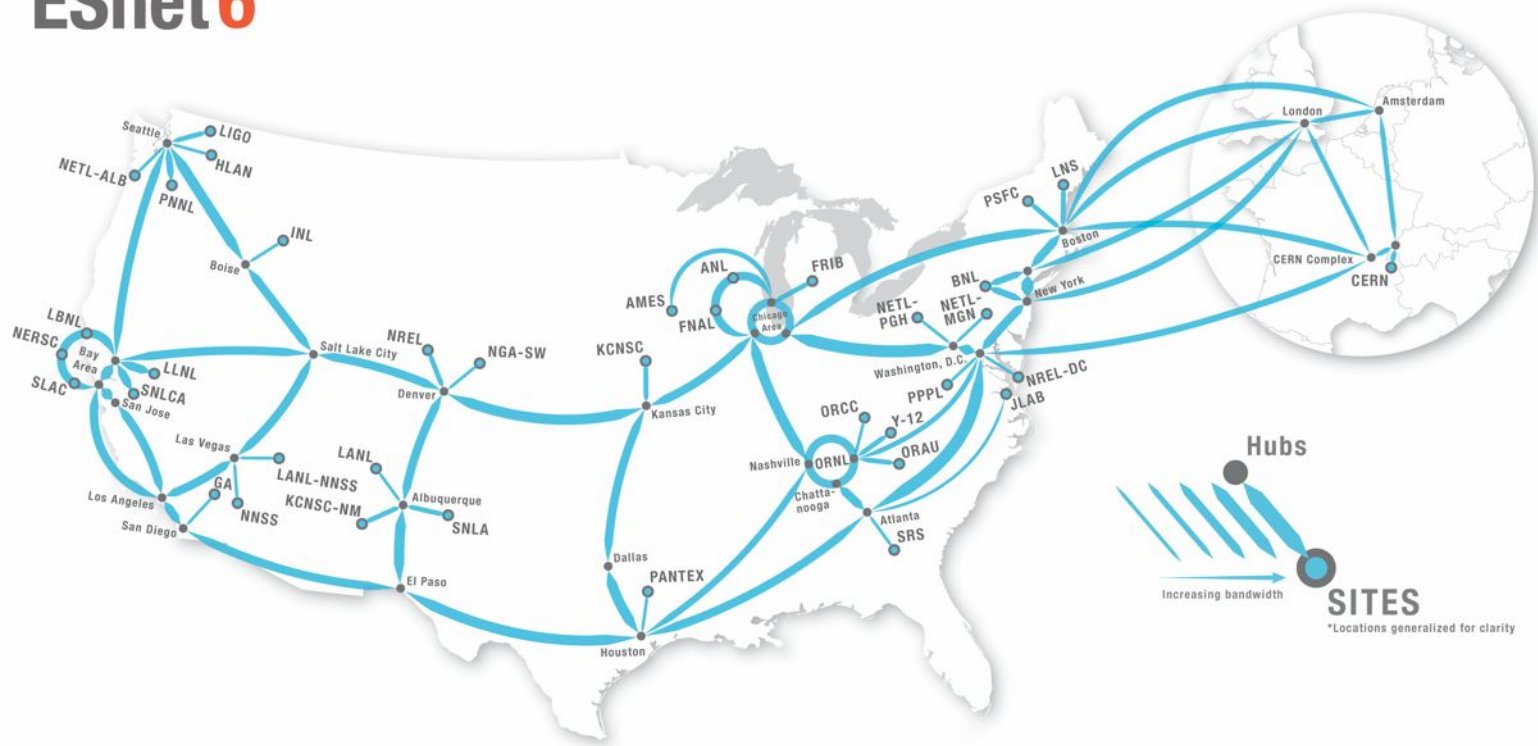
Source: William Johnston

Evolution Over Time

- LHC needs have changed over time
 - Computing model changes
 - Relentless data rate and volume increases
 - Software stack evolution
- ESnet worked with the LHC community to adapt
 - Science mission is paramount
 - Regular communication about requirements informs strategy
 - Long-term strategy allows us to invest in scalable solutions
- ESnet5 and Transatlantic continued that trend
- ESnet6 continues today
- Networking is a key component of the LHC computing model, and ESnet will continue to do our part
- We will continue to work together far into the future

Here's to 20+ more years

ESnet6





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BERKELEY LAB



Thanks!



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