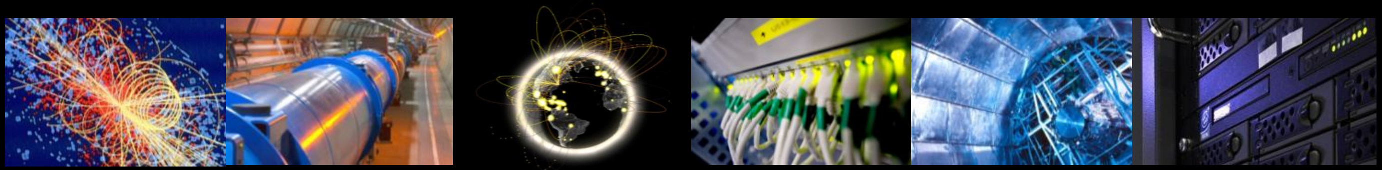
Discussing and Summarizing the TCB Technical Roadmap Chapter 4: Network Infrastructure and Management

Edoardo Martelli / CERN, Shawn McKee / UMich

October 8, 2025

LHCOPN/LHCONE Meeting #55 (https://indico.cern.ch/event/1534556/)



WLCG Worldwide LHC Computing Grid

Open Science Grid

Context and Motivation

The previous presentation provided the technical roadmap overview.

This presentation will discuss the **Networking Chapter** (Chapter 4).

- **Goal: Ensure WLCG network infrastructure meets the demands of HL-LHC physics operations and analysis**
- Why it matters:
  - Sub-standard network capacity increases latency and operational overhead
  - Need for clear, scalable requirements for all sites
  - Prepare for exponential data growth by 2030

Evolving draft is available for comment at:
https://docs.google.com/document/d/1ILR01wJItF62PINWA5y_B9LHGghXkaCToLBQsq4cBkk/edit?usp=sharing

Evolving Network Bandwidth Requirements

- Historical evolution:
  - 2010: Tier-2s at 1–10 Gb/s
  - 2017: Shift to 10+ Gb/s for Tier-2s, 100+ Gb/s for Tier-1s
- Proposed HL-LHC Recommendations:
  - Small Tier-2: **20–40 Gb/s** (redundant)
  - Normal Tier-2: **100–400 Gb/s** (redundant)
  - Large/Leadership Tier-2: **400–1200 Gb/s** (redundant)
  - Tier-1: **N x 800 Gb/s** (redundant, N=1-4)

Are these the right "suggested" targets (given hardware, site and software evolution) ?

Beyond Bandwidth – Network Capabilities Needed

- Protocol evolution (IPv6-only, retire IPv4)
- Data transfer optimization (TCP, jumbo frames, QoS)
- Hardware evolution (host/network/storage improvements)
- Network orchestration (SENSE, Rucio, SDN)
- Data format optimization (file size, data organization, caching)
- Comprehensive monitoring and analytics

Collaboration & Stakeholders

- Networking is collaborative:
  - WLCG experiments
  - Computing sites (Tier-1, Tier-2, AFs)
  - Research & Education (R&E) networks
- Key coordinating bodies:
  - LHCONE/LHCOPN (2-3 meetings/year)
  - HEPiX, DOMA/BDT, OTF, TCB, RNTWG, GNA-g
  - Middleware providers (EGI, OSG, etc.)

Activities with R&E Networks

- Joint planning for HL-LHC bandwidth
- Facilitating access to HPCs, clouds, and opportunistic resources
- Network monitoring and diagnostics (bandwidth, errors, SciTags)
- Collaboration on SDN and advanced network features

Open Science Grid

WLCG Worldwide LHC Computing Grid

LCG

Major Technical Roadmap Proposed Milestones

- **Site network monitoring**: 80% coverage before HL-LHC startup
- **SciTags**: 80% site adoption for key VOs by DC29
- **Jumbo frames monitoring**: Hourly tests between perfSONAR sites
- **LHCONE traffic engineering**: Support for 32-bit ASes by 2026
- **IPv6 adoption**: LHCOPN and LHCONE targets by 2026/2030
- **Security**: New recommendations by end 2027

Long-term Planning & Gap Analysis

- **Long-distance networks**: 400+ Gb/s international links by 2030
- **Access networks**: Advance connectivity, enable opportunistic resource use.
- **Datacenter networks**: Ensure policies allow for collaborative access
- **Monitoring & visibility**: Scalable, multi-site metrics.
- **Optimization**: Jumbo frames, IPv6, TCP tuning, server/network hardware.
- **Security**: Science DMZ, firewall best practices, vulnerability monitoring.

Risks, Challenges, and Opportunities

- **Risks**:
  - Delays in upgrades; insufficient funding
  - Technology adoption and integration challenges
  - Security vulnerabilities
- **Opportunities**:
  - Leverage R&E partnerships
  - Innovation in orchestration and automation
  - AI/ML for monitoring and troubleshooting

Summary & Next Steps

- Clear scaling targets and technical evolution plans toward HL-LHC
- Collaborative, international effort across experiments, sites, and networks
- Continuous monitoring, analytics, and R&D to ensure readiness
- Track milestones, adapt to new technologies, maintain global leadership

Comments or Discussion

Any questions, comments or suggestions?

References & Further Reading

- perfSONAR Documentation
- WLCG Technical Roadmap Chapter 4 Networking