

HEPiX IPv6 WG - Status and Plans

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WLCG OTF meeting, CERN, 10 Sep 2025

On behalf of all members of the HEPiX IPv6 working group - (many thanks all!)

The logo for HEPiX, featuring the text "HEPiX" in white on a blue background, with an orange square to the right.

G Attebury (UNL), M Babik (CERN), M Bly (RAL), N Buraglio (ESnet),
T Chown (Jisc), D Christidis (CERN/ATLAS), J Chudoba (FZU Prague),
P Demar (FNAL), J Flix Molina (PIC), C Grigoras (CERN/ALICE), B Hoeft (KIT),
H Ito (BNL), D P Kelsey (RAL), E Martelli (CERN), S McKee (U Michigan),
C Misa Moreira (CERN), R Nandakumar (RAL/LHCb), K Ohrenberg (DESY),
F Prelz (INFN), D Rand (Imperial), A Sciabà (CERN/CMS), T Skirvin (FNAL),
C J Walker (Jisc)

- Many more in the past, and members join/leave from time to time
- **many thanks** also to *WLCG operations, WLCG sites, LHC experiments, networking teams, monitoring groups, storage developers...*

Outline

- The HEPiX IPv6 working group and WLCG
- IPv6 on data storage
- IPv6 on CPU & worker nodes
- Identifying and removing use of IPv4
- Plans for IPv6-only WLCG
- Summary

Use of IPv6 on Internet - (from APNIC)

- A general plot - not HEP/WLCG etc

Use of IPv6 for France (FR)



HEPiX IPv6 working group

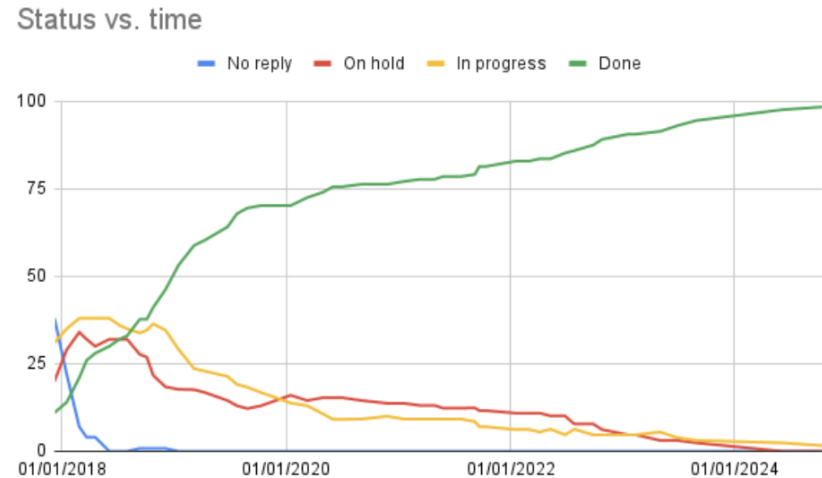
History and drivers for use of IPv6

- [2011-2016](#) - analysis, investigations, testbed, fix storage
- [2017-2023](#) - deploy IPv6 on WLCG data storage
- [2023 onwards](#) - deploy IPv6 on CPU services and WLCG clients
- Sites running out of routable IPv4 addresses
- To be ready to support use of IPv6-only CPU clients
- **Other drivers** for IPv6:
 - scitags.org – packet marking (in header of IPv6 packets)
 - USA Federal Government – [directive](#) on “IPv6-only” (Nov 2020)
 - Global Research Networking - single protocol easier to manage

IPv6 on WLCG Storage (Tier2s)

- “IPv6 on storage services”
 - 2017 to 2023
- Goal to support IPv6-only WNs
- Now complete
 - **But took lots of time!**

Status always visible
from a [twiki page](#)



IPv6 on CPU services and Worker Nodes

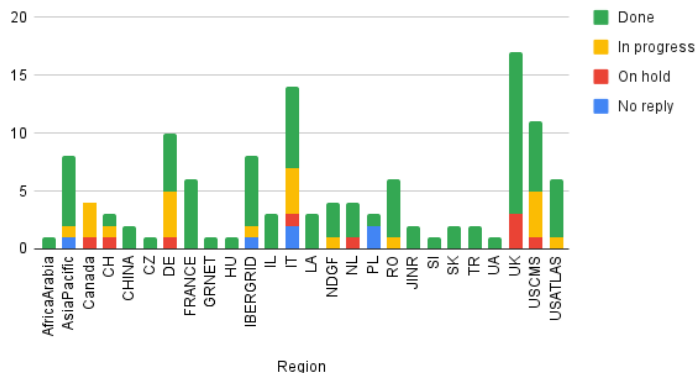
<https://twiki.cern.ch/twiki/bin/view/LCG/Wlcv6>

CPU - GGUS support ticket campaign

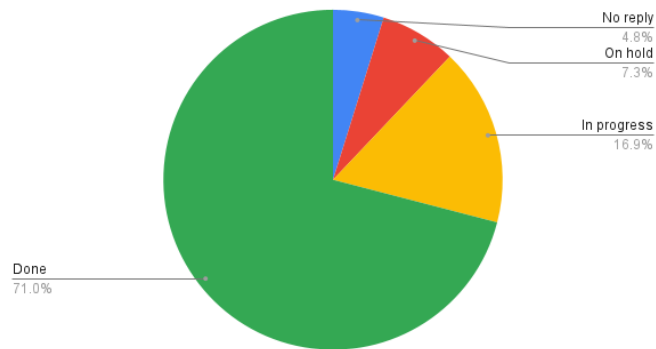
- Eliminate IPv4 data transfers - between WNs and remote storage
 - Approved by WLCG MB in October 2023
- **“Please deploy dual-stack connectivity (IPv4+IPv6) on your computing services (computing elements and worker nodes) as soon as possible and by 30 June 2024 at the latest”**
- Reasons for delay include
 - New data centres, new hardware, OS updates
 - Other priorities - AuthZ Tokens, End of life CentOS 7
 - Nvidia Skyway Infiniband gateway - no support yet for IPv6

CPU/WN IPv6 status

Tier-1/2 IPv6 CE/WN deployment status [03-09-2025]



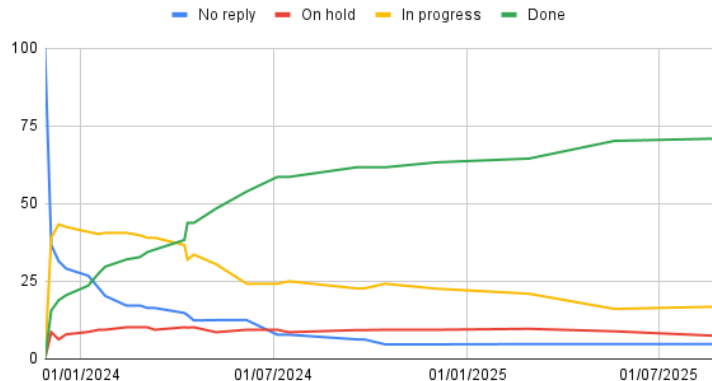
Tier-1/2 IPv6 CE/WN deployment status [03-09-2025]



>70% sites done

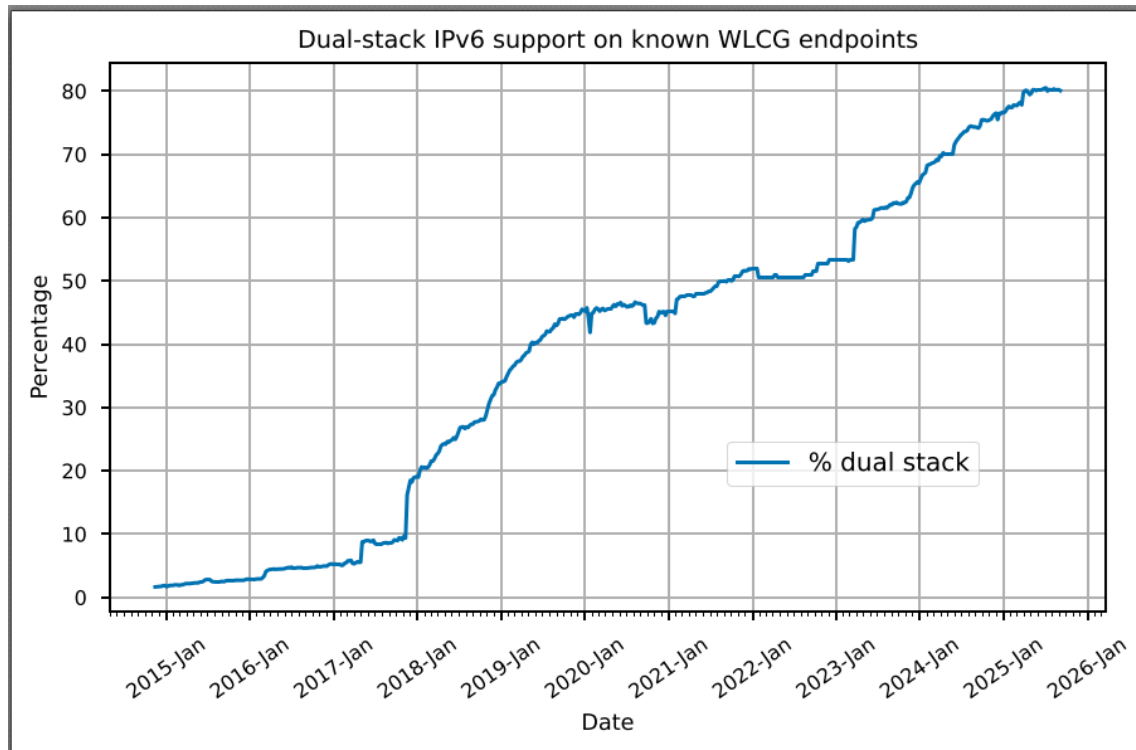
Status always visible from a [twiki page](#)

Tier-1/2 CE/WN IPv6 deployment status vs. time



All WLCG services - “VOfeeds”

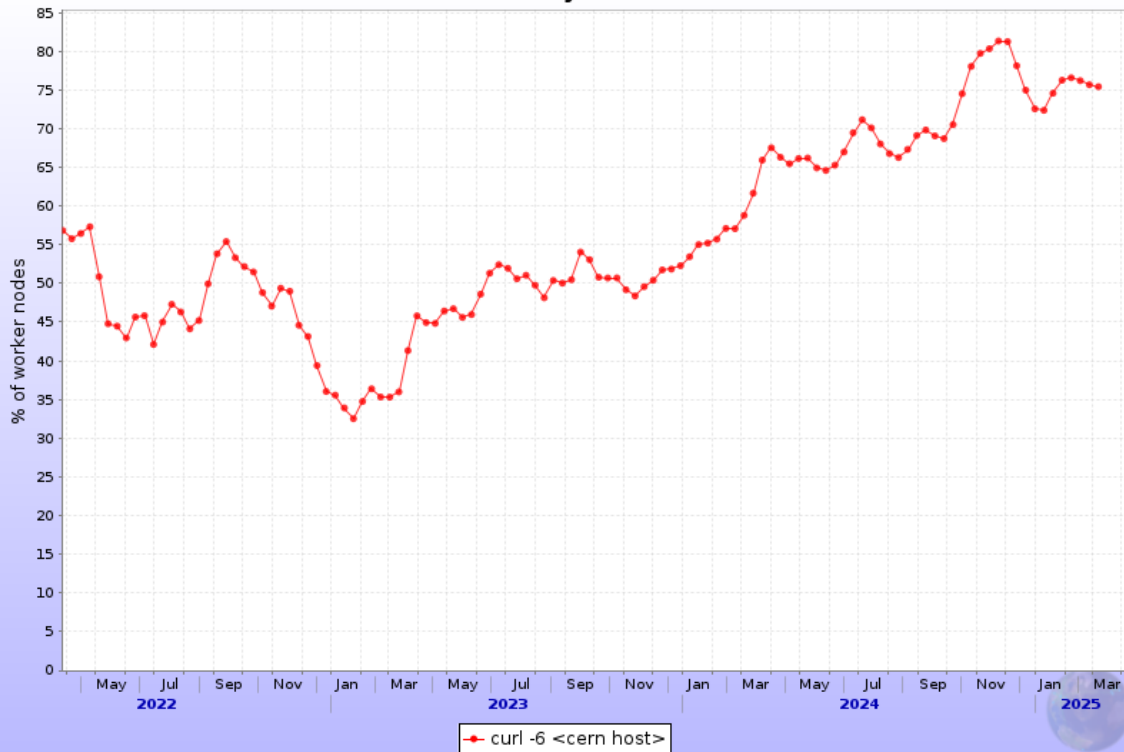
https://orsonline.mi.infn.it/~prelz/ipv6_vofeed/



August 2025:
~80% IPv6/IPv4
~20% IPv4

ALICE experiment monitoring

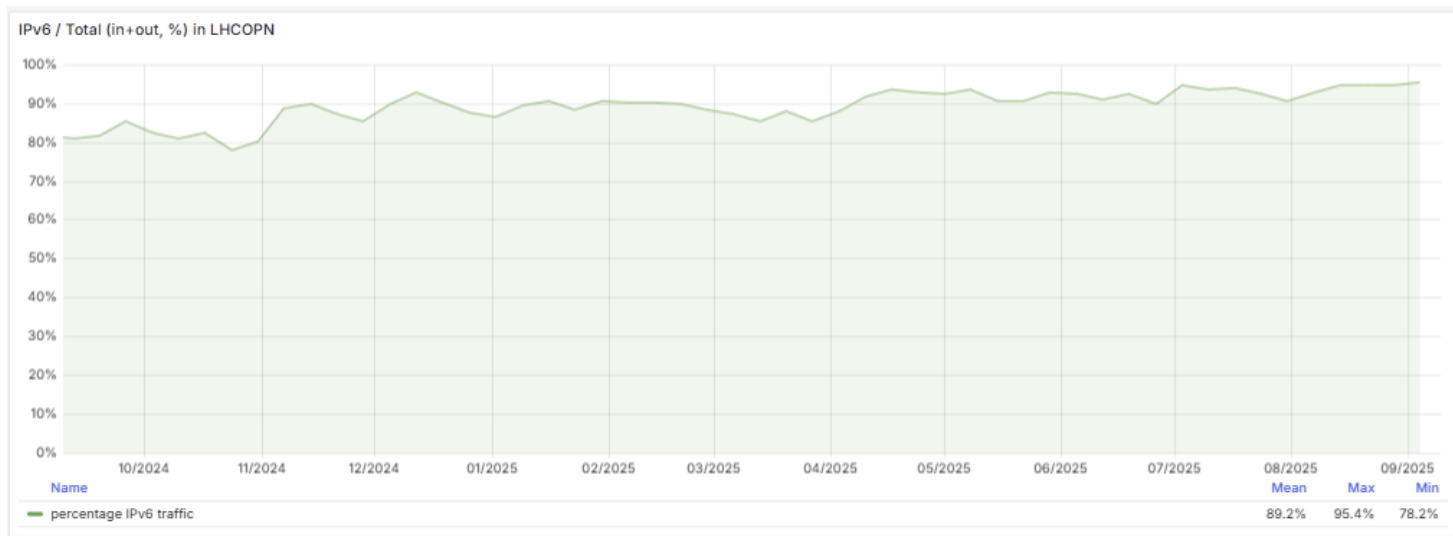
`curl` connectivity to CERN servers



% IPv6 WNs
since May 2022

WLCG Data Transfers - % IPv6 And Identifying/fixing use of IPv4

LHCOPN - CERN/Tier1 % IPv6 - last year



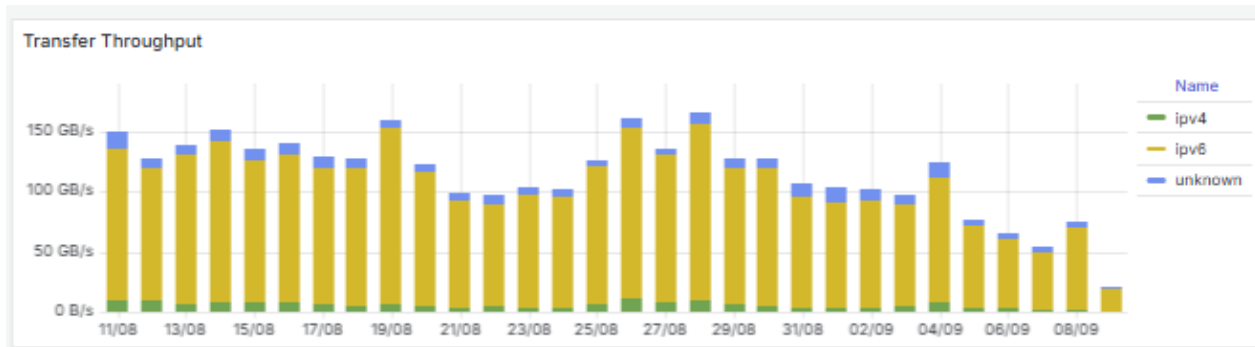
80%

90%

95%

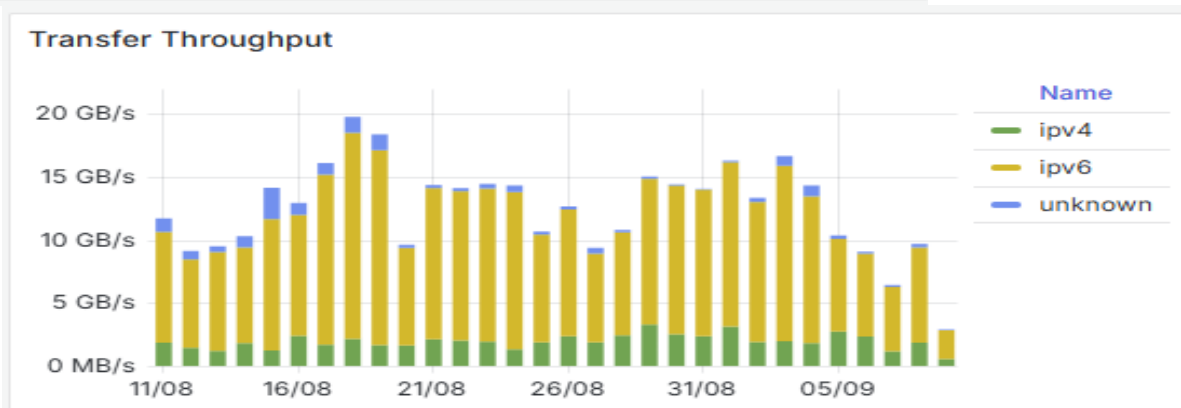
WLCG FTS and XRootD - Last 30 days

Mostly over IPv6 (is factor of 10 FTS to XRootD correct?)



← FTS

XRootD →

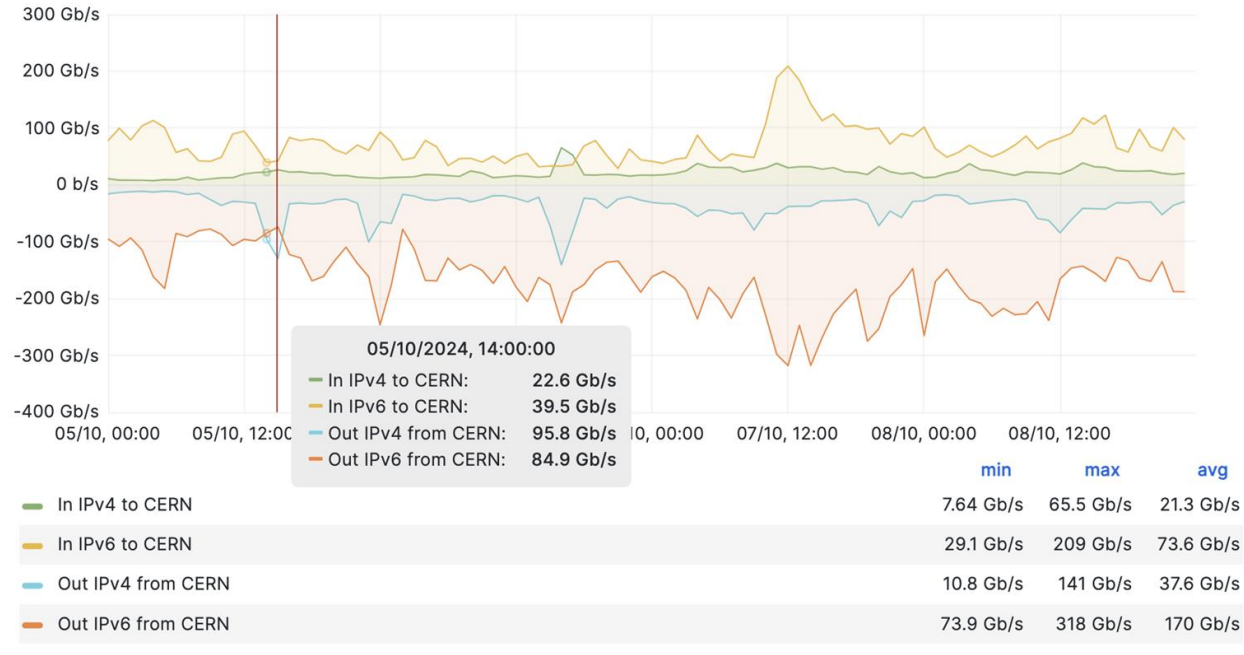


Old data - shown at CHEP2024

LHCOPN total traffic, split IPv4 & IPv6 (as seen at CERN)

<https://monit-grafana-open.cern.ch/d/cumEJJb4z/lhcopn-one-ipv6-vs-ipv4?orgId=16&from=1728079200000&to=1728424799000>

IPv4 vs IPv6 in LHCOPN



- 5 to 9 Oct 2024
- IPv6 Out of CERN
 - Avg 170 Gbps
- IPv4 Out of CERN
 - Avg 37.6 Gbps
- BUT
 - Large IPv4 peaks, e.g.
 - 5/10 @ 14:00
 - Out 95.8 Gbps

Identifying and fixing use of legacy IPv4

- Not easy to identify/understand use of IPv4
 - Need monitoring both by the network and by the site/experiment
- We often see use of IPv4 between two endpoints that are already enabled to use IPv6 (dual-stack)
 - Preference for IPv4 can be requested in **many** different config files
- We (the IPv6 WG) together with experiments and networks
 - Have been working on this for more than 2 years
- An early observation was data transfers requested by IPv4-only CPU/worker nodes (WLCG clients)
 - Hence the start of the campaign to deploy IPv6 on all CPU services and worker nodes (from end of 2023)

- See our CHEP Papers in 2023 and 2024 for more details

Use of legacy IPv4 when site IPv6-capable

- `java.net.preferIPv6Addresses` (default: false)
 - was a dCache problem
- A site with hardware-related issues
- Wrong info in config file `gai.conf`
- Localhost configuration issues
- Frontier/CVMFS/Squid configuration issues
- Experiments that use “old” software to analyse “old” data
- The investigations in the lead up to removal of IPv4 on USA LHCOPN links (next talk)
 - Identified several issues all of which were fixed to use IPv6
 - ATLAS, CMS & DUNE

Plans for IPv6-only WLCG

IPv6-only on WLCG (CHEP2019)

<https://doi.org/10.1051/epjconf/202024507045>

- The end point of the transition from IPv4 is an **IPv6-only** WLCG core network - already agreed by WLCG MB - not a dual-stack network!
 - LHCOPN and LHCONE in particular
- To **simplify** operations
 - Dual-stack infrastructure is the most complex
 - Reduced complexity reduces chance of making security errors
 - And dual-stack does not reduce pressure on IPv4 address space
- Large infrastructures (e.g. Facebook, Microsoft,...) use IPv6-only internally
- The goal is still: *all Wide-area data transfers over IPv6*

IPv6-only plans and testing

- Some sites are keen to move to IPv6-only services
 - Including USATLAS (AGLT2, NET2, ...)
 - PL Tier1 NCBJ (provide some IPv6-only storage to CMS)
 - others
- Some sites have been testing IPv6-only clusters for some years
 - CERN, Brunel (UK), KIT, others....
- CMS has recently (re) tested at KIT and CERN
- CMS confirms - they are perfectly able to work with IPv6-only sites

Plans for “IPv6-only” WLCG data transfers

For discussion with all stakeholders

LHCOPN (the easiest - just Tier 0/1)

- By end Run 3 encourage the deployment of IPv6 on **all** WLCG services (today ~80%)
- Need to continue to identify/remove IPv4 on LHCOPN
- Propose IPv4 peering removed from LHCOPN as soon as possible/sensible
- Before Data Challenge DC27 (should test what we plan to use) - my personal view
- See next talk (Martelli/McKee) - USA test removal of IPv4 on LHCOPN

For transfers over LHCONE:

- Identify/remove ongoing use of IPv4 on LHCONE network (WLCG traffic)
- Move the WLCG LHCONE to be IPv6-only (if confirmed to be sensible)

End point of the IPv6 work:

- Well before start HL-LHC Run 4 - exact date still to be agreed with the WLCG MB

Tony Cass - CHEP 2024
Networking Plenary talk

Global Networking Challenges for the Coming Decade

Tony Cass, CHEP 2024, 23rd October 2024

With thanks to Carmen Misa Moreira, Edoardo Martelli, Marian Babik, Enzo Capone, Bruno Hoefft,
Lars Fischer, Pepe Flix, David Kelsey & Shawn McKee



Summary *(Tony Cass CHEP2024)*

- Wide area networking will continue to deliver quality services for the HEP community into the HL-LHC era.
- But
 - we need to (re)learn how to transfer data efficiently,
 - we need to understand and perhaps manage traffic flows,
 - IPv4 has to go, and
 - life will be more complicated in a multi-science world.



And he said ... "Before HL-LHC"

Summary

- WLCG already supports use of IPv6-only clients
- Majority of WLCG data transfers already use IPv6
- Campaign for IPv6 on CPU and WN's - underway but slow
- We still observe ongoing use of legacy IPv4 on LHCOPN/ONE
 - We continue to chase “preference of IPv6” in service configuration
- We should complete the move to IPv6-only data transfers
 - before start HL-LHC Run 4
 - LHCOPN before DC27, LHCONE before Run 4
- ***Message to all WLCG sites & LHC experiments:***
 - ***Please deploy IPv6 on all services & clients and prefer its use***
 - ***And monitor and check/fix***

More information

- The HEPiX IPv6 Working Group meets regularly
 - <https://indico.cern.ch/category/3538/>
- Next (in person meeting) at CERN - 24/25 September 2025
 - An open meeting (but please do register if you wish to attend)
- WLCG IPv6 task force information
 - <https://twiki.cern.ch/twiki/bin/view/LCG/Wlclpv6>

CHEP2023 paper “Overcoming obstacles to IPv6 on WLCG”

<https://doi.org/10.1051/epjconf/202429507036>

Questions, Discussion?

Backup slides

“Obstacles” to IPv6

There are many reasons stopping the full use of IPv6/IPv4

- Dual stack is an essential step on the journey to IPv6-only

The Obstacles that we have been addressing:

1. **WLCG Sites not yet deployed IPv6 networking**
2. **Sites have IPv6 but Tier-2 has no dual-stack storage**
3. **IPv6 monitoring not available or broken**
 - Monitoring is essential
4. **Service is dual-stack but IPv4 still being used**
 - We continue to chase these problems

Obstacles to IPv6 - being addressed

5. **Non-storage services not yet dual-stack**
 - a. ~80% of all WLCG services are dual-stack today, we need 100%
6. **WLCG client CPU (worker nodes, VMs, containers) some IPv4-only**
 - a. GGUS ticket campaign well underway
7. **Services/clients outside of WLCG Tier-1/Tier-2 not yet addressed**
 - a. Tier-3, Public/Commercial Clouds, Analysis facilities, Experiment portals...
8. **Use of new or evolving technologies not yet tested or tracked**
 - a. New CPU architectures (GPU, non-x86, ...), container orchestration, ...
9. **Staffing issues can be an obstacle**
 - a. Lack of effort, lack of IPv6 training/knowledge, pressure of other work