

An IPv6-only LHCOPN

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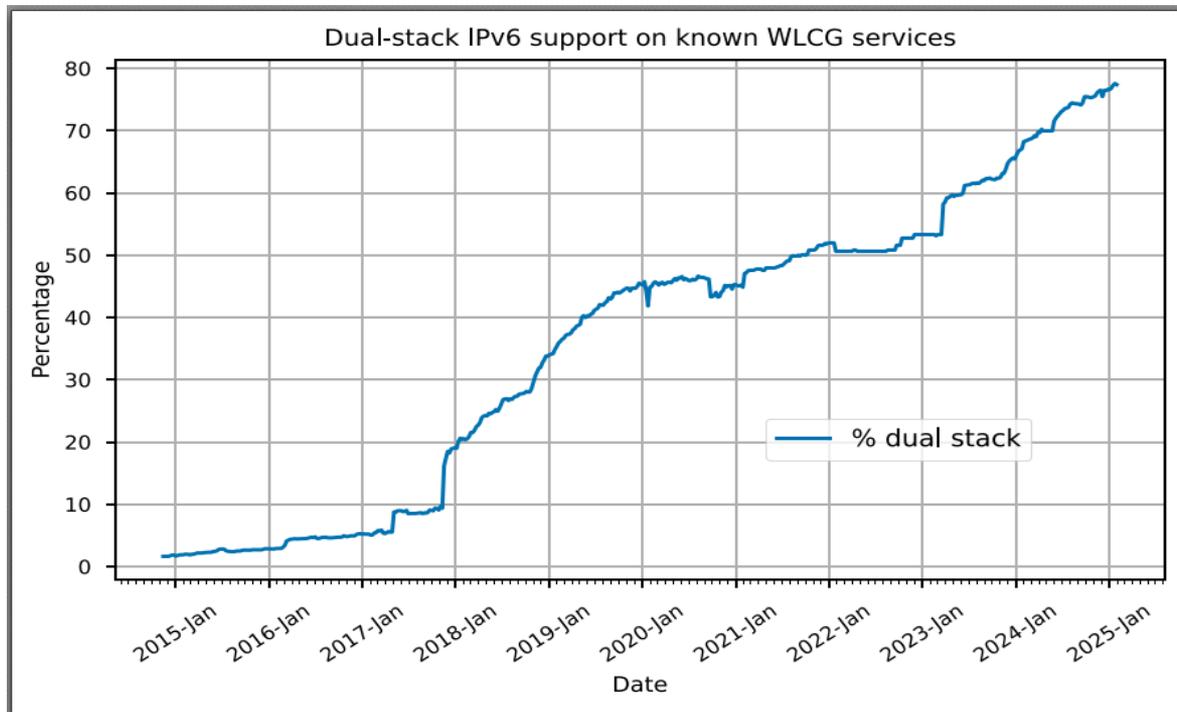
Outline

- On behalf of all members of the HEPiX IPv6 Working Group
- Reminder - 3 slides shown at LHCOPN #54 meeting (March 2025)
- Recent use of IPv4 on LHCOPN
 - IPv6-only sites and ongoing IPv4 issues

Next 3 slides shown at LHCOPN
meeting #54, 19 Mar 2025 - SKAO

All WLCG services - “VOfeeds”

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



6 Mar 2025:
~78% IPv6/IPv4
~22% IPv4

Update

2 Oct 2025:
~84% IPv6/IPv4
~16% IPv4

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!
- 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
- This is the goal we are still working towards:
 - i.e. *all Wide-area data transfers over IPv6*
- **Timetable** still to be defined - but aiming for “well before LHC Run 4”

Plans for “IPv6-only” WLCG (March 2025)

The plan (LHCOPN):

- By end Run 3 encourage the deployment of IPv6 on **all** WLCG services (today ~80%)
- We need monitoring in place to continue to identify/remove IPv4 on LHCOPN
- Propose IPv4 peering **removed from LHCOPN as soon as possible/sensible**

For transfers over LHCONE:

- Identify/remove ongoing use of IPv4 on LHCONE network (WLCG traffic)
- We need appropriate monitoring to achieve this
- Prepare the WLCG **LHCONE overlay to be IPv6-only** (if can be shown to be sensible)

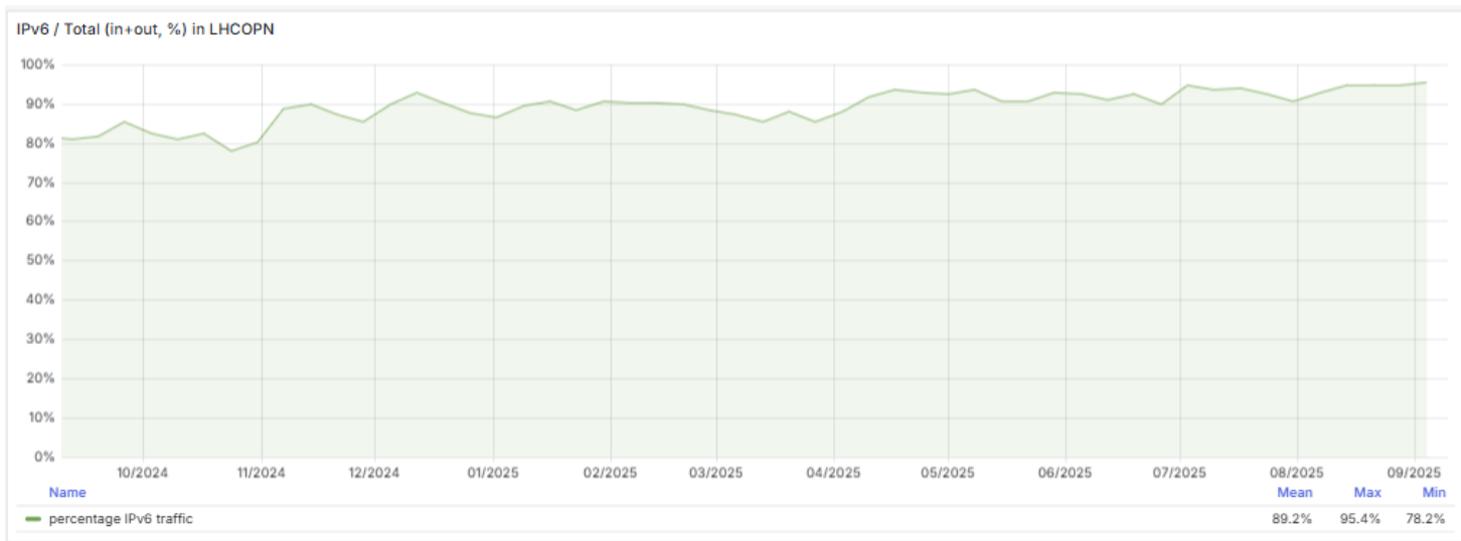
End point of the IPv6 work:

- Complete all above during the first half of the LHC Long Shutdown 3
- Well before start HL-LHC Run 4 - exact date still to be agreed with the WLCG MB

Recent use of IPv4 on LHCOPN

And wishes for IPv6-only sites & IPv4 issues to be solved

LHCOPN - CERN/Tier1 % IPv6 - last year



80%

90%

95%

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
- NVIDIA Skyway InfiniBand to Ethernet gateway - still IPv4-only
 - Support for IPv6 is we hope “on the way”
- 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

IPv4 issues to get solved: (thank you to Bruno Hoeft for this slide)

- DE-KIT IPv6 testbed
 - Alice: still loopback address software hardcoded : IPv4 address (127.0.0.1)
 - Solved in 1,5 days → now protocol independent
 - Missing home directories
 - IPv6 at NFS server “mis-”configured
- Only hitting sites with PBR configuration
 - during IPv4 interface shutdown → PBR failsafe was active
 - turned out: failsafe configured with IPv4 only
- Some more IPv4 issues:
 - IPv4 issues with JINR solved
 - RAL, BNL, NGDF, PIC and lots of data exchange with CERN
 - Belle 2 (BNL,...) still depending on IPv4

HEPiX IPv6 WG meeting 24-25 Sep 2025 (CERN)

Discussion of

- Results of IPv4 removal tests (USA)
- Plans for IPv6-only LHCOPN (& LHCONE)

Remove IPv4 from LHCOPN - Intro

- Agreed endpoint of the transition from dual-stack to IPv6-only WLCG (WLCG MB)
 - IPv6-only services
 - All WAN data transfers should use IPv6-only
 - Especially on LHCOPN and LHCONE
- The working group always recognised that the LHCOPN would be the first place that IPv4 could be removed
- See results of successful USA test (Edoardo Martelli)
 - IPv6 WG pleased that the USA test was proposed and pushed by ESnet, BNL and FNAL and US LHC experiments - and gets our full support
- In the weeks before the test, we were pleased to see that the use of IPv4 was decreased on FNAL and BNL LHCOPN links

IPv4 removal from LHCOPN - policy issues (part 1)

IPv6 WG aware of several **policy issues**, including:

For one specific LHCOPN network link

- Who is involved in the decision to remove IPv4?
- If the Tier1, CERN and the LHC experiments using the link all agree, is that sufficient?
- Or should more stakeholders be consulted (e.g. WLCG MB)?

For the LHCOPN community (and stakeholders) to agree

IPv4 removal from LHCOPN - policy issues (part 2)

More LHCOPN **policy issues**, including:

Currently some Tier1s can use LHCOPN to route transit traffic from one Tier1 to another Tier1 via CERN - others use LHCONE

See [RoutingPolicies < LHCOPN < TWiki](#)

(e.g. DE-KIT and FNAL + CNAF - t1-t1 via LHCONE)

- Do all Tier1's using LHCOPN for transit T1-T1 have to also agree?
- And what about other non-LHC experiments? Do they have a veto?

Proposal from IPv6 WG for LHCOPN timetable to remove IPv4

- **LHCOPN timetable**
 - **IPv4 peering should be removed from all links as soon as possible**
 - **Certainly by second half of 2026 - well before DC27**
- Several sites are now seeking to remove IPv4 from all their clients and WLCG services
 - WLCG should allow sites to move to IPv6-only soon - when?
 - The LHC Experiment is most important stakeholder here
 - Soon/now is OK if experiment(s) agree
 - But certainly well before DC27

LHCONE timetable for removal IPv4

The IPv6 WG feels it is important to consider now a timetable for removing IPv4 data transfers from LHCONE

- To make this work Sites clients need to deploy IPv6 everywhere
- Ongoing use of IPv4 will result in additional cost
 - Must push ahead with the WN and CPU IPv6 deployment
- The percentage of data transfers using IPv6 on LHCONE is already high
- Working group, experiments and sites should continue to identify use of IPv4 if between two dual-stack endpoints and fix the preference to ensure use of IPv6

We feel strongly we should aim for use of IPv6-only on LHCONE before start of HL-LHC Run 4

- **Therefore important to test fully during DC29**
- **We should aim to remove IPv4 from LHCONE before DC29**

Summary

- Proposals from the IPv6 WG re removal of IPv4
- **LHCOPN timetable**
 - IPv4 peering should be removed from all links as soon as possible
 - Certainly by second half of 2026 - well before DC27
- **LHCONE timetable**
 - before start of HL-LHC Run 4
 - Important to test fully during DC29
 - We should aim to remove IPv4 from LHCONE before DC29

Questions, Discussion?

Backup slides

Some more traffic plots

LHCOPN - BNL 19-31 Aug 2025 (%IPv6)



LHCOPN - FNAL 19-31 Aug 2025 (%IPv6)



LHCOPN - UK-RAL (last 30 days) %IPv6

IPv6 / Total (%) per direction in LHCOPN



Name	Mean	Max	Min
percentage IPv6 incoming traffic	98.6%	100.0%	82.0%
percentage IPv6 outgoing traffic	99.5%	100.0%	90.5%

LHCOPN - KIT-DE Last 30 days (%IPv6)

IPv6 / Total (%) per direction in LHCOPN



percentage IPv6 incoming traffic

Name	Mean	Max	Min
percentage IPv6 incoming traffic	96.4%	100.0%	52.7%
percentage IPv6 outgoing traffic	97.7%	100.0%	81.8%

percentage IPv6 outgoing traffic