IPv6 in UK Academia

Dr Graeme Bragg
gmb@ecs.soton.ac.uk
17th of March 2022, UK Design Forum, Newcastle

Who am I?

- Someone convinced me to become a teaching fellow at University of Southampton.
- Previously postdoc on PRiME, Graceful and POETS EPSRC programme grants
- Involved with Glacsweb and Mountain Sensing projects (sticking IPv6-enabled sensors on glaciers and mountains)
- I build RTI domes for cultural heritage
- and I’m now your friendly neighbourhood UKDF webmaster…

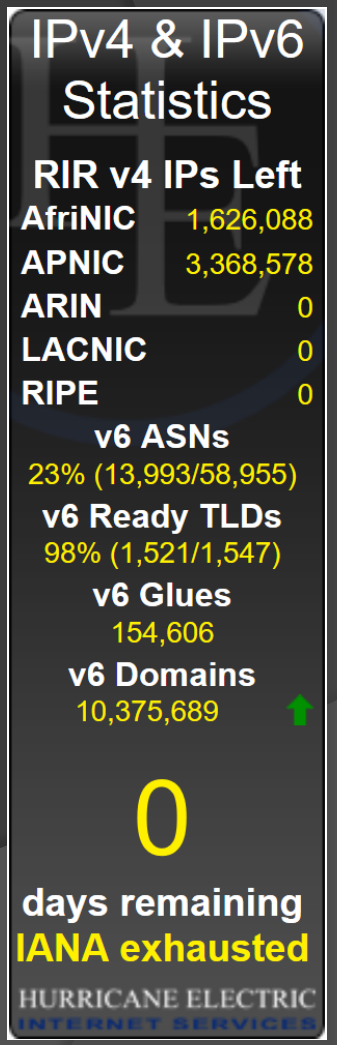
IPv what now?

- An IP address is like a postal address – it (uniquely?) identifies a computer so packets can get to you
- Each computer* connected to the Internet needs at least one
- Current dominant standard is IPv4
  - 32-bit, ~4 billion addresses

* Some technologies make it possible for multiple computers to share one address.

IPv4 Address Exhaustion

- We have run out of IPv4 addresses:
  - << 3.7 bn useable addresses,
  - ~ 46 bn connected devices in 2021,
  - >> 125 bn connected devices by 2030.
- IANA ran out of unallocated blocks in 2011:
  - **RIRs depleted:** ARIN 2015, RIPE 2019, LACNIC 2020
  - RIPE and LACNIC have a waiting list for reused addresses…
  - APNIC will only give you a /23 (512 addresses)
  - AfriNIC had one /11 block left in January 2020
- Existing mitigations are creaking



We've been here before...

- ARPAnet used 8-bit addresses
  - 6-bit IMP identifier, 2-bit host index
  - Seemed a lot at the time…
- Upgraded to 24-bit in 1976
  - 16-bit IMP, 8-bit host
- New protocol adopted in 1983:
  - TCP/IP version 4
  - From 8 to 32 bit addresses
  - 4,294,967,296 addresses should be enough for anybody…

IPv6

- 128-bit addresses
  - 3.4×10^{38} IPv6 addresses
  - Current public pool 4.2×10^{37} addresses
- History:
  - 1998 First draft standard in 1998
  - ~2003/2004 First production use
  - 2011 Support in all major OSes
  - 2012 World IPv6 Launch Day
  - 2016 Significant adoption by UK residential ISPs
  - 2017 Full Internet standard (RFC 8200)

Google IPv6 Stats

2022

- ~35% of global Google users use IPv6:
  - 63.45% in India
  - 57.69% in Malaysia
  - 55.45% Belgium
  - 54.56% in Germany
  - 52.71% in France
  - 51.31% in Greece
  - 46.01% in USA
  - 33.38% in UK
- Total ≈ 2021

2021

- ~ 34% of global Google users use IPv6:
  - 57.96% in India
  - 52.7% in Germany
  - 52.8% in Malaysia
  - 48.7% in Greece
  - 45.5% in USA
  - 34.24% in UK
  - +~4% from 2019

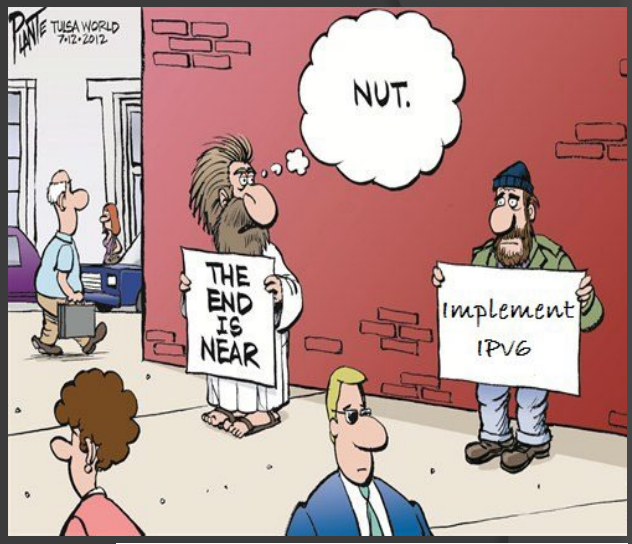
2020

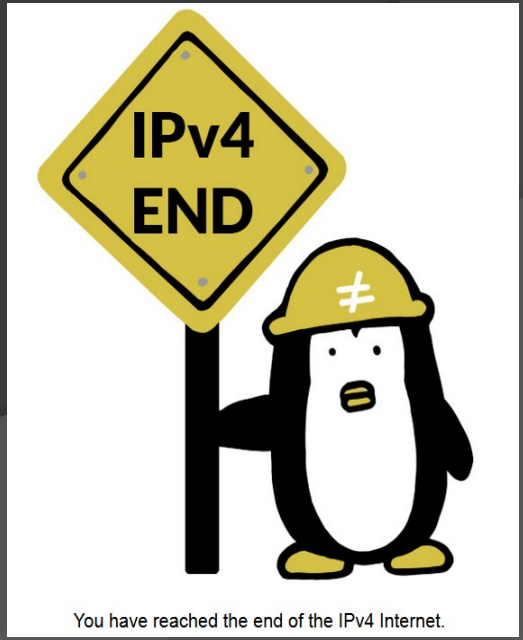
- > 30% of global Google users use IPv6:
  - 45.79 % in Germany
  - 45.37 % in Greece
  - 43.52 % in India
  - 37.17 % in USA
  - 25.12 % in UK
  - +~5% from 2019

Graph reproduced from
https://www.google.com/intl/en/ipv6/statistics.html

Reasons to Deploy NOW

- Pick your metaphor for IPv4:
  - “On borrowed time”, “Deadman walking”
  - “Running on fumes”, “On its last legs"
- IPv6 is ~~fast becoming~~ mandatory:
  - Some ISPs ONLY give out IPv6.
  - Some sites/services are ONLY available on IPv6.
- Enables innovation/teaching/research,
- Supports new applications: e.g. IoT, HEP, big compute
- Allows ~~early-adopters~~ ~~more~~ people to access your services

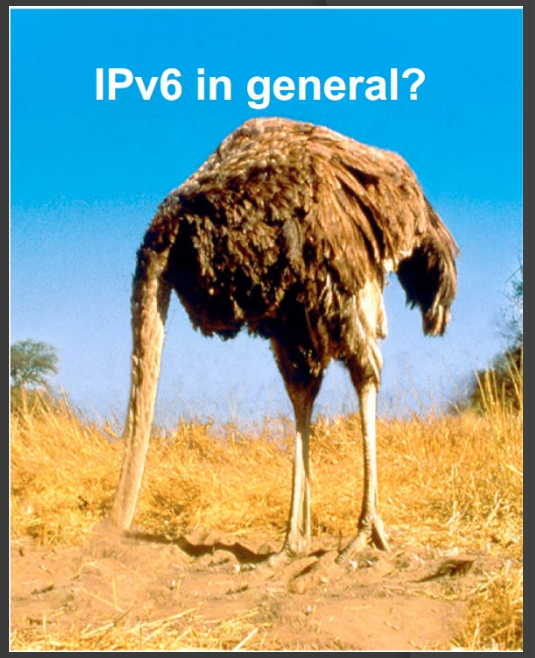




IPv4 End Penguin, https://no-ipv4-here.ungleich.ch/

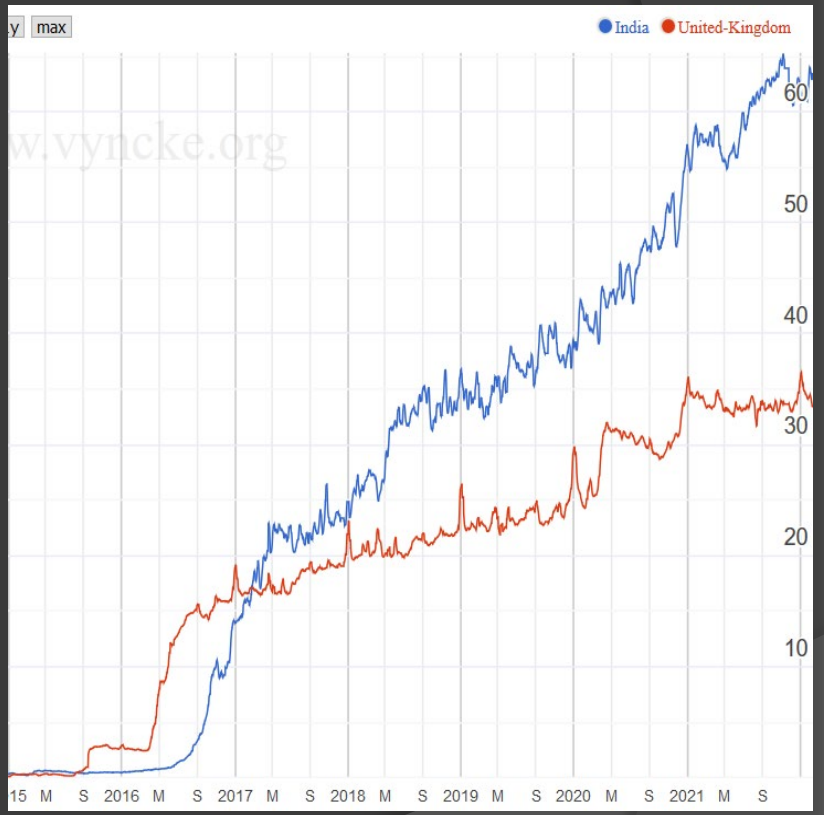
What's blocking IPv6?

- The chicken and egg problem
- "*IPv6 is not needed, we have IPv4 and it works fine" – Management*
- Network admins lack skills
  - And new graduates don't have them either…
- Some older/cheaper hardware does not support it
- "The killer application" is not here yet
- IPv6 deployment requires desire, training, time and money
  - But not much of any of the last three when well planned!



Case study: IPv6 in India

- First country to hit over 60% IPv6 in Google stats.
  - 26% in 2017, < 1% in 2016
  - APNIC put capability @~77%
- Government have a roadmap
- ISPs required to provide IPv6 to customers
- ERNET (equivalent of JISC) is fully dual stack. Also provides consultancy and training, and has a hands-on IPv6 training facility for Sys Admins.



https://www.vyncke.org/ipv6status/compare.php?metric=p&countries=in,gb

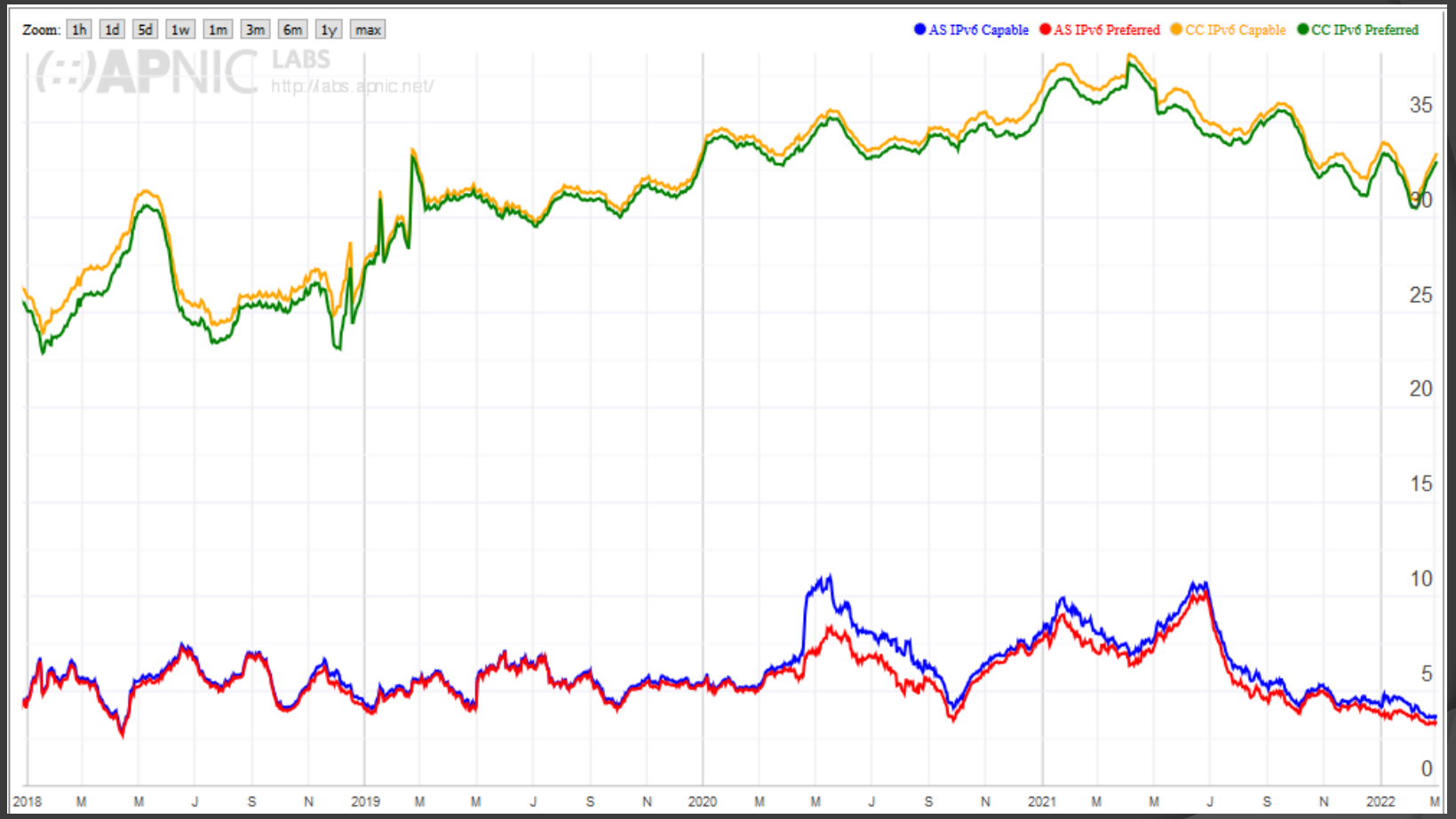
APNIC Labs IPv6 measurements: https://stats.labs.apnic.net/ipv6/

What about UK academia?

- UK IPv6 traffic: ~30-40% 😐
- JANET IPv6 traffic: ~10-15% ☹

- This is despite:
  - JANET being IPv6-enabled for over 18 years
  - CERN / WLCG traffic (there's a lot of it…) being mostly IPv6
  - Universities running out of global IPv4 address space

UK IPv6 capability



- Yellow/Green: UK in general: 30-35%
- Blue/Red: JISC: ~3.3%

Adoption by institution

- Of 177 degree-awarding institutions in the UK:
  - 106 (60.23%) have an IPv6 allocation
    - ~45 (42.45%) of these seem to be routed to institutions
    - Only 30 (28.30%) have been “seen” on the Internet
  - 45 (25.57%) have non-Janet IPv6 DNS servers
    - 20 (44.44%) of these run their own IPv6 DNS servers
  - 32 (18.18%) have a website reachable over IPv6
    - Only 8 (4.55%) self-host. The rest are Cloudflare or similar.
  - 14 (7.95%) have mail-servers reachable over IPv6
    - Only 2 (1.14%) self-host. The rest are Google
  - 3 (1.70%) have a VPN reachable over IPv6 ☹

Who is doing well?

Institution	IPv6					
	Allocation?	Seen?	DNS?	WWW?	MX?	VPN?
Imperial College London	Yes	Yes	Yes	Yes	Yes	
University of York	Yes	Yes	Yes		*Google*	Yes
University of Kent	Yes	Yes	Yes	Yes		Yes
University of Lancaster	Yes	Yes	Yes	Yes		Yes
University of Bolton	Yes	Yes	Yes	Yes		
University of Cambridge	Yes	Yes	Yes	Yes		
University of Leeds	Yes	Yes	Yes	Yes		
University of Reading	Yes	Yes	Yes	Yes		
SOAS	Yes	Yes	*Imperial*		Yes	
University of Aberdeen	Yes	Yes	Yes			
University of Bristol	Yes	Yes	Yes			
Durham University	Yes	Yes	Yes			
The University of Edinburgh	Yes	Yes	Yes			
University of Glasgow	Yes	Yes	Yes			
University of Greenwich	Yes	Yes	Yes			
Queen Mary, London	Yes	Yes	Yes			
Loughborough University	Yes	Yes	Yes			
University of Oxford	Yes	Yes	Yes			
University of Southampton	Yes	Yes	Yes			
University of Sussex	Yes	Yes	Yes			
York St John University	Yes	Yes	Yes			
Prifysgol Aberystwyth	Yes	Yes		Yes		
University College London	Yes	Yes		*Cloudflare*		
University of Sheffield	Yes	Yes			*Google*	
University of Birmingham	Yes	Yes				
Brunel University London	Yes	Yes				
University of Liverpool	Yes	Yes				
Royal Holloway, London	Yes	Yes				
University of Manchester	Yes	Yes				
University of Stirling	Yes	Yes				

Other “Important” Bodies

Institution	IPv6					
	Allocation?	Routed?	Seen?	DNS?	WWW?	MX?
IET					*Incapsula*	
BCS					*Cloudflare*	
Engineering Council						
Royal Society				*AWS*		
IEEE						
The British Academy						
RAEng						
Jisc	Yes	Yes	Yes	Yes	*Cloudfront*	
NOMINET	Yes	Yes	Yes	Yes	*Cloudflare*	Yes
UK Mirror Service	Yes	Yes	Yes	Yes	Yes	
GEANT	Yes	Yes	Yes	Yes		
Sanger Institute	Yes	Yes	Yes	Yes	Yes	*PPHosted*
Royal Observatory	Yes	Yes	Yes		*Pantheon*	
RAL (STFC)	Yes	Yes	Yes			
ECMRWF	Yes	Yes				
NIBSC	Yes	Yes				
NSIRC	Yes	Yes				
Francis Crick Institute	Yes	Yes				
Pirbright Institute	Yes	Yes				

IPv6 in teaching

- Of 177 degree-awarding institutions in the UK:
  - 118 (67.05%) offer Computer Science or Computing undergraduate degrees.
  - Of these:
    - 24 (20.34%) do not have an IPv6 allocation
    - 10 (8.47%) mention IPv6 in the publicly available syllabus
      - But one doesn't have an IPv6 allocation?!?!

Let's look at the "Top 20"

Institution	IPv6						IPv6 Sylabus?	Times Ranking	Guardian Ranking
	Allocation?	Seen?	DNS?	WWW?	MX?	VPN?			
University of Oxford	Yes	Yes	Yes				Yes	1	3
University of Cambridge	Yes	Yes	Yes	Yes			Yes	2	2
University of St Andrews	Yes							3	1
Imperial College London	Yes	Yes	Yes	Yes	Yes			4	5
University of Manchester	Yes	Yes						5	8
University of Glasgow	Yes	Yes	Yes					6	10
University College London	Yes	Yes		Cloudflare				7	6
University of Warwick	Yes							8	
Durham University	Yes	Yes	Yes					9	9
University of Bristol	Yes	Yes	Yes					10	13
University of Birmingham	Yes	Yes						11	20
King's College London	Yes							12	
University of Aberdeen	Yes	Yes	Yes					13	4
University of Leeds	Yes	Yes	Yes	Yes				14	
University of Bath	Yes							15	18
University of Exeter	Yes			Cloudfront				16	
University of Sheffield	Yes	Yes			Google			17	16
Heriot-Watt University	Yes							18	
University of York	Yes	Yes	Yes		Google	Yes		19	
University of Southampton	Yes	Yes	Yes				Yes	20	
University of Stirling	Yes	Yes							7
University of Lancaster	Yes	Yes	Yes	Yes		Yes			11
The University of Edinburgh	Yes	Yes	Yes						12
University of Dundee	Yes								14
Loughborough University	Yes	Yes	Yes						15
University of Liverpool	Yes	Yes							17
University of Buckingham									19

Why is a lack of IPv6 adoption in academia a problem?

- More research will depend on/benefit from IPv6 in the near future:
  - IoT, pervasive networks, sensor networks, 5G
  - Cybersecurity
  - “big” scientific compute (e.g. HEP)

- Students can’t experience it:
  - One blocking factor for wider IPv6 deployment out of academia is a lack of knowledge and experience
  - We are producing graduates without key knowledge

Case Study: Imperial College

- Started experimenting with IPv6 in 2003
- Production deployments started in stages
  - It's not all or nothing: IPv4 and IPv6 can coexist
- Current production IPv6 deployment:
  - IPv6 everywhere
  - All new datacentre services dual-stack by default
  - IPv6 parity mandatory in all equipment procurement
- IPv6 traffic by volume in 2020: ~35%
  - 50% on BYOD, 80%+ for HEP
- Considering an IPv6-only future
  - HPC refresh is already IPv6 only

Case Study: University of Southampton

- Playing with IPv6 since 1996
  - Acquired first IPv6-native WAN connection in 1997
  - Significant involvement in several IPv6 projects, including EU-funded 6Net project (2002) [1]
- *Had* early working IPv6 deployments:
  - First UK University to have ***production*** IPv6: client network deployments ~2005
  - IPv6 enabled public-facing services (web, DNS, maiil, ssh, VPN, etc.)
  - Experimenting with IPv6-only eduroam ~2014
  - Deployment (mostly) tied to research within one school
- BUT staff moved on, interim hardware was not replaced and central IT took over:
  - Most of the IPv6 deployment has gone since 2016/2017…
  - Services that had IPv6 now don't (IPv4 load-balancers for security…)
  - Why? Lack of skills, investment and buy-in at the central level

1. https://cordis.europa.eu/project/id/IST-2001-32603

Case Study: University of Southampton

- We have retained IPv6 in *some* key areas.
- Our Electronics and CS teaching labs still have IPv6
  - Students are exposed to it in labs
  - Students use it in projects
- Some research subnets still have it
  - It is used for research projects
  - PhD students can use it
- eduroam is still dual stack
- Central IT are (slowly) gaining skills and capability

1. https://cordis.europa.eu/project/id/IST-2001-32603

To Summarise

- IPv6 is here
  - Major UK residential ISPs and mobile carriers
- Academia is doing a bad job of:
  - Adopting IPv6
  - Using IPv6
  - Teaching IPv6
- Physicists, biologists and astronomers seem to be doing better than engineers…