



**RIPE NCC**

RIPE NETWORK COORDINATION CENTRE

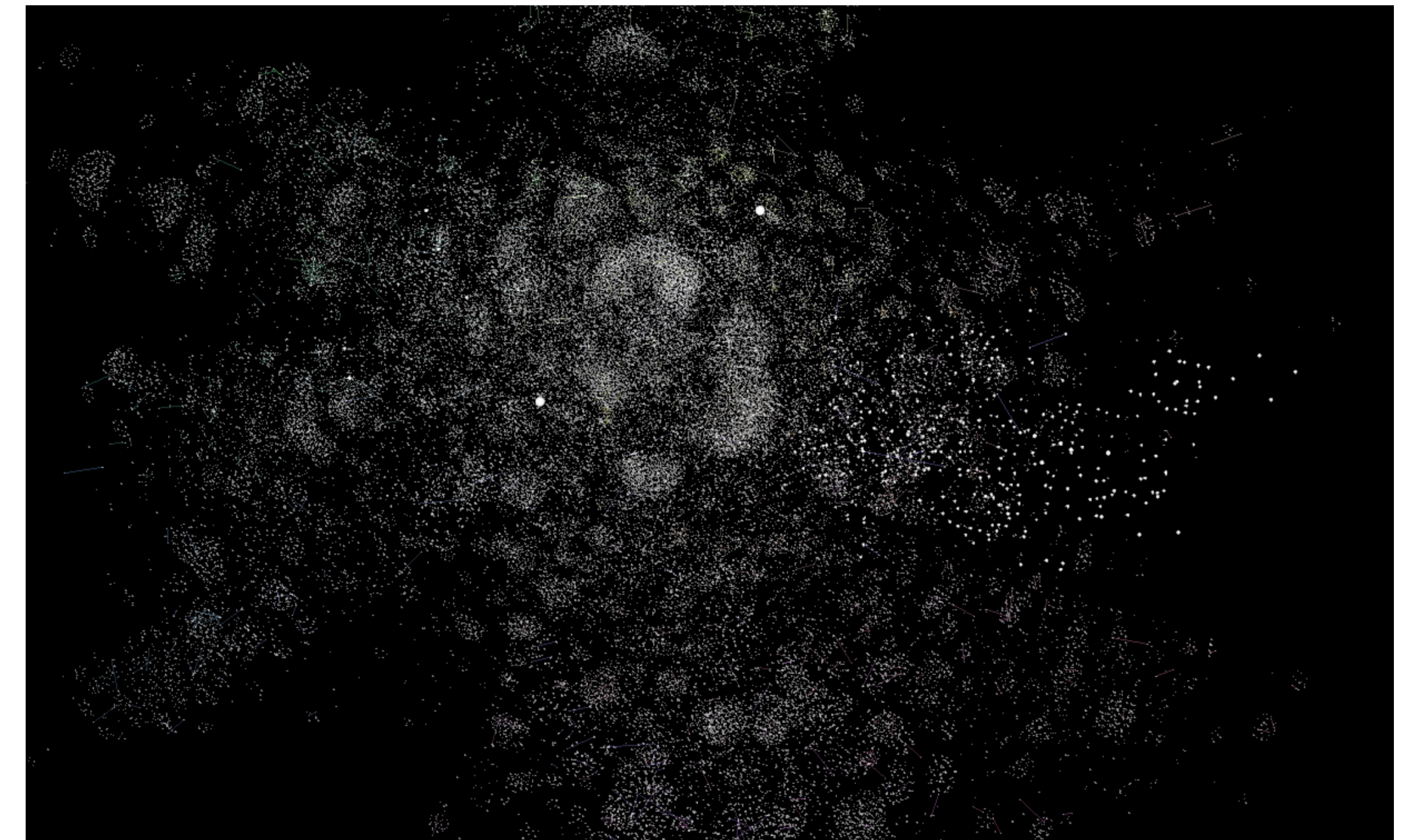
# The Future of the Interconnected Internet

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# What Is The Internet?



- Size: 15M km<sup>2</sup>
- Population: 4.9G (63% of earth population)
- Addresses
  - IPv4: 4,294,967,296 (many unusable)
  - IPv6: 340,282,366,920,938,463,463,374,607,431,768,211,456
- Sub-units: "Autonomous Systems" (ASes, or ASNs)
  - 75,057 ASNs visible on the Internet (RIS)
  - 1,084,717 IPv4 prefixes (aggregate)
  - 229,476 IPv6 prefixes (aggregate)
- Impression of complexity: <https://as2914.net/>



# What Is The Internet?



- A single shared medium for communication that benefits humanity
- Global, decentralised, borderless
- Based on a common set of protocols (IETF)
  - BGP - Interdomain routing
  - DNS - Name to number (and more)
- But also: Operating within geopolitical boundaries
  - Internet infrastructure is physically somewhere
  - Internet infrastructure is operated by people (net ops)



# Its Future? According to ChatGPT



EM What are the challenges for the future of the Internet? 

 The future of the internet is likely to be shaped by a number of challenges, some of which include:  

- Managing the continued growth and expansion of the internet, including the allocation of internet resources and the development of new technologies
- Ensuring the security and privacy of online activities and protecting against cyber threats
- Providing access to the internet for everyone, regardless of location or socioeconomic status
- Managing the increasing amount of data and traffic on the internet and ensuring that networks remain stable and efficient
- Addressing the potential negative impacts of the internet on society, such as the spread of misinformation and the erosion of privacy
- Developing and implementing effective internet governance frameworks to address these and other challenges.

Overall, the future of the internet is likely to be characterized by a number of complex and interconnected challenges that will need to be addressed in order to ensure its continued growth and success.

# What is RIPE NCC?



- Distributes Internet Resources (as one of 5 RIRs)
- Community Coordination
- Data & Tools

- <https://www.ripe.net/>

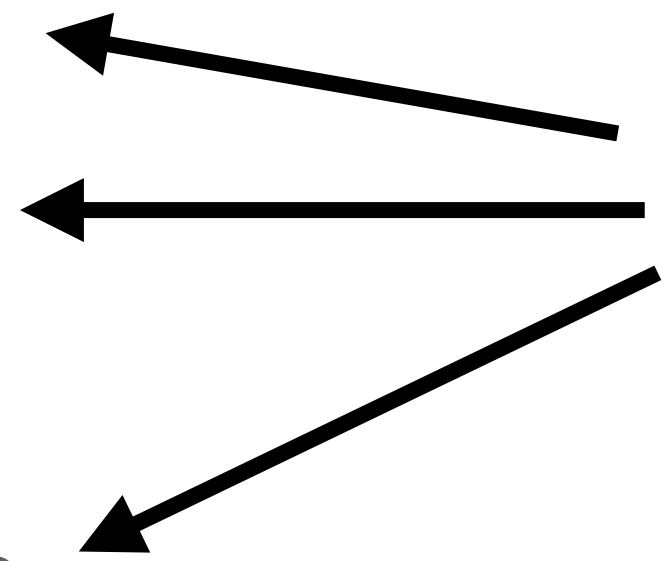


# IPv4 / IPv6



- Not every user can get an IPv4 address
  - Users share (NAT), but there are limits
- Policy around address usage used to be needs-based. Now it is market based.
- Current routing table: 3.0G IPv4 addresses
  - Top 3 networks
    - AS749 (US Dept of Defence) 6.7%
    - AS4134 (China Telecom) 3.4%
    - AS7018 (AT&T) 3.1%
  - 18k networks announce 256 addresses

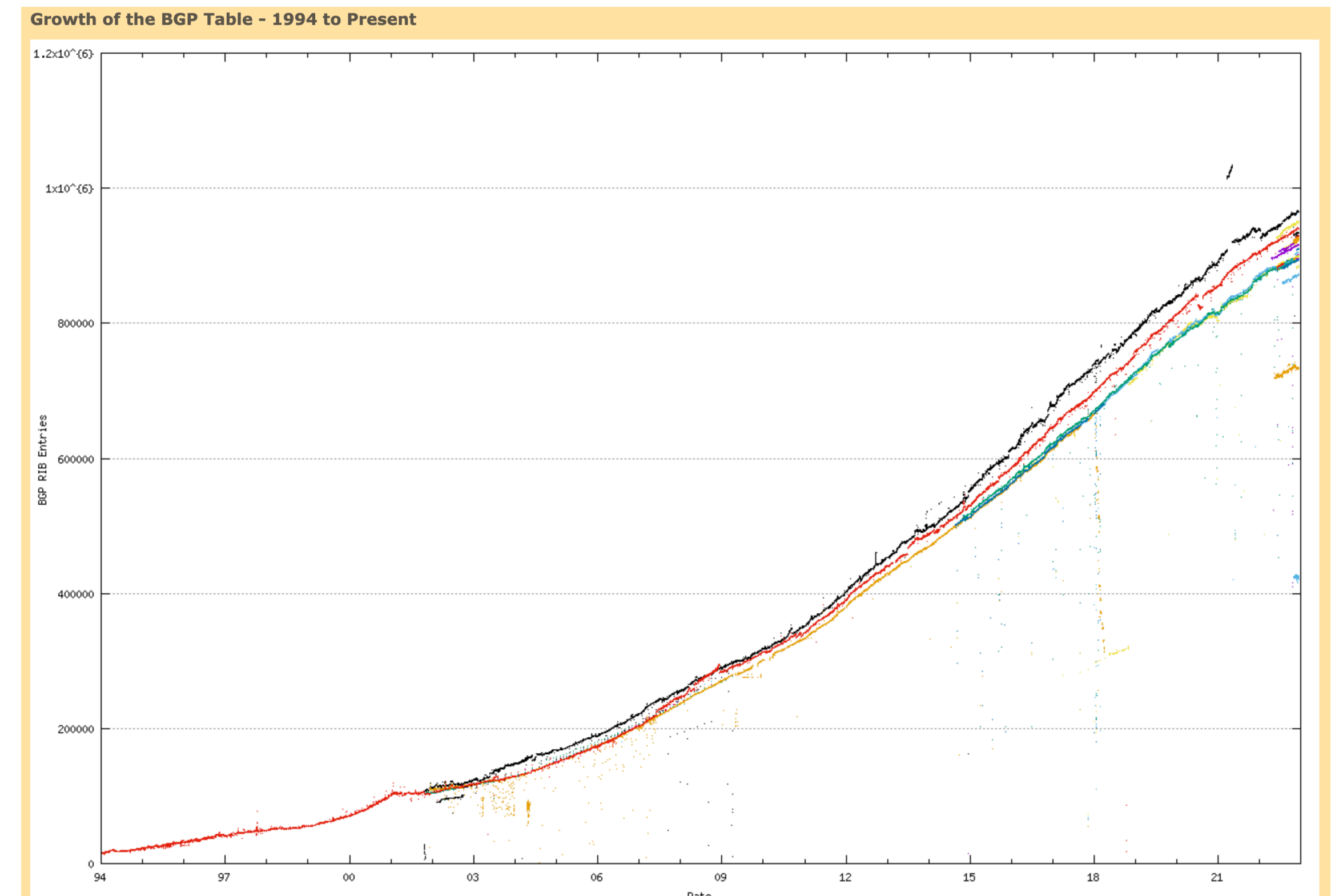
Very heterogeneous!



# Routing Table Growth



- At the same time there is still routing table growth
  - Number of participants (ASN) is still growing
  - Number of prefixes (IPv4) is still growing
- Not all routing tables are equal!
  - End-to-end connectivity is not a guarantee
  - Bigger routing tables need newer equipment
- “Global Routing Commons”



[bgp.potaroo.net](http://bgp.potaroo.net)



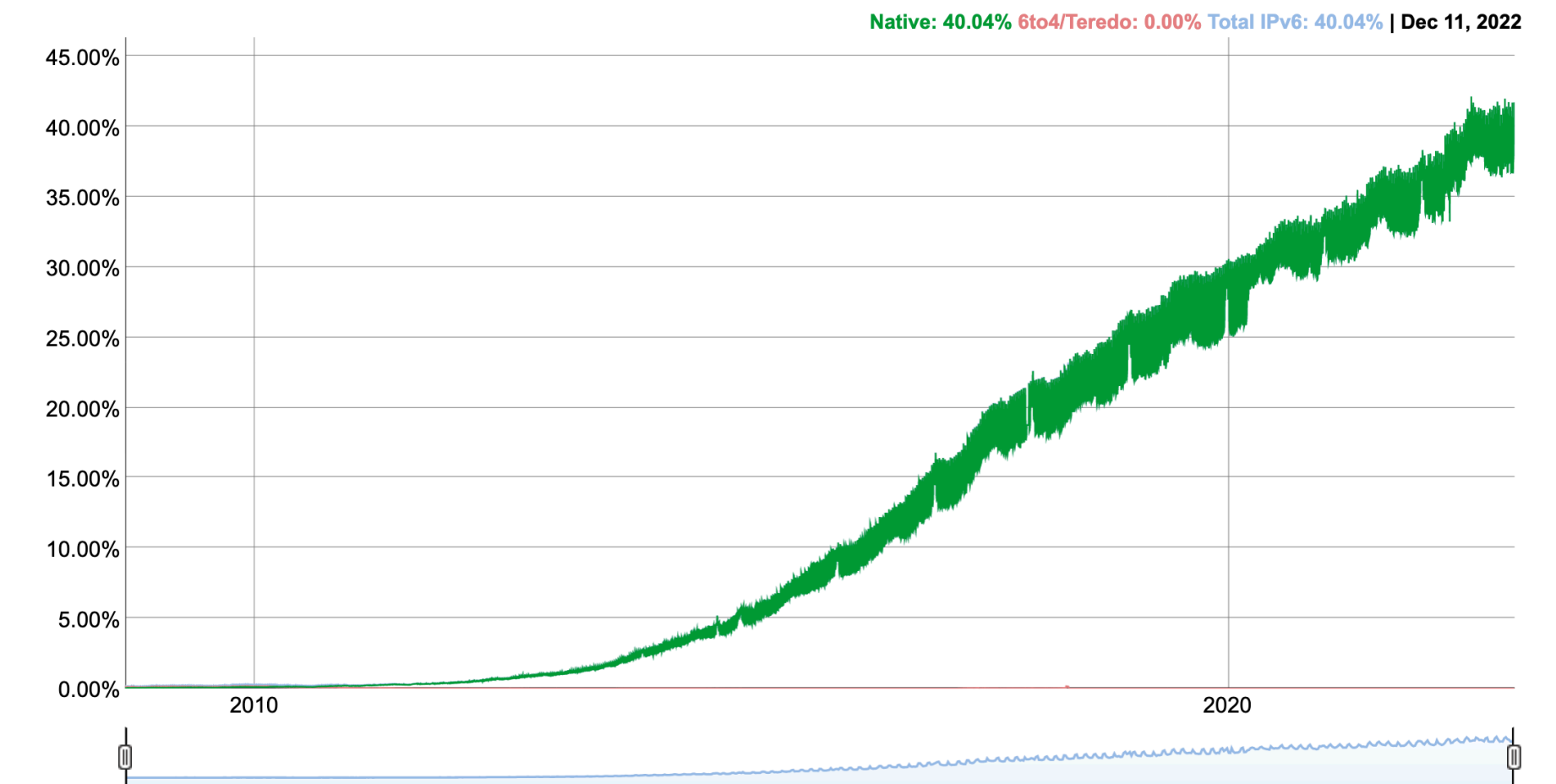
# IPv6 Adoption



- Since mid-2000s
- ~40% of users now
  - Heterogeneously deployed
- Adoption of new protocols is hard!

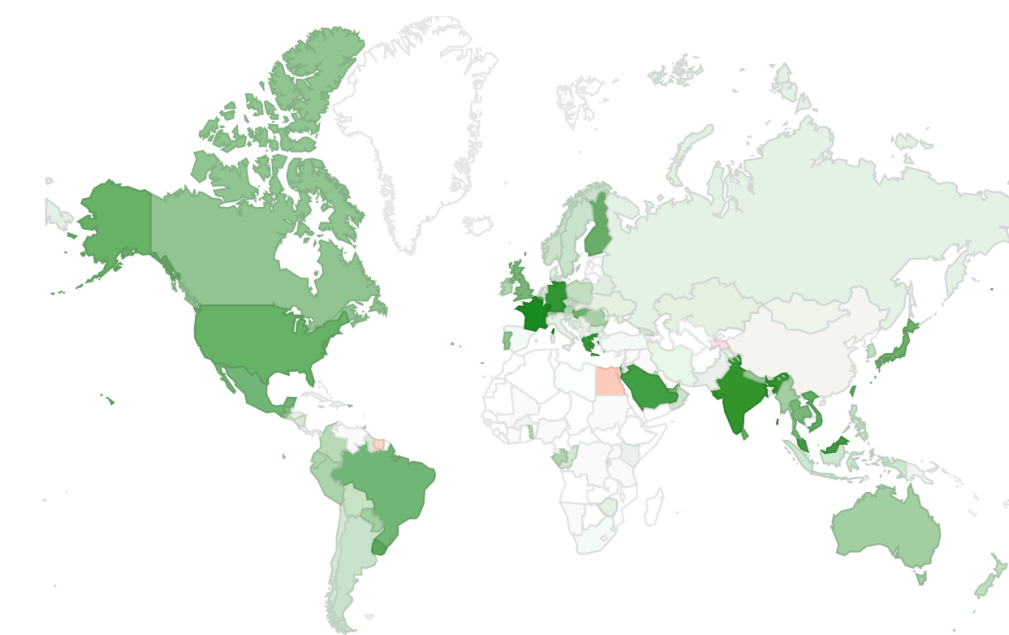
## IPv6 Adoption

We are continuously measuring the availability of IPv6 connectivity among Google users. The graph shows the percentage of users that access Google over IPv6.



## Per-Country IPv6 adoption

### Per-Country IPv6 adoption



World | Africa | Asia | Europe | Oceania | North America | Central America | Caribbean | South America

The chart above shows the availability of IPv6 connectivity around the world.

- Regions where IPv6 is more widely deployed (the darker the green, the greater the deployment) and users experience infrequent issues connecting to IPv6-enabled websites.
- Regions where IPv6 is more widely deployed but users still experience significant reliability or latency issues connecting to IPv6-enabled websites.
- Regions where IPv6 is not widely deployed and users experience significant reliability or latency issues connecting to IPv6-enabled websites.



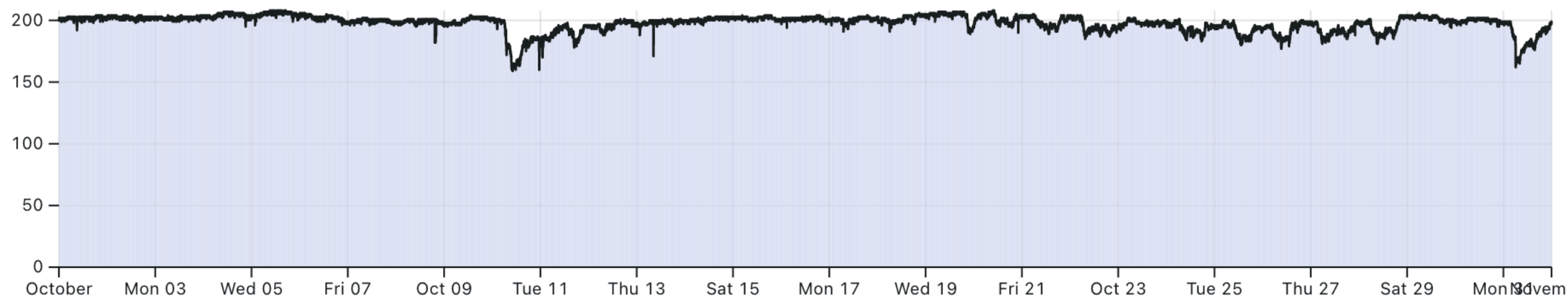


**Energy**

# Issue: Environmental Constraints



- Internet: an interconnected system for communication within the limits of our planet
- Energy is a basic need for the Internet, and it's geopolitical
- Can our environment (your country, our planet) cope?
- <https://www.reuters.com/world/europe/russian-missiles-hit-30-ukraines-energy-infrastructure-two-days-minister-2022-10-12/>



Ukr RIPE Atlas probes





**Humans**

# Competition vs. Collaboration



- Networks can be competitors, but have to collaborate to achieve global Internet reachability
- >12,000 networkers take care of Internet interconnection
  - How do they coordinate?
  - Network Operator Groups (NOGs) ( <https://labs.ripe.net/nogs/> )
    - Small (NetLdn) and large (NANOOG)
    - Virtual (IRC, etc.) and in real life (events, like RIPE meetings)
- [https://labs.ripe.net/author/uta\\_meier\\_hahn/](https://labs.ripe.net/author/uta_meier_hahn/)



# New networkers



- How will new networkers find their way?
  - Internet is complex
  - Formal (protocols) and informal rules
- “Personal ASNs”: Small networks that are used to learn how to do BGP interconnect.
  - 885 out of 75k networks ( >1% of ASNs in the current routing table )



# Fragmentation

# Fragmentation of Fragmentation



- What does fragmentation even mean?

## Scoping the Fragmentation Discussion

If we want to find our way to practical strategies and measures to avoid fragmentation, we need to scope the problem a bit more clearly. And many have made various attempts at this over the past two decades. One notable example came via [a paper](#) published in 2016, commissioned by the World Economic Forum, and authored by William Drake, Wolfgang Kleinwächter and Vint Cerf. Here, fragmentation was considered in three distinct categories:

- Technical Fragmentation
- Governmental Fragmentation
- Commercial Fragmentation

More recently, the Internet Governance Forum has established a Policy Network on Internet Fragmentation (PN-IF), which has similarly tried to develop a [framework](#) that captures a range of fragmentation concerns, albeit with some slightly different focus points:

- Fragmentation as it relates to user experience
- Fragmentation at the technical layer
- Fragmentation at the governance/coordination layer

These efforts, and many others, have helped illustrate and draw attention to a range of threats, whether to the Internet itself or to the rights and expectations of those who use the Internet. They have ensured that fragmentation (and the importance of fostering and maintaining a single, interoperable global Internet) has remained a focal point for governance discussions. But I'm not sure we've nailed down the practical implications of that principle for all stakeholders.

<https://labs.ripe.net/author/chrisb/fragmentation-still-the-internets-big-bad/>

# Fragmentation = damage



- “Internet routes around damage”
  - Netops make the Internet route around damage, if it doesn't automatically
- Fragmentation / censorship can be seen as damage
- Compare to natural disasters
  - Humans come together to make things work again





**Security**

# Attack/Defense



- DDoS is cheap
  - No inherent security in the Internet
  - Anybody can send anything to anyone
- Adds cost to reliable hosting of content on the Internet
  - Anti DDoS is a whole industry
  - <https://bgp.tools/tags/ddosm> list 59 ASNs that do mitigation
- Results in higher barrier of entry for content

# Hijacks



- BGP has no inherent security
  - Inherent trust in the routes your neighbour networks provide you
  - Filtering and observability
- RPKI is being deployed to improve security
  - “This address space can be originated by this ASN”
- For now we have to do with observability
  - RIS & RIPE Atlas are public platforms that enhance network observability
  - How do we make these platforms better?



**Complexity**



# Complexity



- Core Internet protocols get more complex over time
  - “DNS Camel”
  - Fewer people actually understand all of the protocol
- Internet itself has an increasing complexity
  - More ASNs, routes
  - But also a flattening of topology
    - Big content and big eyeballs are typically directly connected
- Mimics evolution of biological ecosystem?



# Conclusion

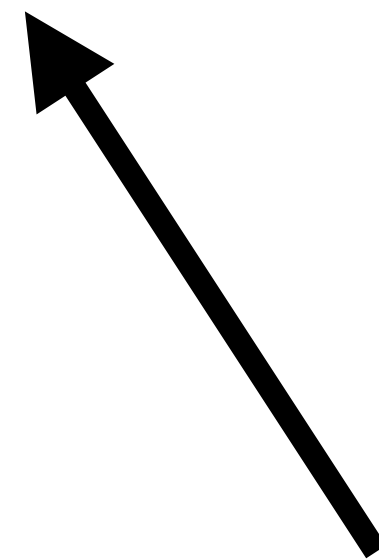
- Internet is a fascinating, evolving, complex system
- It's future determined by humans
  - Users
  - Networkers
  - Regulators
- Because it's a complex system, it's hard to predict consequences of actions
- For better understanding we need interdisciplinary collaborations



# Questions



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Not a typo!