Research and Education Networking Ecosystem

Campus Network Design & Operations Workshop

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UNIVERSITY OF OREGON

Last updated 4th November 2023

NSRC
Network Startup Resource Center

History of the Internet

- ARPAnet 1969-early 80's
  - Funded by US Department of Defense, but used for academic purposes until MILnet was developed for service to DOD.
- NSFnet 1986-1995
  - Connections to Universities and Research Centers for access to US National Science Foundation funded supercomputer centers
  - About 2000 hosts in 1986, more than 2,000,000 by 1993
  - World Wide Web 1991, first widely available web browser 1993
  - The bulk of this growth was funded by the National Science Foundation and hosted by Universities and Research Centers
- Privatization of the Internet 1993-1998 and onwards

US National Science Foundation Role

- *For 30+ years, NSF has invested in Internet connectivity linking the scientific research and education (R&E) communities in the U.S. to the rest of the world. At first, NSF was the sole funder of international R&E connectivity. In that time span, external funding elsewhere has grown substantially. Today, trans-oceanic 100 Gigabit per second (Gbps) links made available specifically to the R&E community approach or exceed an aggregate Terabit per second (Tbps) between some continents, with some 100Gbps links dedicated to specific science communities and instruments.**
- NSF investments in the International Research Network Connections (IRNC) program 2005-present has been ~$150M

* See https://www.nsf.gov/pubs/2020/nsf20535/nsf20535.htm

European Union Investment

- While the US National Science Foundation was instrumental in Internet development in the early days, the global spread of Research and Education Networking has been funded significantly by the European Union (EU).
- EU has funded a number of regional networking activities, including South & Central American (RedCLARA), Africa (UbuntuNet, WACREN, ASREN), Mediterranean (EUMEDCONNECT), Central Asia (CAREN), Asia (TEIN), and others
  - EU total investments to develop these regional networks is estimated to be €234M ($251M USD)

NSF IRNC and NSRC

NSRC is partially funded by the NSF's Office of Advanced Cyberinfrastructure in the IRNC program with a focus on **Engagement for Training and Human and Network Capacity Building**, especially in areas of the world where research and education network connectivity remain a challenge to collaborations with U.S. scientists and educators.

Ultimately, the NSRC's work to strengthen global the R&E network community builds goodwill for U.S. scientists and the U.S. government; fosters open, interoperable and secure Internet operations; expands and increases secure Internet access in emerging markets for universities, research institutions, and governments via dissemination of best practices for network operations and cybersecurity.

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NSF Award #2029309

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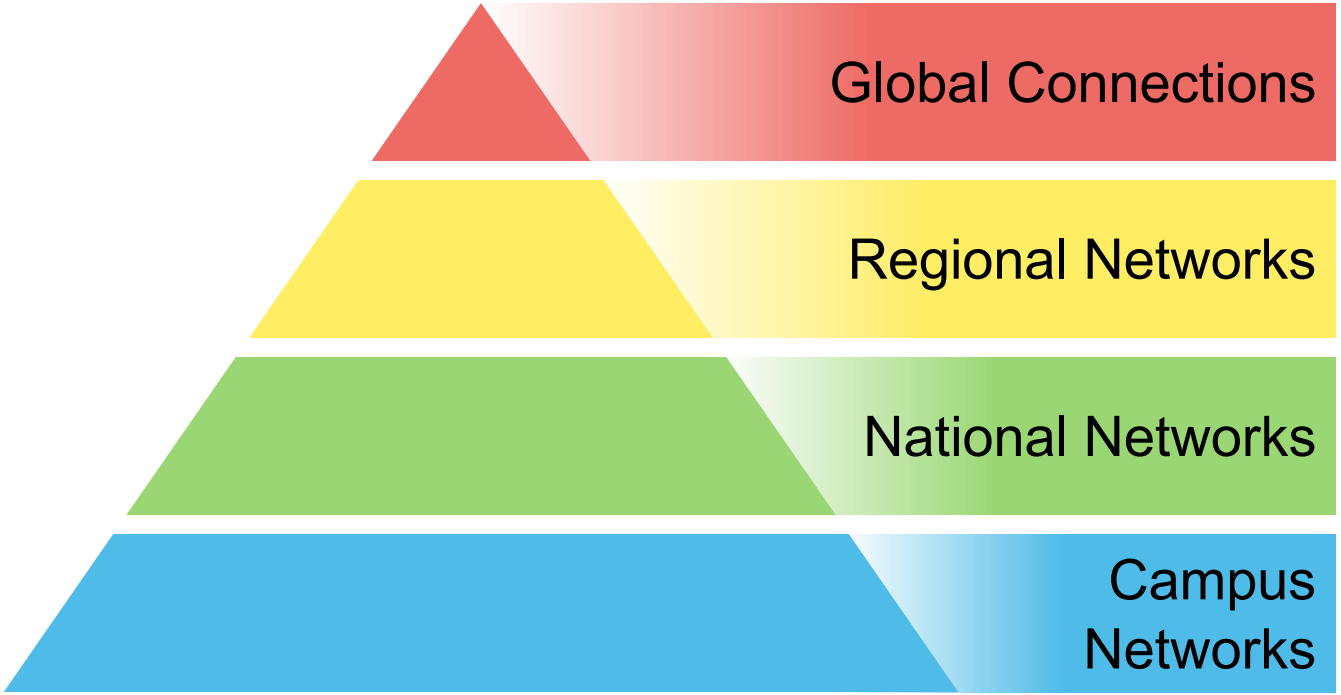
Research and Education Networks

- Some Terminology
  - Research and Education = R&E
  - Research and Education Network = REN
  - National REN = NREN
- Globally, the REN connectivity is complex and difficult to understand
- Why RENs?
  - Commercial ISPs exist to make money for shareholders and owners
  - RENs exist to serve the needs of the research and education community

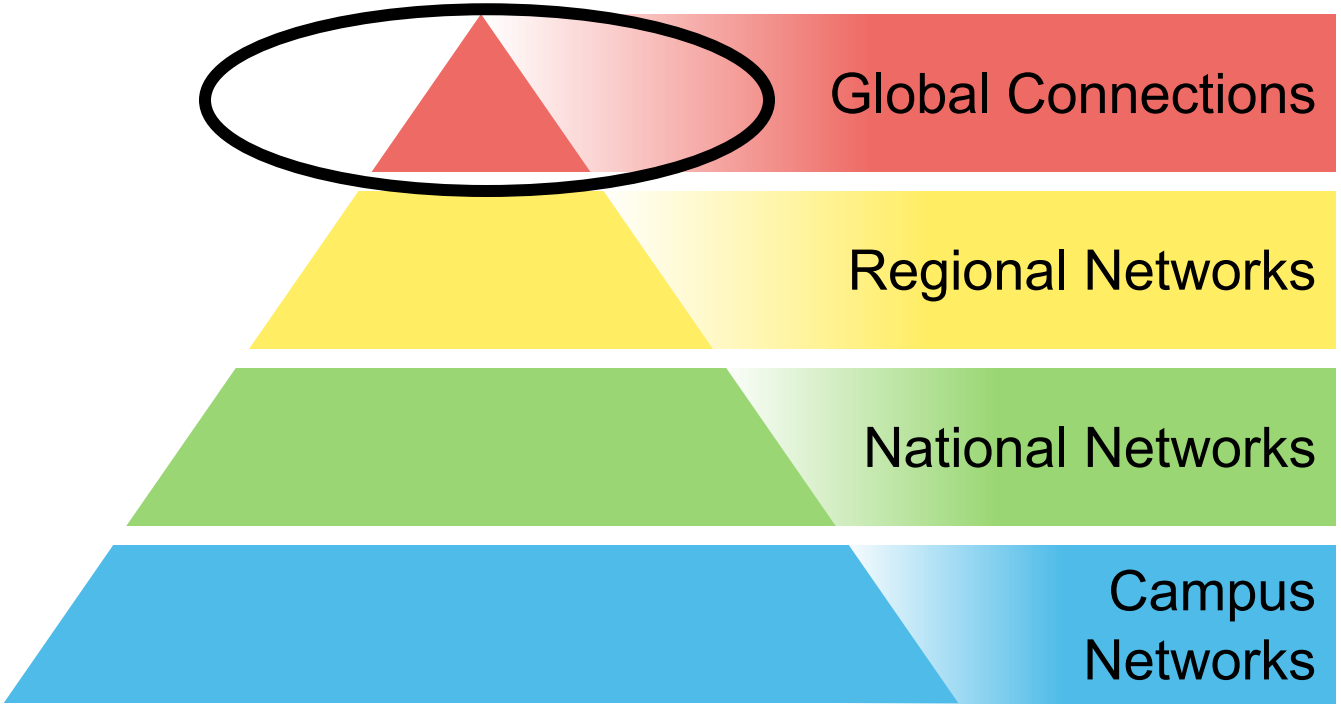
REN Characteristics

- High bandwidth networks
  - 10G backbones with more and more 40G and 100G
  - Some R&E networks are doing pilot roll-outs of 400 Gbps
  - Research typically needs uncongested networks
    - Which means many RENs are lightly used with lots of unused capacity (we call the unused capacity headroom)
- Low latency
  - Terrestrial fiber
- Open Networks with no filtering
  - Firewalls can make it hard for ad-hoc activities

NREN Ecosystem



NREN Ecosystem

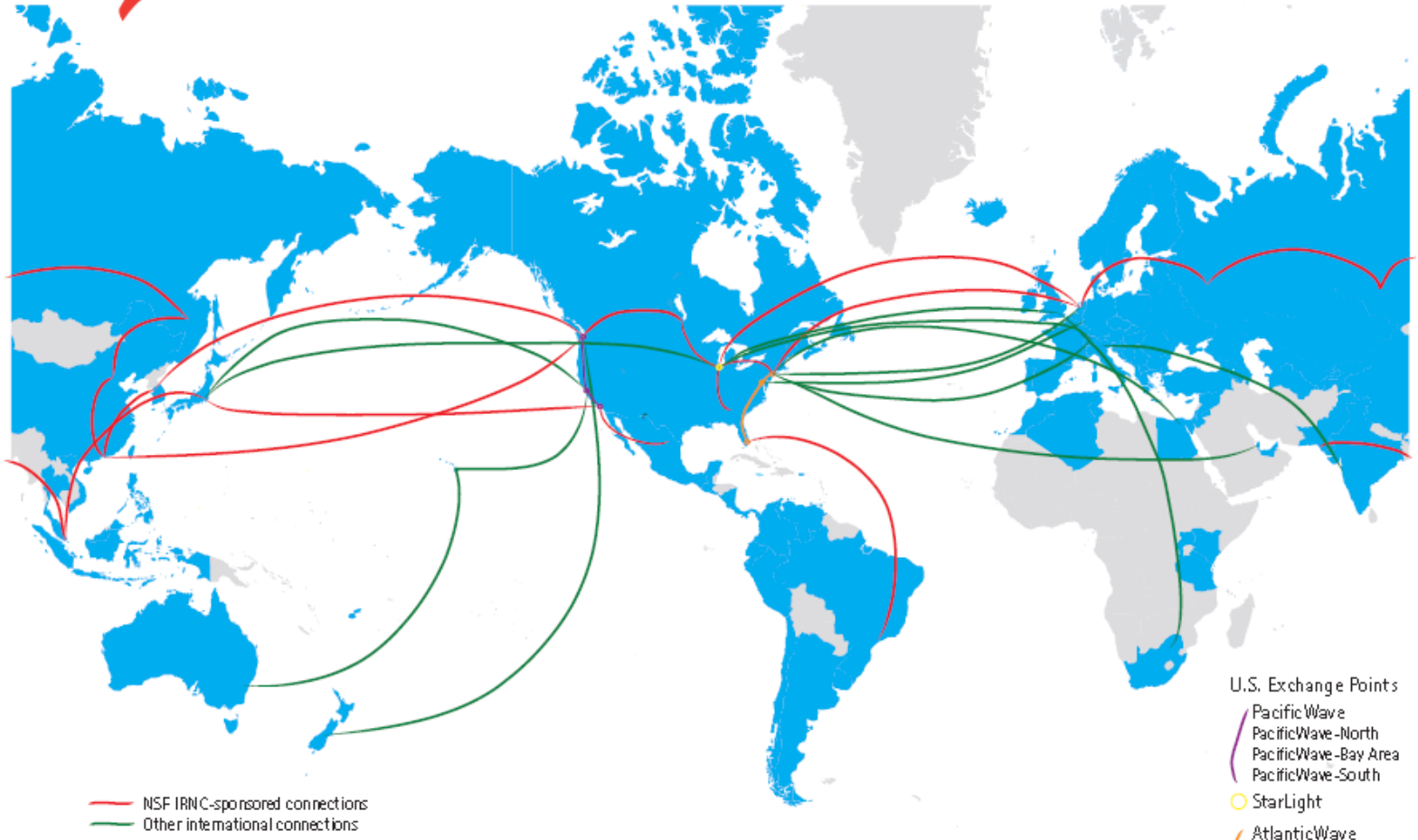


Global REN Connections

- Connect Regional or National networks together
- Tend to be longer, more expensive circuits
- Not always well coordinated
- Routing policies often inconsistent

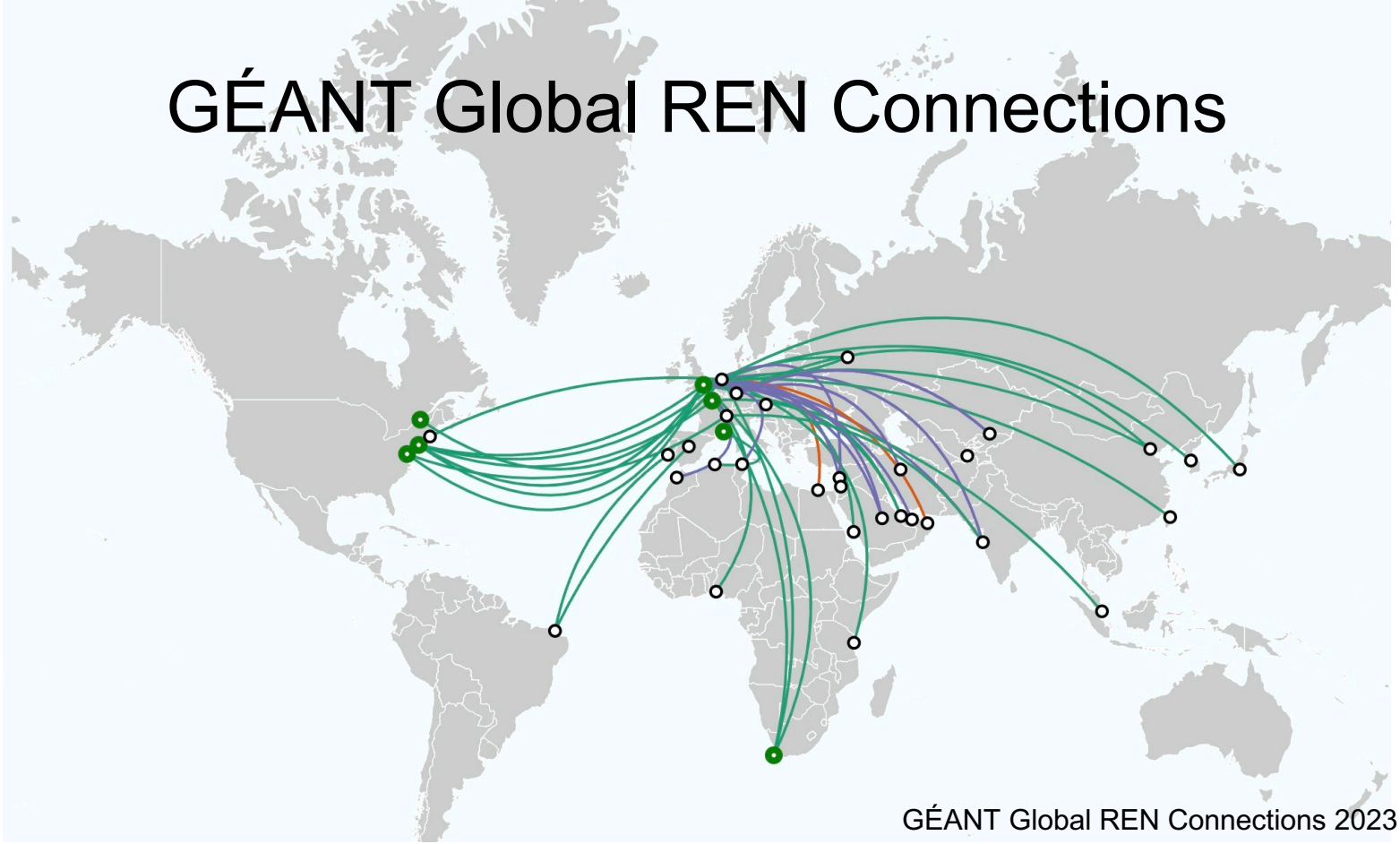
INTERNET2® www.internet.edu

THE INTERNATIONAL REACH OF THE INTERNET2 NETWORK

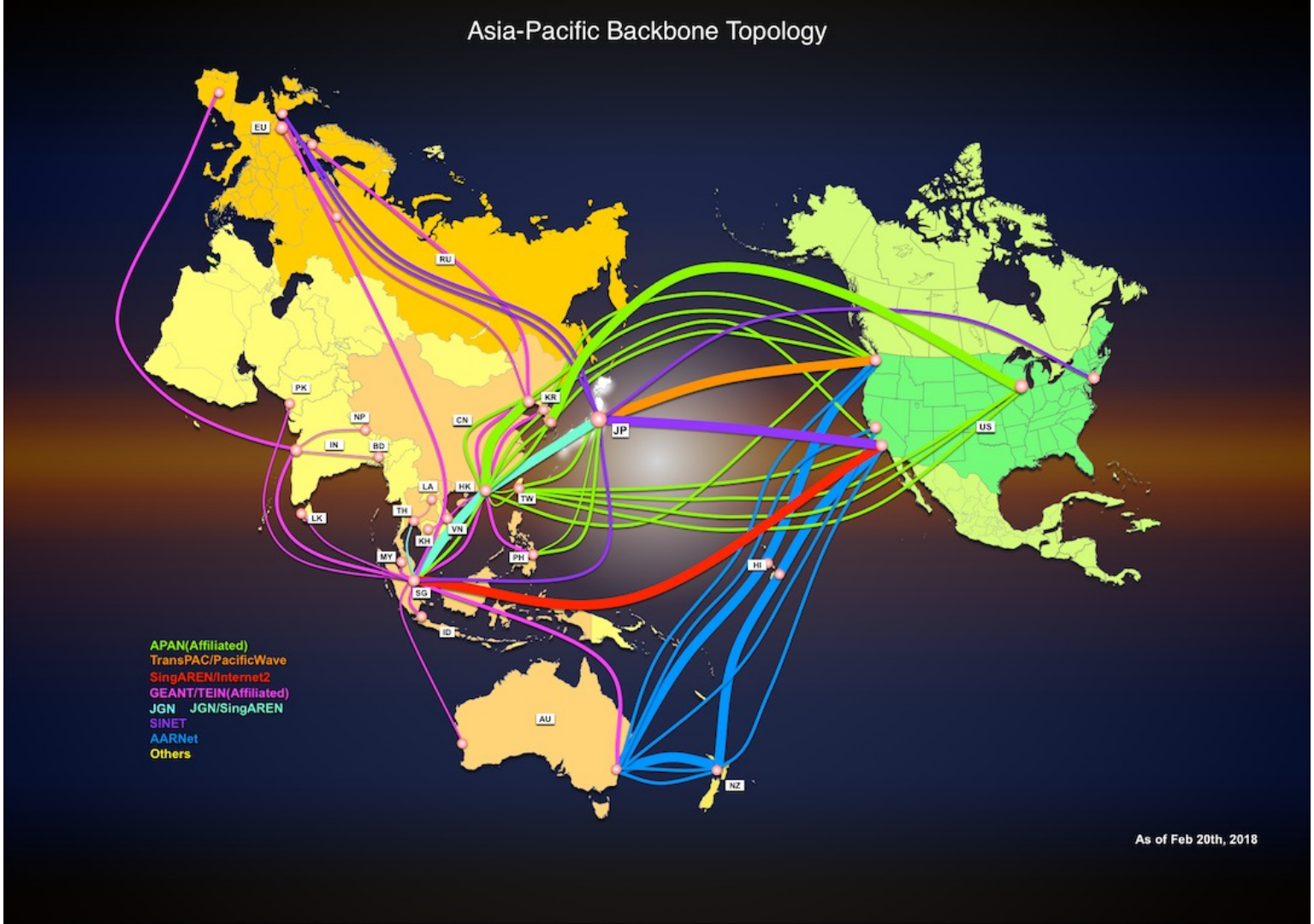


For further information regarding the international programs of Internet2, visit http://internet2.edu/international or contact Heather Boyles, International Relations Director, international@internet2.edu.
A listing of networks reachable via the Internet2 Network is found on the back of this page.

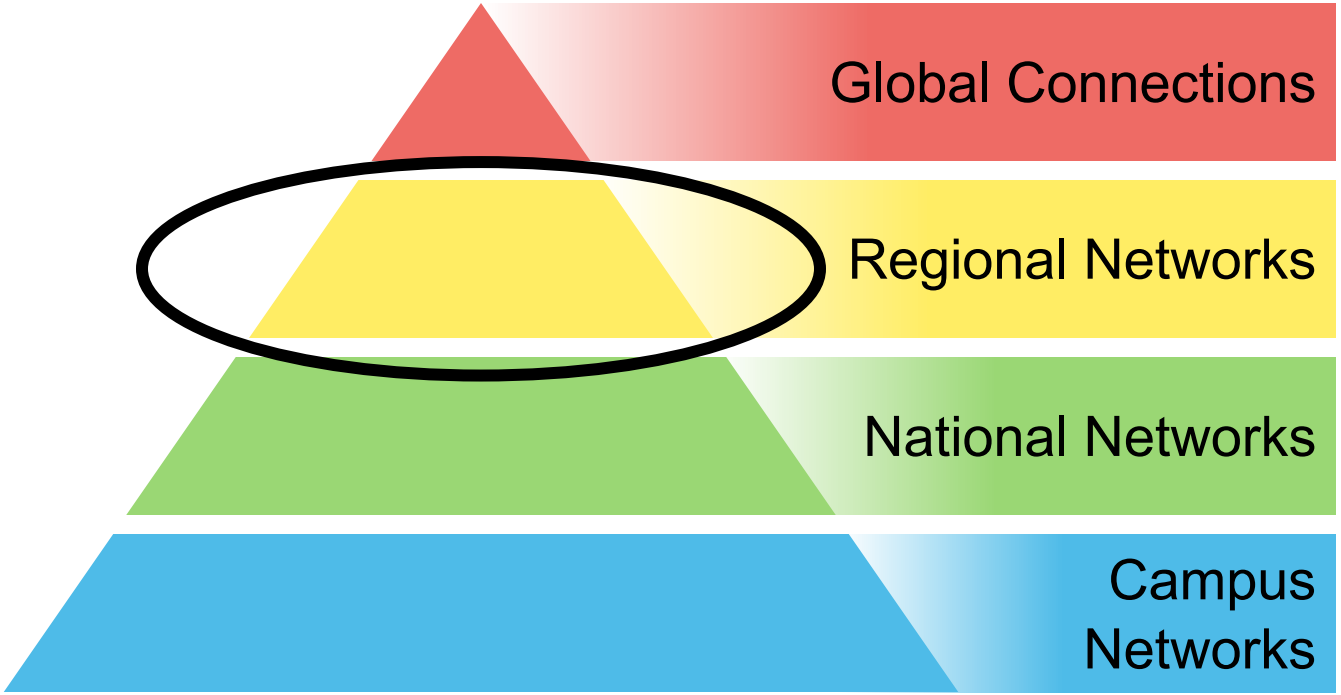
GÉANT Global REN Connections



GÉANT Global REN Connections 2023


Asia-Pacific Backbone Topology
EU
RU
PK
NP
IN
BD
CN
KR
JP
US
LA
HK
TW
TH
LK
VN
KH
MY
PH
HI
SG
ID
AU
NZ
APAN(Affiliated)
TransPAC/PacificWave
SingAREN/Internet2
GEANT/TEIN(Affiliated)
JGN JGN/SingAREN
SINET
AARNet
Others
As of Feb 20th, 2018

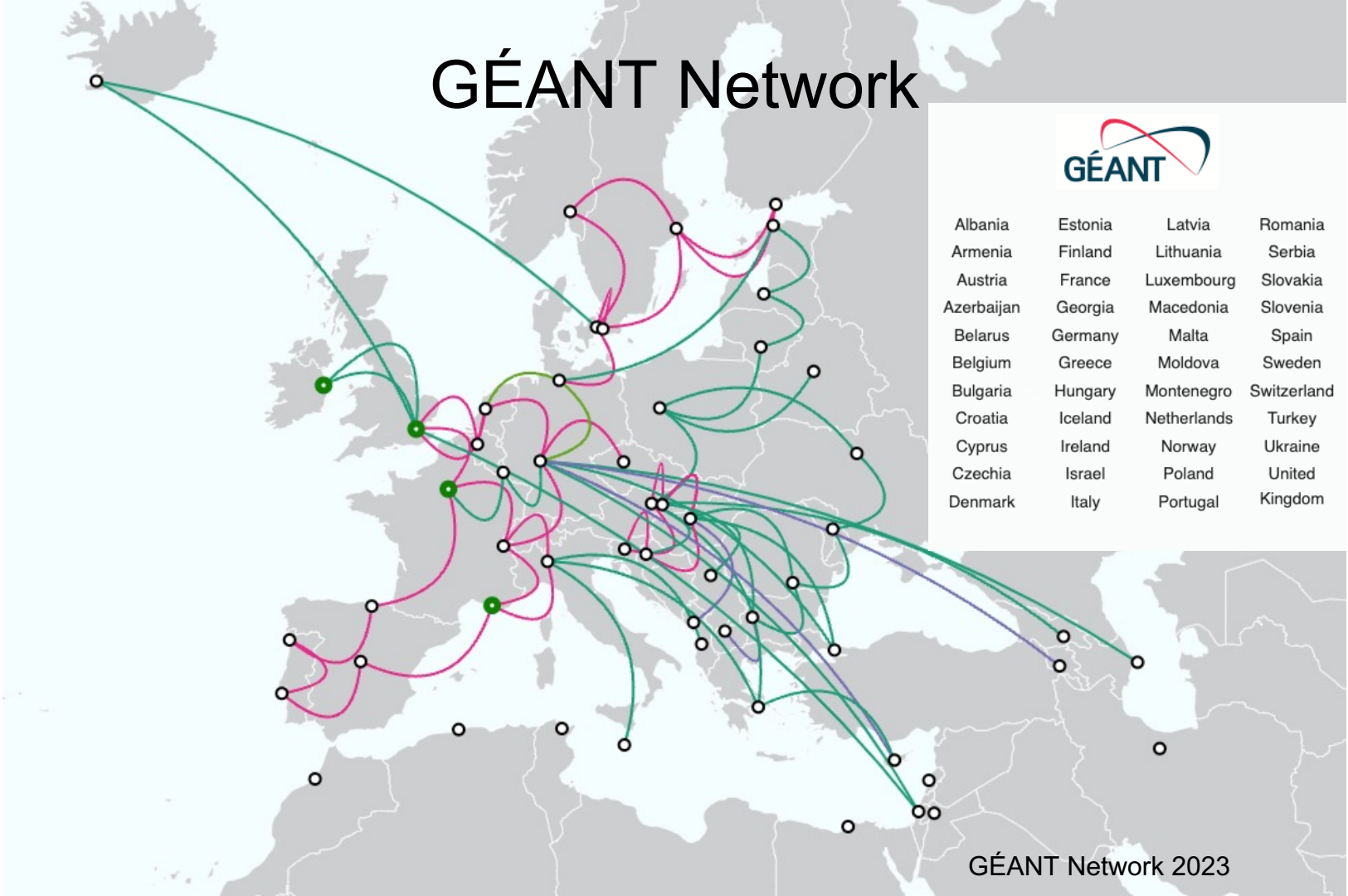
NREN Ecosystem



Regional REN Connections

- Regional RENs connect REN of individual countries within a geographic region
- Many regional networks have funding from European Union
  - GÉANT, ASREN, Asi@Connect, ALICE/ALICE2 (RedCLARA), Ubuntunet and WACREN

GÉANT Network

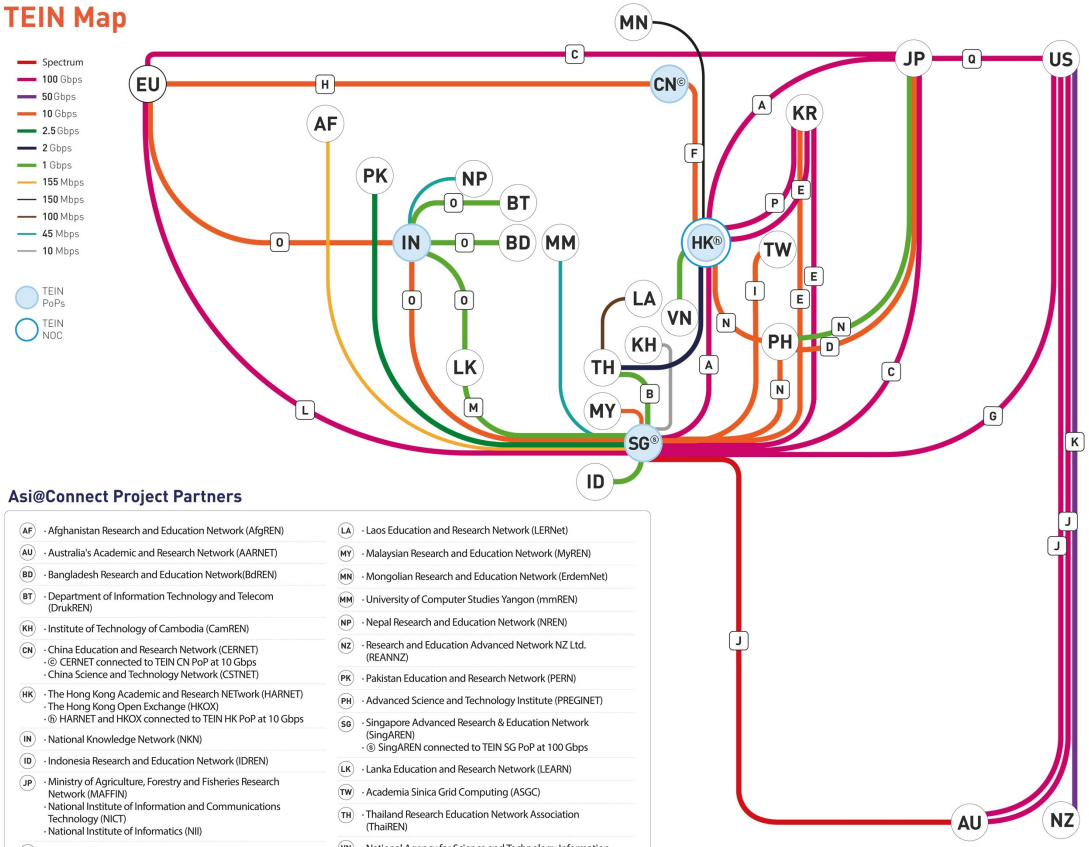


GÉANT Network 2023

Asi@Connect

The EU co-funded Asi@Connect project provides a dedicated regional high capacity and high quality internet network, Trans Eurasia Information Network(TEIN), for Research and Education (R&E) communities across Asia-Pacific and Europe, and leverages e-infrastructures developed for public service projects.

TEIN Map



Asi@Connect Project Partners

- AF · Afghanistan Research and Education Network (AfgREN)
- AU · Australia's Academic and Research Network (AARNET)
- BD · Bangladesh Research and Education Network(BdREN)
- BT · Department of Information Technology and Telecom (DrukREN)
- KH · Institute of Technology of Cambodia (CamREN)
- CN · China Education and Research Network (CERNET)
  · ⓒ CERNET connected to TEIN CN PoP at 10 Gbps
  · China Science and Technology Network (CSTNET)
- HK · The Hong Kong Academic and Research NETwork (HARNET)
  · The Hong Kong Open Exchange (HKOX)
  · ⓗ HARNET and HKOX connected to TEIN HK PoP at 10 Gbps
- IN · National Knowledge Network (NKN)
- ID · Indonesia Research and Education Network (IDREN)
- JP · Ministry of Agriculture, Forestry and Fisheries Research Network (MAFFIN)
  · National Institute of Information and Communications Technology (NICT)
  · National Institute of Informatics (NII)
- KR · National Information Society Agency (KOREN)
  · Korea Institute of Science and Technology Information (KREONET)
- LA · Laos Education and Research Network (LERNet)
- MY · Malaysian Research and Education Network (MyREN)
- MN · Mongolian Research and Education Network (ErdemNet)
- MM · University of Computer Studies Yangon (mmREN)
- NP · Nepal Research and Education Network (NREN)
- NZ · Research and Education Advanced Network NZ Ltd. (REANNZ)
- PK · Pakistan Education and Research Network (PERN)
- PH · Advanced Science and Technology Institute (PREGINET)
- SG · Singapore Advanced Research & Education Network (SingAREN)
  · ⓢ SingAREN connected to TEIN SG PoP at 100 Gbps
- LK · Lanka Education and Research Network (LEARN)
- TW · Academia Sinica Grid Computing (ASGC)
- TH · Thailand Research Education Network Association (ThaiREN)
- VN · National Agency for Science and Technology Information (VinaREN)

* As of 31 January 2022.
** Other regions (Central Asia, Africa and Latin America) can be connected via global R&E networks such as EU(GÉANT) and US(Internet2)

The following links are fully financed/co-financed by the link owners whose support is gratefully acknowledged

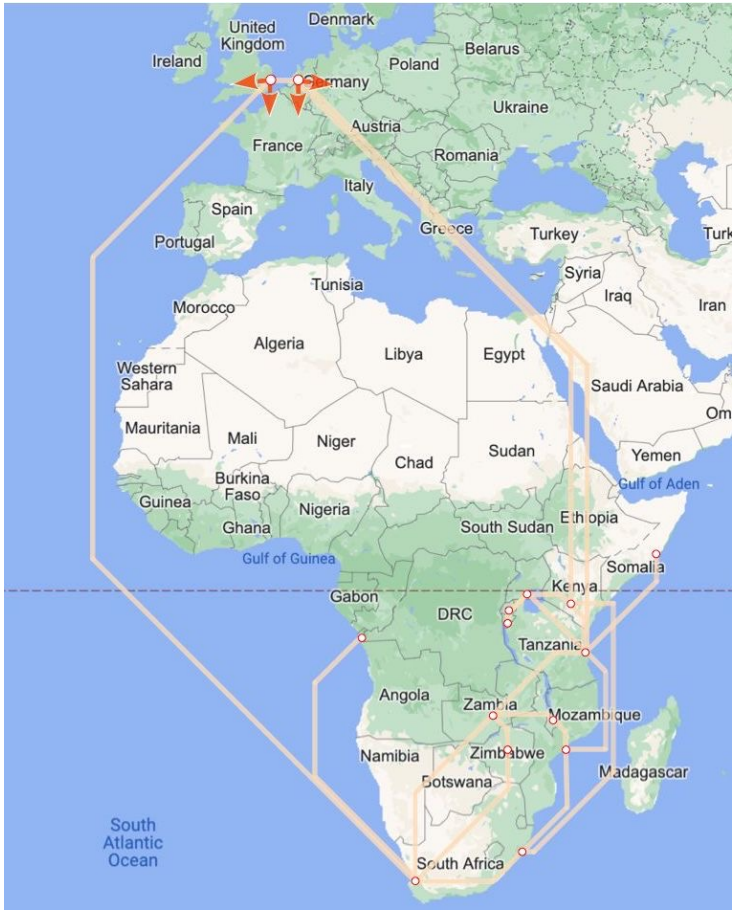
- A · National Institute of Information and Communications Technology
  National Supercomputing Centre
  Singapore Advanced Research & Education Network
  Hong Kong Academic and Research NETwork
- B · National Institute of Information and Communications Technology
  Thailand Research and Education Network
- C · National Institute of Informatics
- D · Ministry of Agriculture, Forestry and Fisheries Research Network
- E · National Information Society Agency
- F · China Education and Research Network
  TEIN*Cooperation Center
- G · Internet2
  ARENA-PAC
  TransPAC/Pacific Wave
  Australia's Academic and Research Network
- H · Co-funded by China and EU
- I · Academia Sinica Grid Computing
- J · Australia's Academic and Research Network
- K · Research and Education Advanced Network New Zealand
- L · aarnet GÉANT NORDUnet SingAREN SURFnet TEIN*
- M · LEARN Lanka Education and Research Network
- N · Advanced Science and Technology Institute
- O · National Knowledge Network
- P · Korea Research Environment Open NETwork
- Q · National Supercomputing Centre
  Singapore Advanced Research & Education Network

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RedCLARA Network



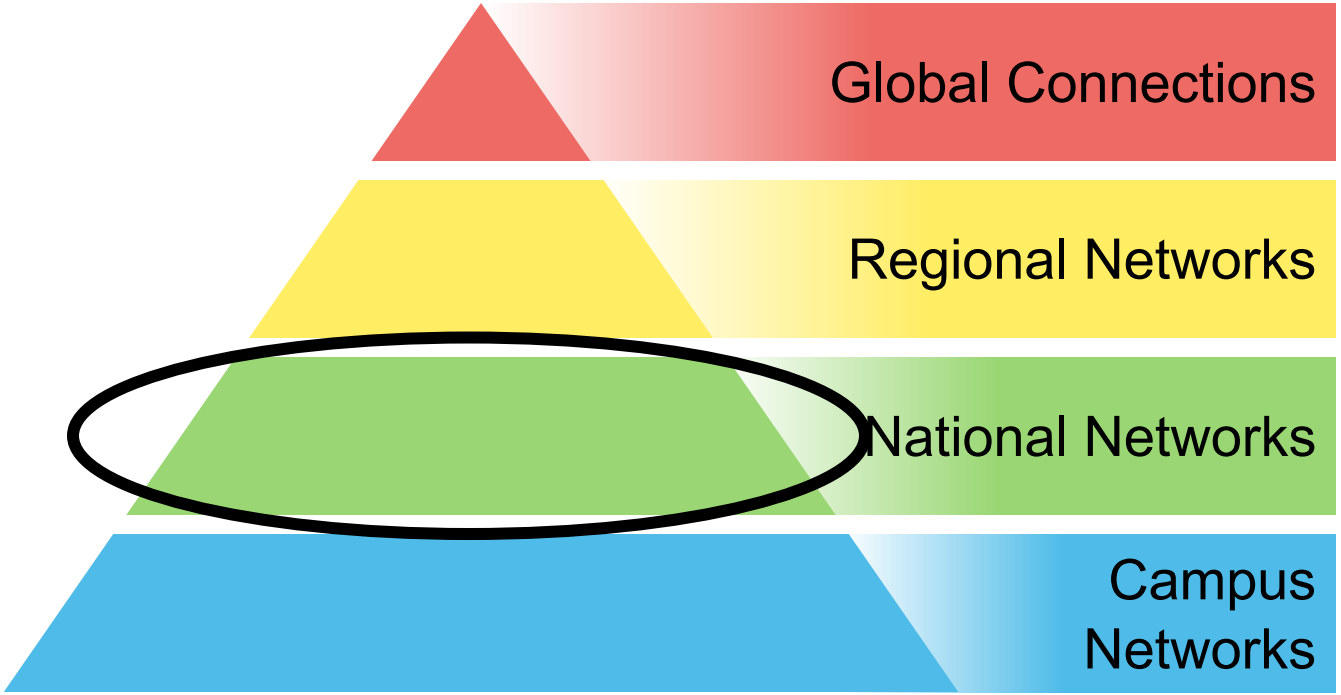
UbuntuNet Network



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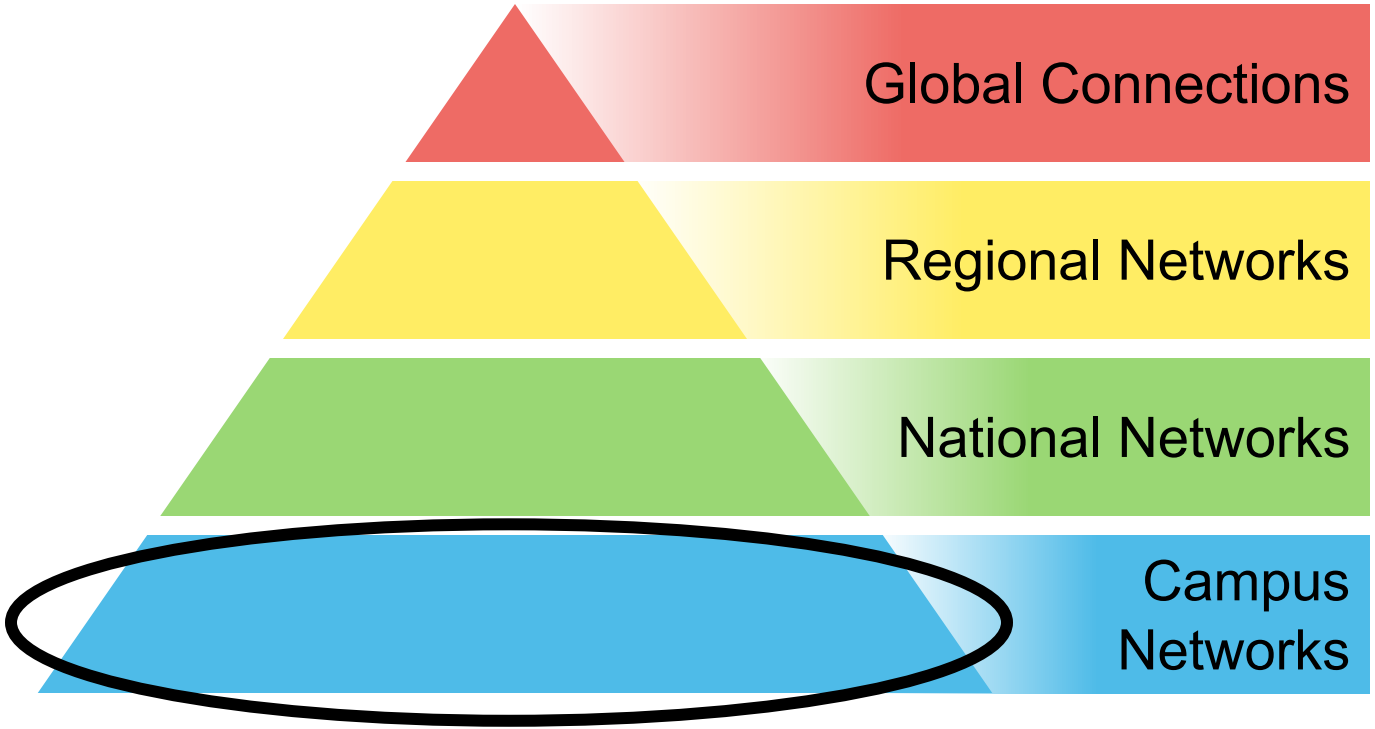
NREN Ecosystem



National RENs (NRENs)

- Provides service to Universities, Colleges, research labs, and others in an entire country
- Often hosted and operated by a prestigious university in the country
- Often provides “value add” services to members
  - Video conferencing, e-learning, web hosting, access to donated or discounted hardware, technical capacity building of member institutions, data center space for disaster recovery, etc.

NREN Ecosystem



Campus Network Role

- No student, researcher, or faculty member is connected directly to a Global, National, or Regional Network.
  - They are all connected to a campus network
- Without a good campus network, the entire ecosystem is affected
  - You can have a 100-gigabit connection to your Regional Network and a 100-gigabit backbone in your national network, but if the users have a poor connections on campus, the entire investment is wasted
- The campus network is the foundation that the entire REN ecosystem is built upon

Foundation Failures



Foundation Failures



Campus Network Challenges

- Many campus networks are not structured properly and can't effectively utilize high bandwidth connections
- Many make heavy use of NAT and firewalls that limit performance
- Many are built with unmanaged network equipment that provide no ability for monitoring or tuning the network
- Some NRENs force campuses to dual home

Campus Network Structure

- Campus networks have often grown organically over time without thought to proper architecture
- Campus networks are often built with outdated fiber optic cabling that can't support high speeds
  - Multi-mode fiber is unsuitable for a campus network – it is limited on speed and distance.
  - We will discuss this in more detail
- But remember, the campus network is the foundation
  - We encourage the entire REN community to look at campus networks and consider improvements and investments

Conclusion

- The Global Research and Education Network ecosystem is large, complex, and is a result of many billions of dollars of investments
- The campus network is the foundation that all of that investment relies upon.
- Campus networks are often not properly built and need to be improved
- The need for improvement is the motivation for this course

Questions/Discussion?

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