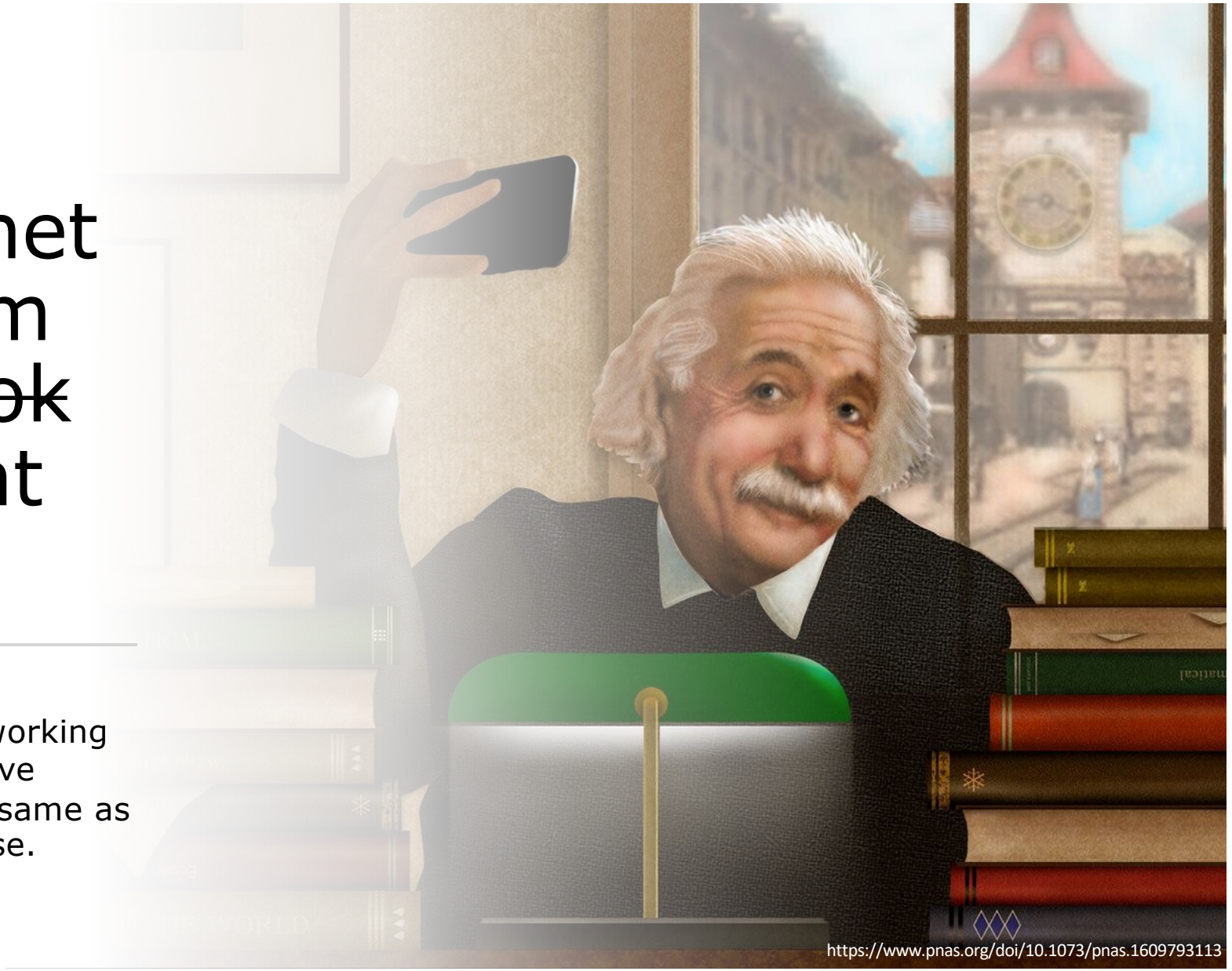
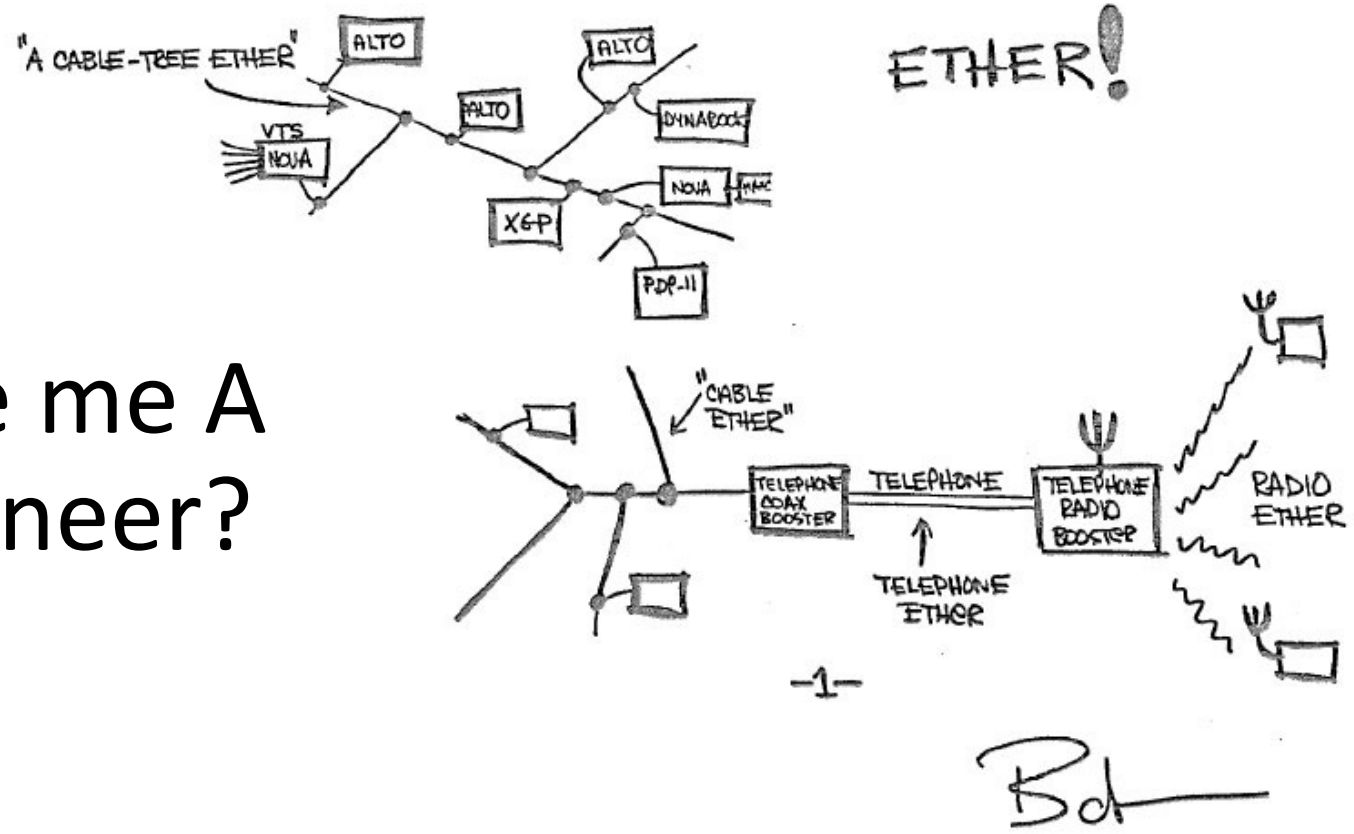
“The internet is fine – I'm on ~~Facebook~~ TikTok right now!”

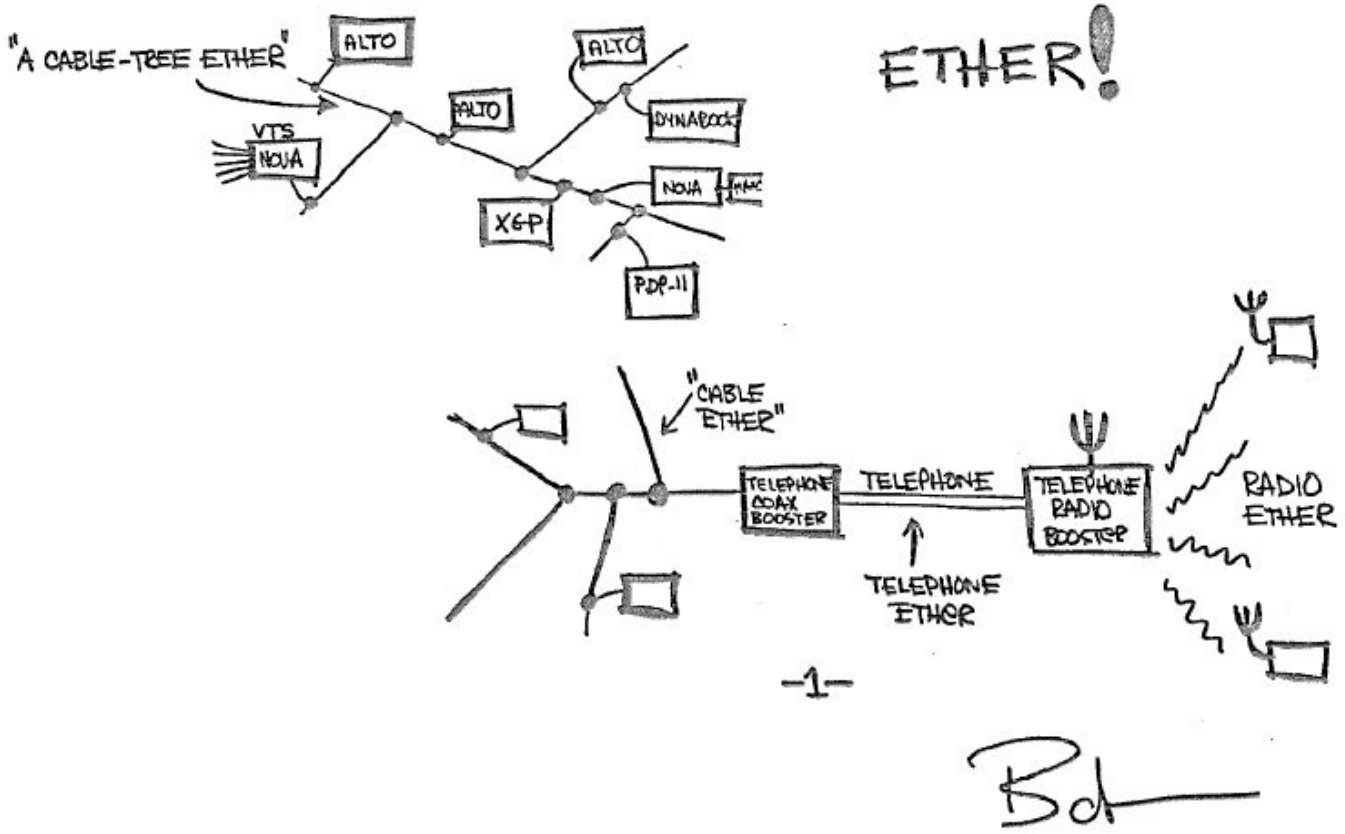
A discussion on how networking in support of data intensive research is not at all the same as networking for general use.



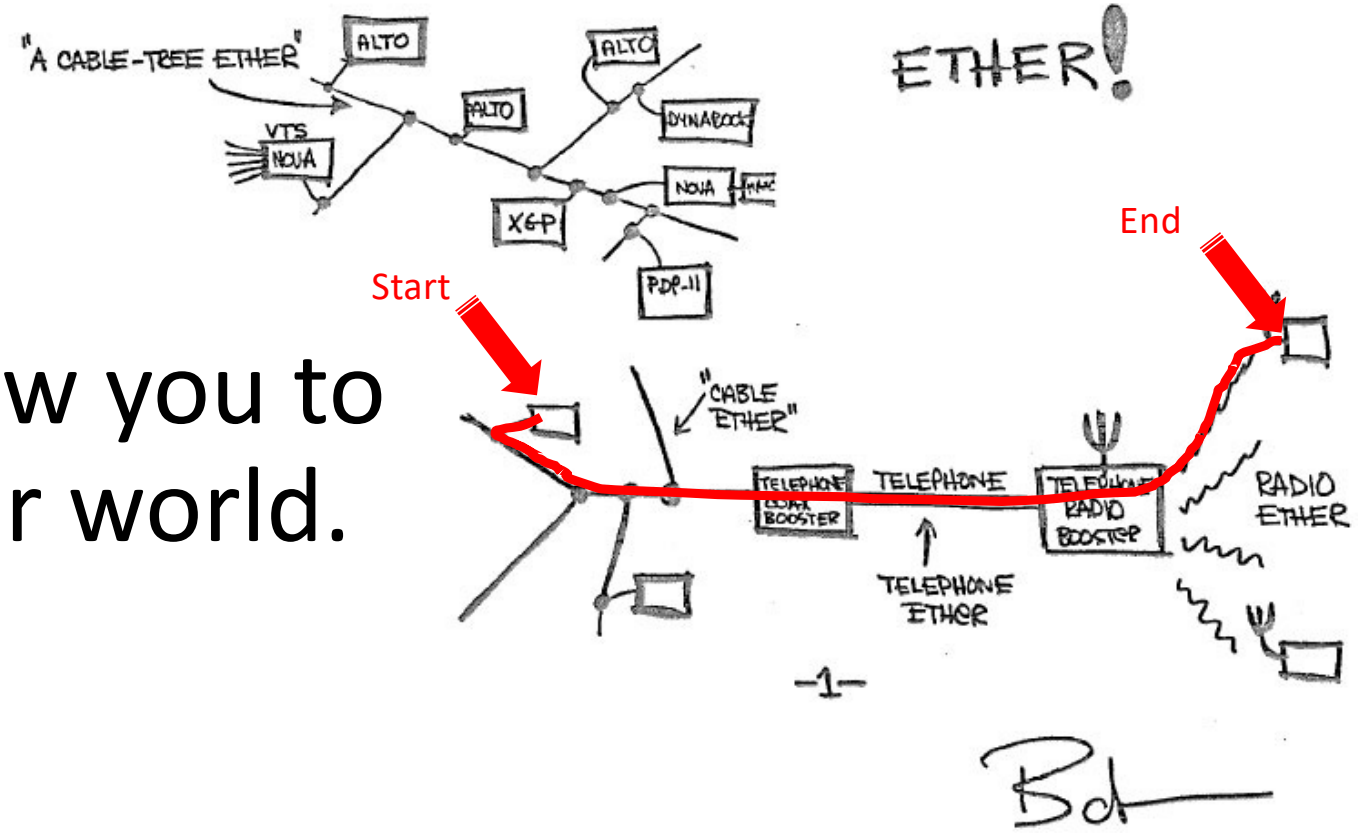
Will this make me A Network Engineer?



No.

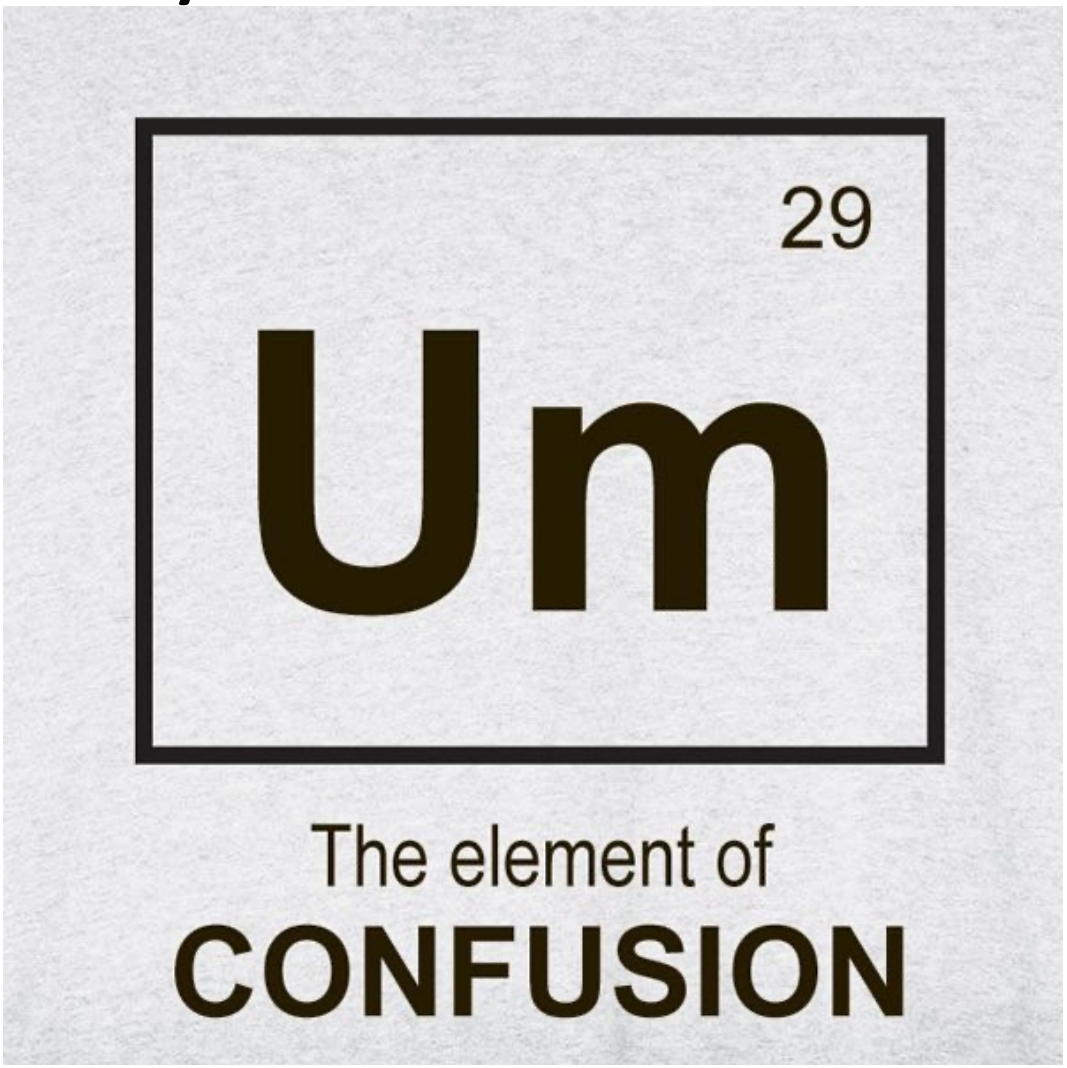

"A CABLE-TREE ETHER"
ALTO
ALTO
ALTO
DYNABOOK
VTS
NOVA
NOVA
X6P
PDP-11
ETHER!
"CABLE ETHER"
TELEPHONE COAX BOOSTER
TELEPHONE
TELEPHONE RADIO BOOSTER
RADIO ETHER
TELEPHONE ETHER
-1-

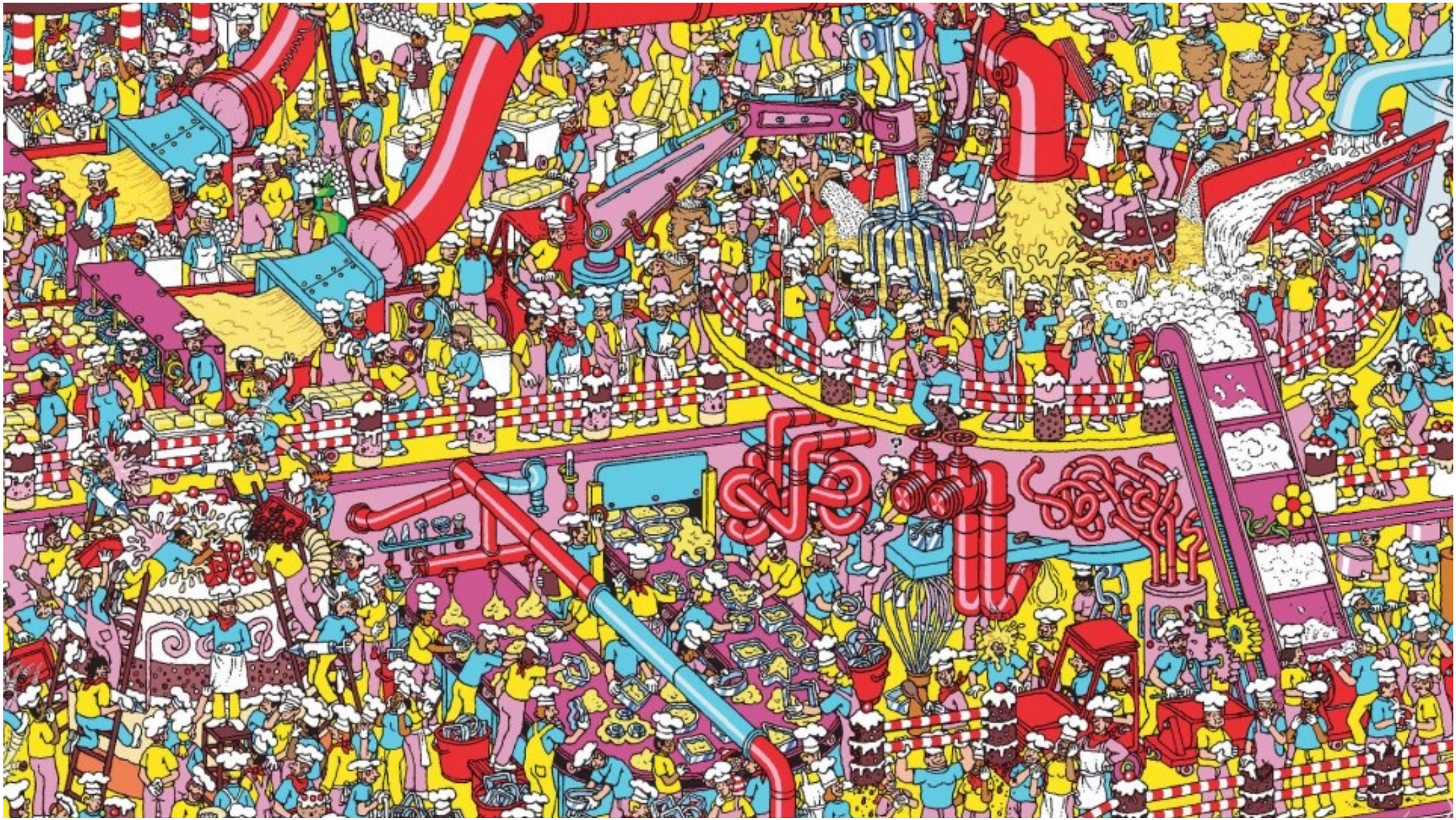
But it will allow you to navigate their world.



Maybe even understand them…

But why do I need to know this?





Tēnā koutou katoa,
nau mai haere mai ki tenei hui!

Wallace Chase

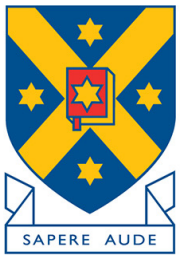
Head of Department, ITS

wallace.chase@otago.ac.nz

Aaron Murrihy

Technical Lead - Networks

aaron.murrihy@reannz.co.nz



UNIVERSITY of OTAGO

Te Whare Wānanga o Otāgo

NEW ZEALAND

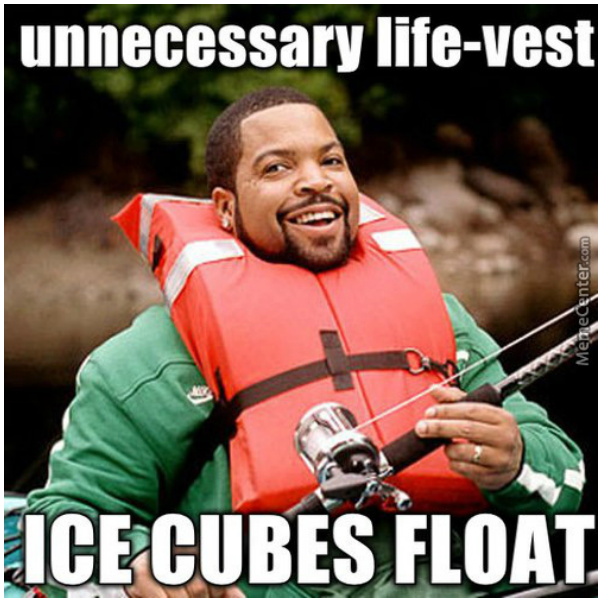
REANNZ

So, what is the difference in the data?

twitch

YouTube

NETFLIX

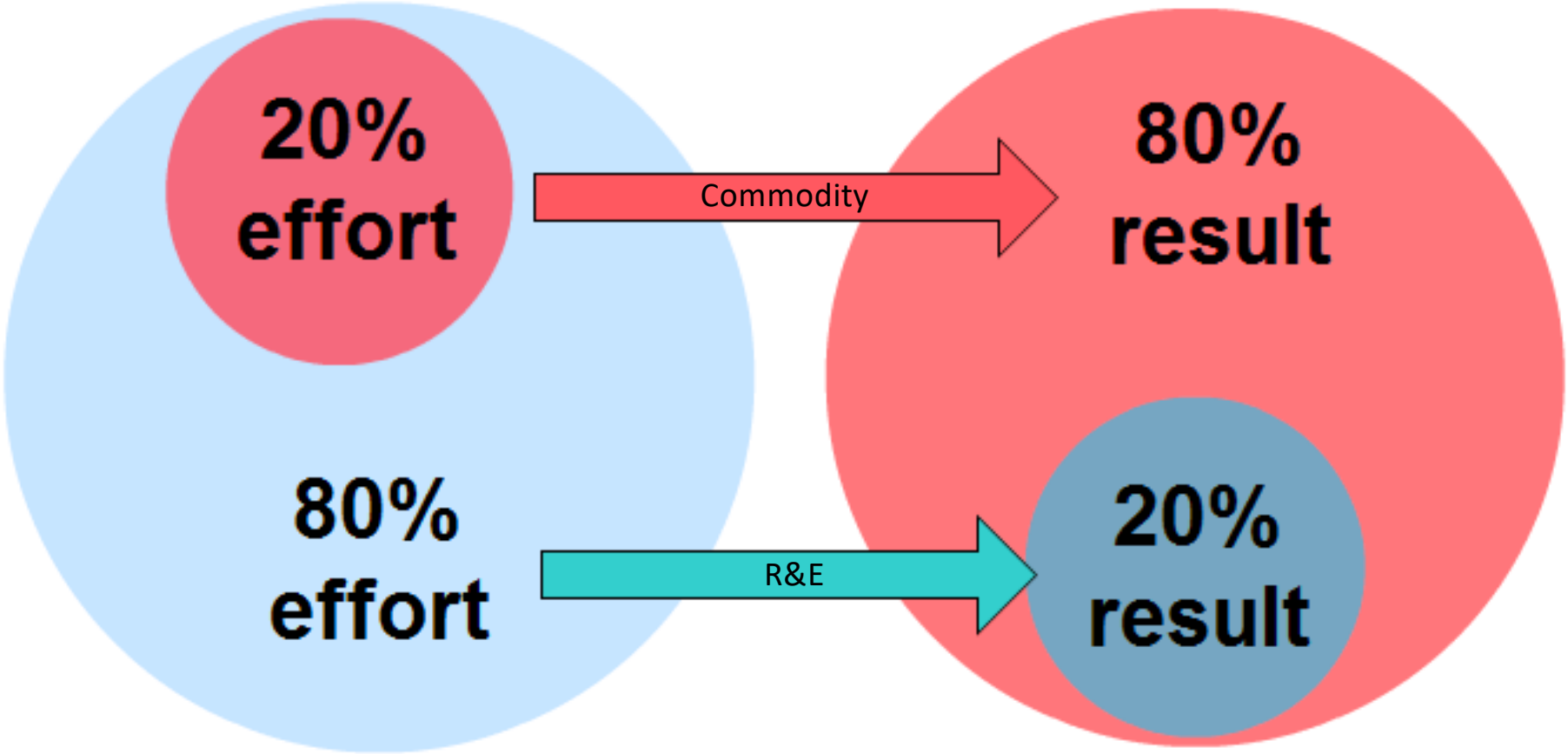


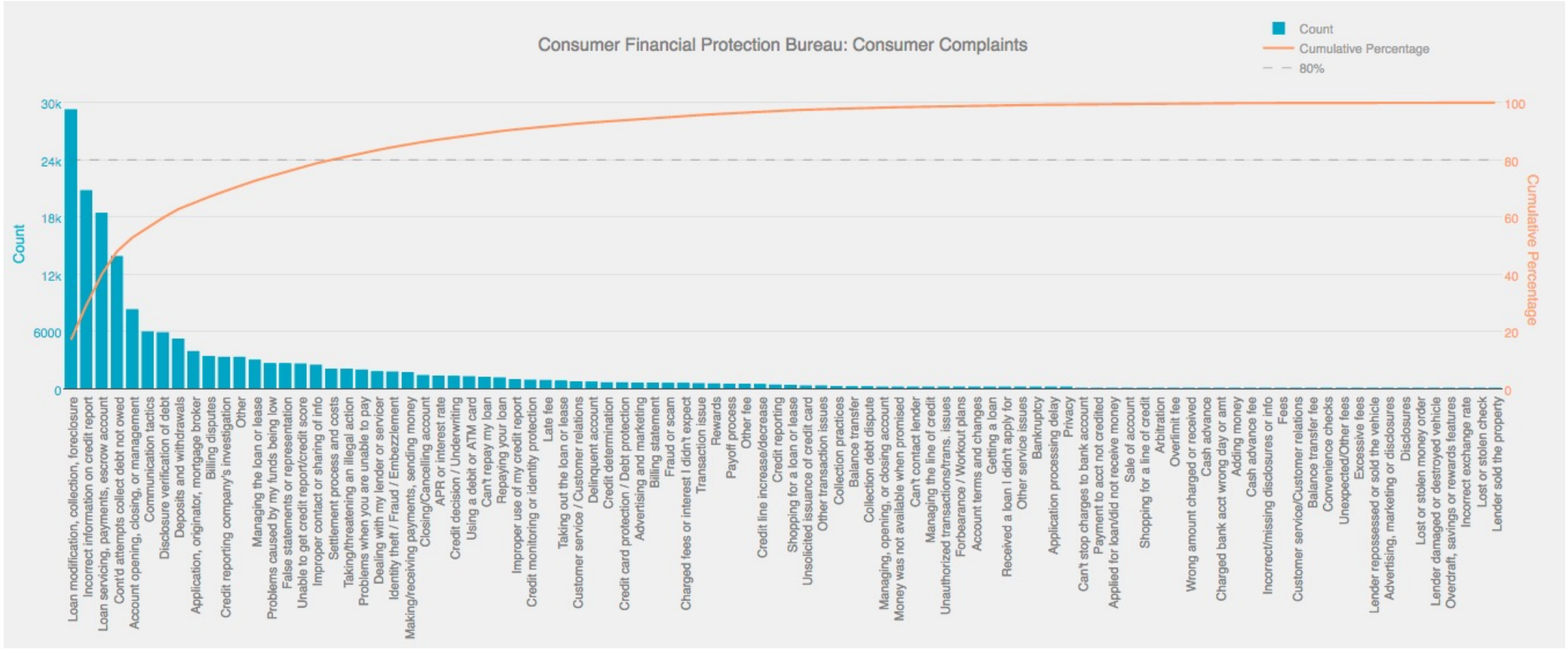
Commodity/commercial Networks

Research data

Research data

Effort




Consumer Financial Protection Bureau: Consumer Complaints
Count
Cumulative Percentage
80%
Count
Cumulative Percentage
30k
24k
18k
12k
6000
0
100
80
60
40
20
0
Loan modification, collection, foreclosure
Incorrect information on credit report
Loan servicing, payments, escrow account
Cont'd attempts collect debt not owed
Account opening, closing, or management
Communication tactics
Disclosure verification of debt
Deposits and withdrawals
Application, originator, mortgage broker
Billing disputes
Credit reporting company's investigation
Other
Managing the loan or lease
Problems caused by my funds being low
False statements or representation
Unable to get credit report/credit score
Improper contact or sharing of info
Settlement process and costs
Taking/threatening an illegal action
Problems when you are unable to pay
Dealing with my lender or servicer
Identity theft / Fraud / Embezzlement
Making/receiving payments, sending money
Closing/Cancelling account
APR or interest rate
Credit decision / Underwriting
Using a debit or ATM card
Can't repay my loan
Repaying your loan
Improper use of my credit report
Credit monitoring or identity protection
Late fee
Taking out the loan or lease
Customer service / Customer relations
Delinquent account
Credit determination
Credit card protection / Debt protection
Advertising and marketing
Billing statement
Fraud or scam
Charged fees or interest I didn't expect
Transaction issue
Rewards
Payoff process
Other fee
Credit line increase/decrease
Credit reporting
Shopping for a loan or lease
Unsolicited issuance of credit card
Other transaction issues
Collection practices
Balance transfer
Collection debt dispute
Managing, opening, or closing account
Money was not available when promised
Can't contact lender
Managing the line of credit
Unauthorized transactions/trans. issues
Forbearance / Workout plans
Account terms and changes
Getting a loan
Received a loan I didn't apply for
Other service issues
Bankruptcy
Application processing delay
Privacy
Can't stop charges to bank account
Payment to acct not credited
Applied for loan/did not receive money
Sale of account
Shopping for a line of credit
Arbitration
Overlimit fee
Wrong amount charged or received
Cash advance
Charged bank acct wrong day or amt
Adding money
Cash advance fee
Incorrect/missing disclosures or info
Fees
Customer service/Customer relations
Balance transfer fee
Convenience checks
Unexpected/Other fees
Excessive fees
Lender repossessed or sold the vehicle
Advertising, marketing or disclosures
Disclosures
Lost or stolen money order
Lender damaged or destroyed vehicle
Overdraft, savings or rewards features
Incorrect exchange rate
Lost or stolen check
Lender sold the property

State/regional networks

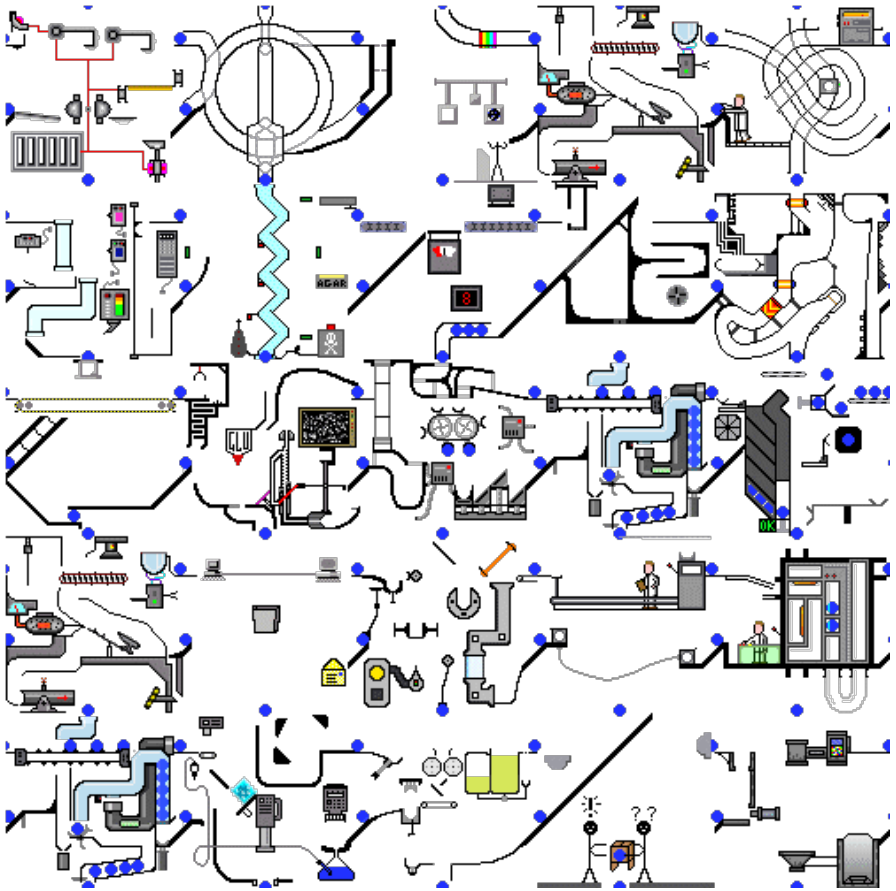
aka “your ISP”

But they go about it in different ways…

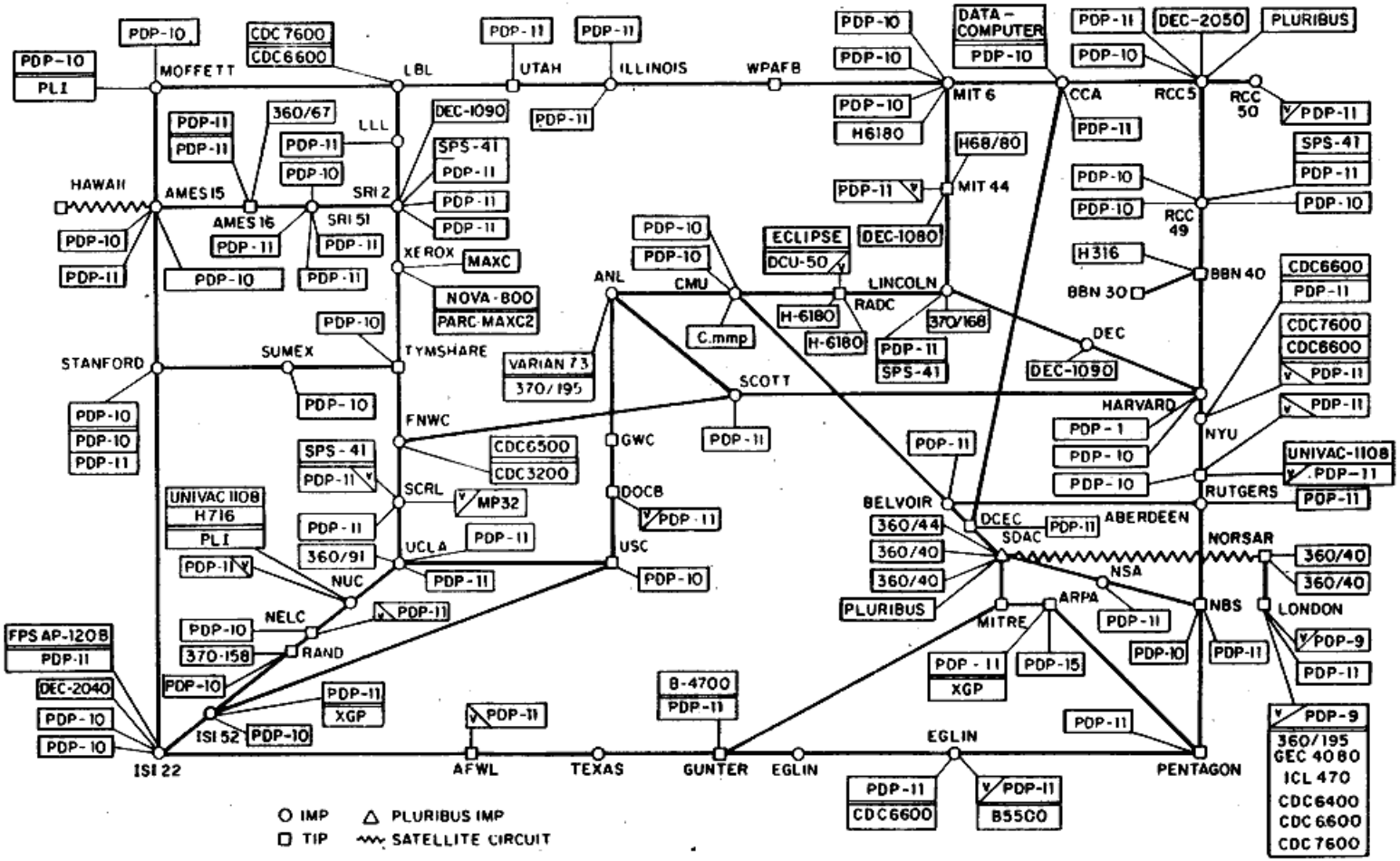
They both eat the leaves…


DEPTH
GAUGE
FROM: DISNEY

Now to the technical reasons…



ARPANET LOGICAL MAP, MARCH 1977



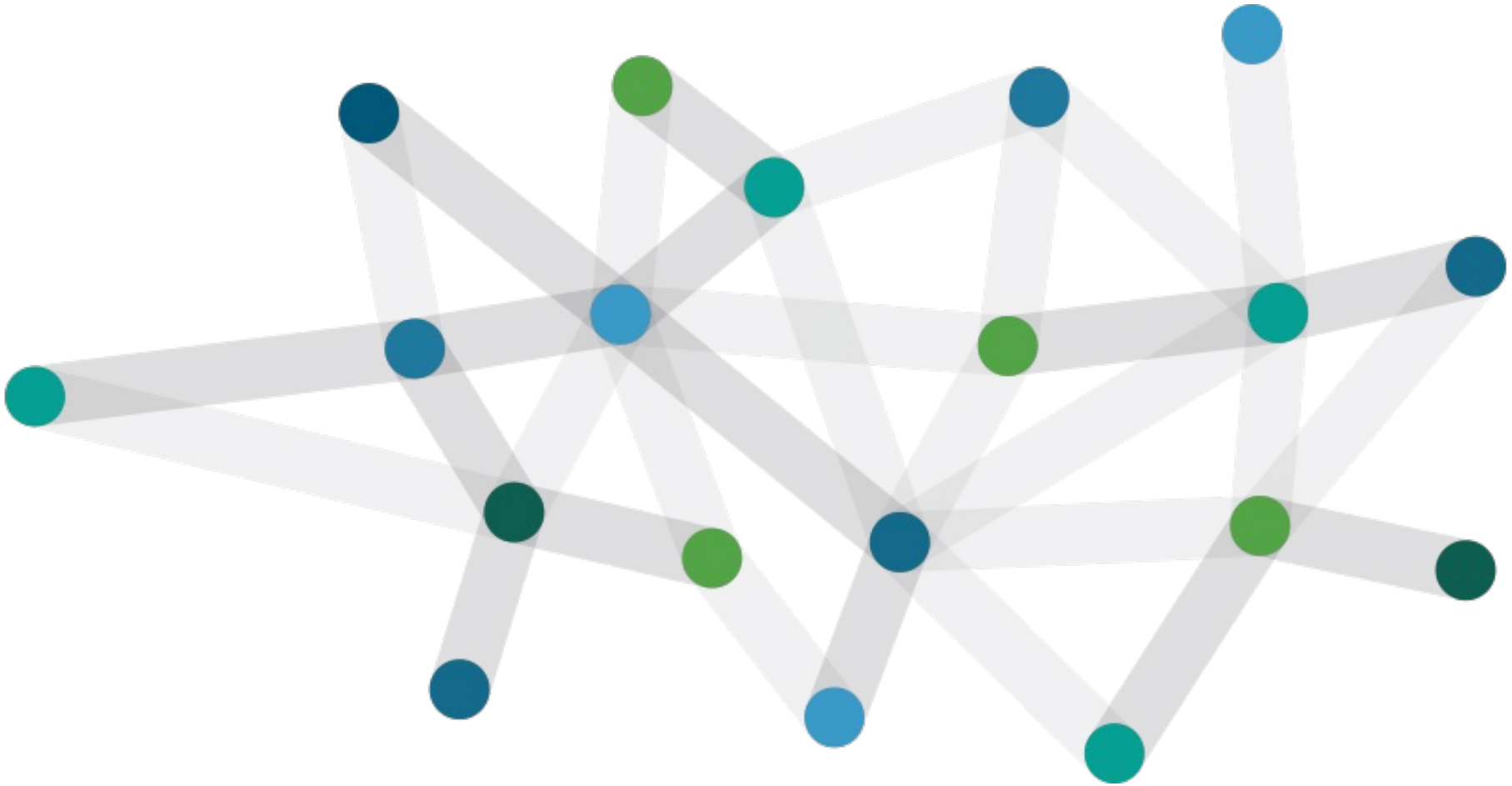
(PLEASE NOTE THAT WHILE THIS MAP SHOWS THE HOST POPULATION OF THE NETWORK ACCORDING TO THE BEST INFORMATION OBTAINABLE, NO CLAIM CAN BE MADE FOR ITS ACCURACY)

NAMES SHOWN ARE IMP NAMES, NOT (NECESSARILY) HOST NAMES

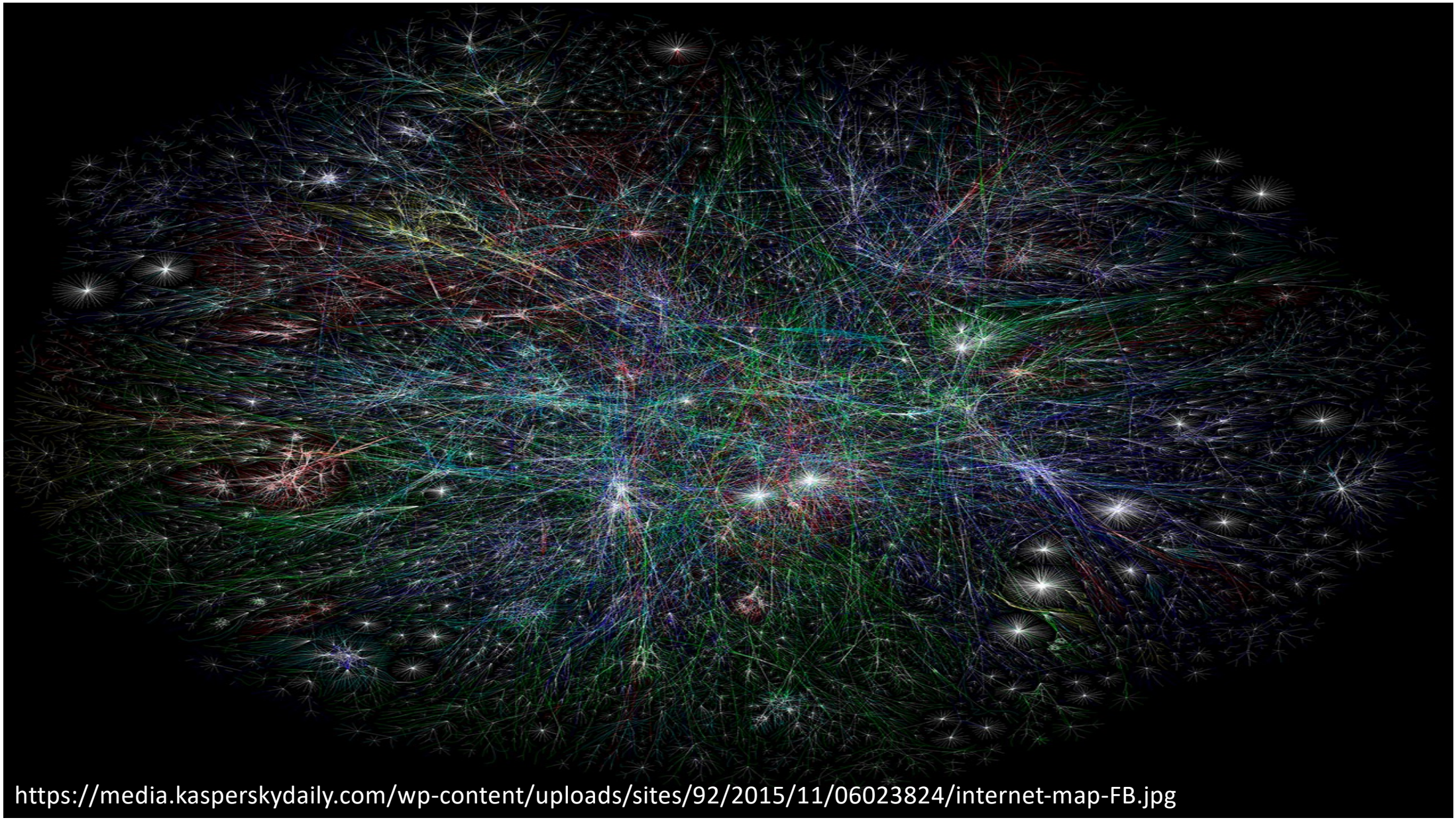
The goal was to exploit new computer technologies to meet the needs of military command and control against nuclear threats, achieve survivable control of US nuclear forces, and improve military tactical and management decision making.

Stephen J. Lukasik

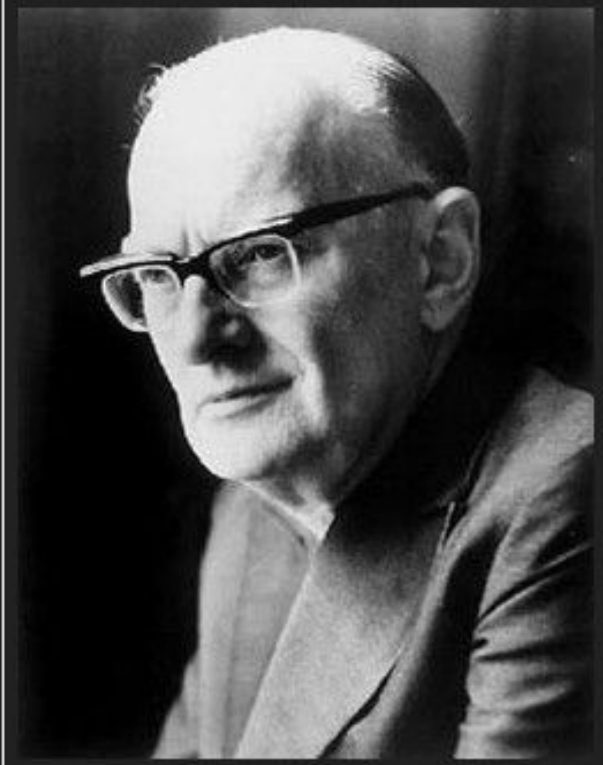
Lukasik, Stephen J. (2011). "Why the Arpanet Was Built". *IEEE Annals of the History of Computing*. **33** (3): 4–20. doi:10.1109/MAHC.2010.11



Autonomous systems, interconnecting using standardized protocols…



https://media.kasperskydaily.com/wp-content/uploads/sites/92/2015/11/06023824/internet-map-FB.jpg

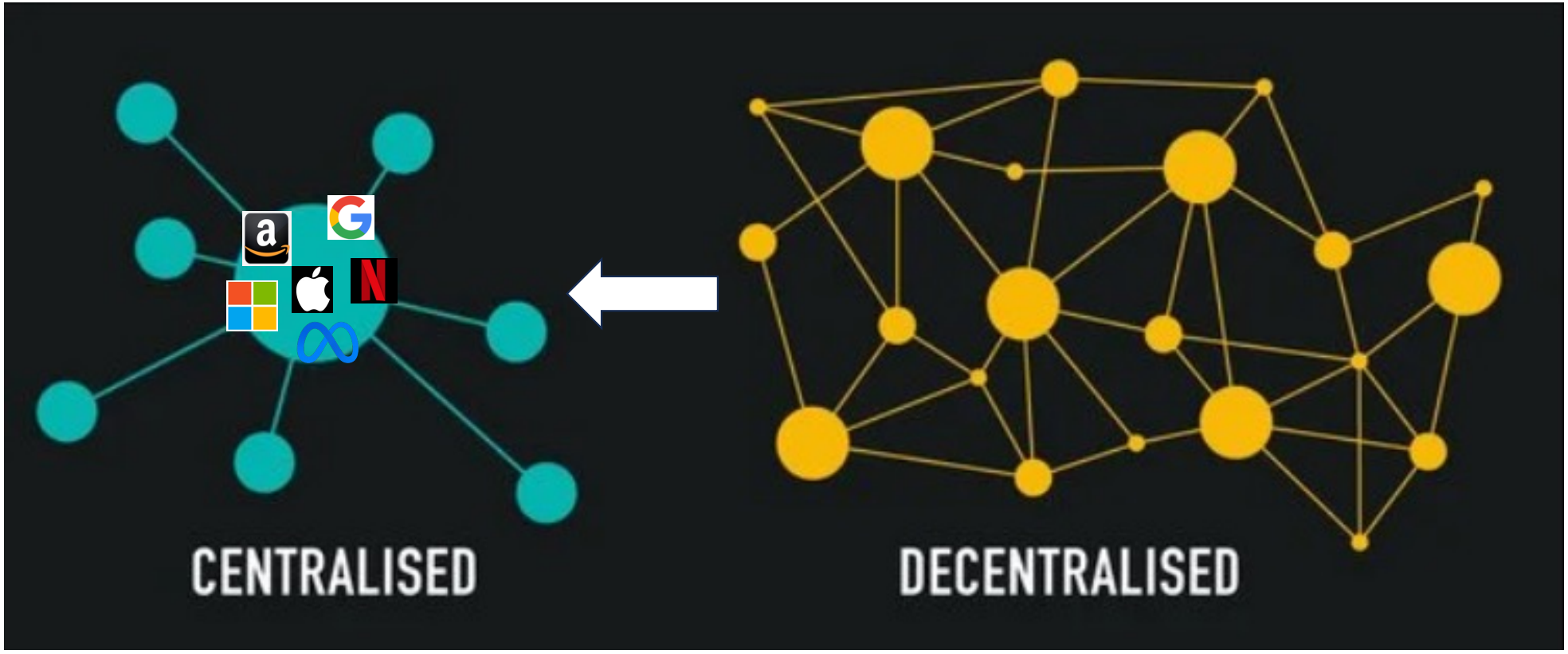


Clarke's Third Law: Any sufficiently advanced technology is indistinguishable from magic.

(Arthur C. Clarke)

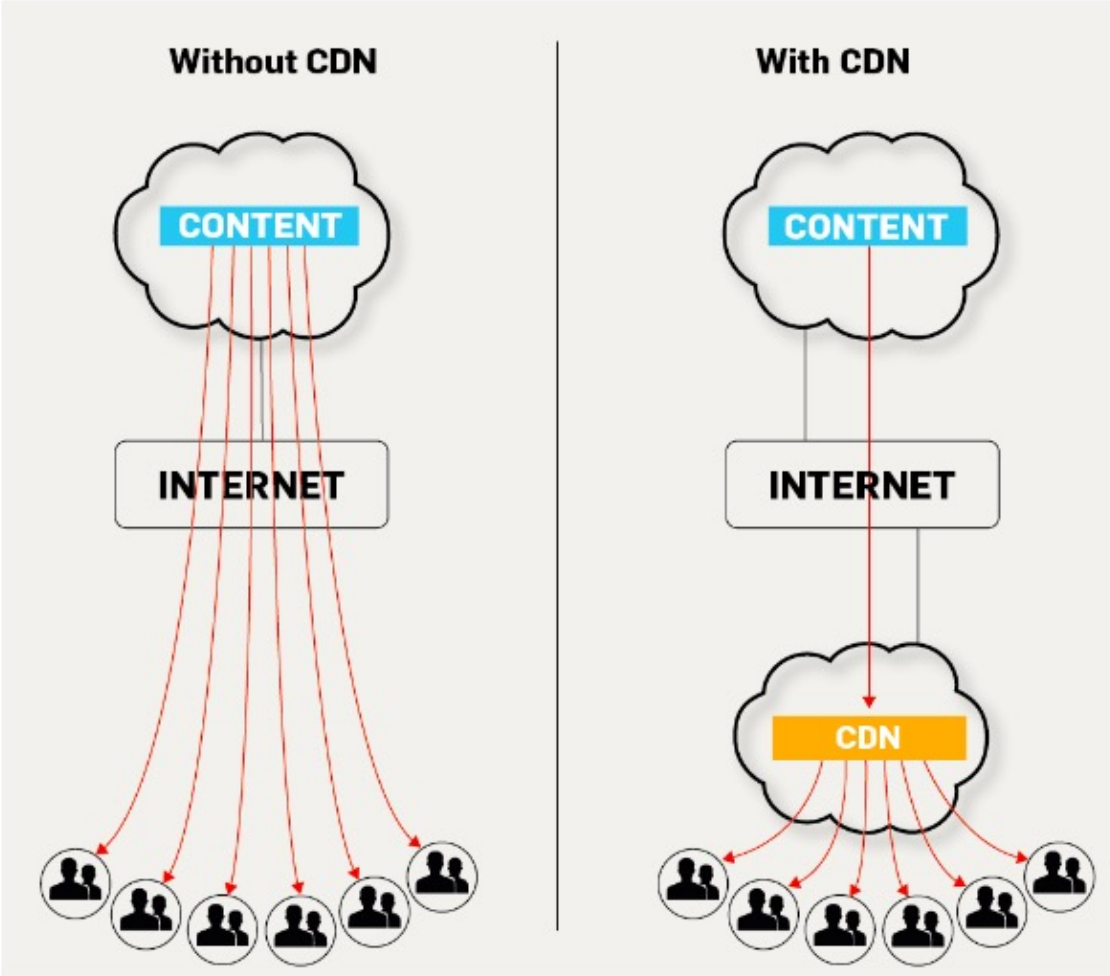
izquotes.com

OG Internet was decentralised


CENTRALISED
DECENTRALISED

Rise of the Content Delivery Network

- Content Delivery Networks vs eyeball networks
- Globally distributed network of web servers or Points of Presence (PoP) whose purpose is to provide faster content delivery.
- Content is replicated and stored throughout the CDN so the "eyeballs" can access data as geographically close as possible.



https://www.globaldots.com/resources/blog/content-delivery-network-explained/

R&E Infrastructure Remains (mostly) Decentralised

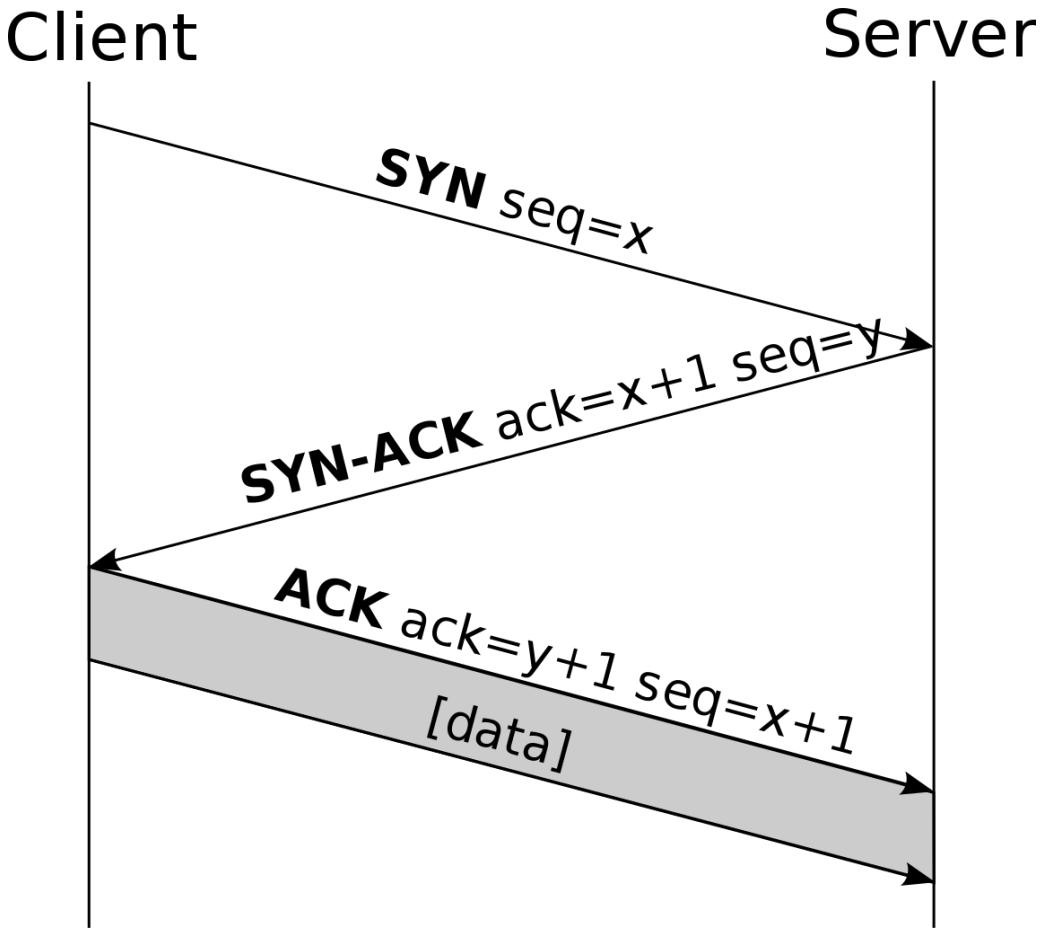
- Distributed scientific instrumentation
- Sovereignty and privacy of research data
- Specialised data storage and compute requirements
- Each research use case tends to have unique requirements
- But leverage commodity services where it makes sense

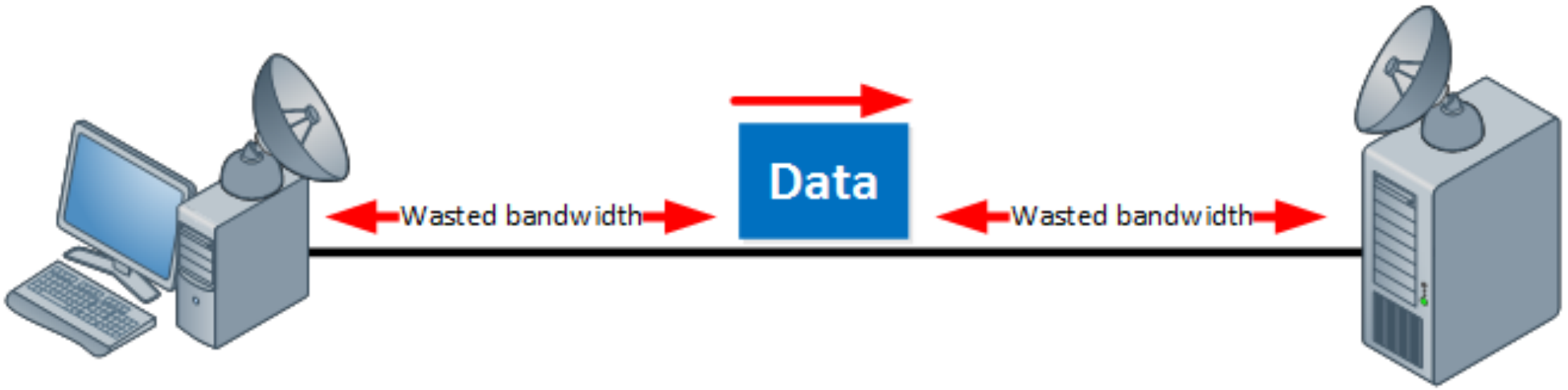
Transmission Control Protocol (TCP)

There are three major factors that affect TCP performance (there are others, but these are the Big Three):

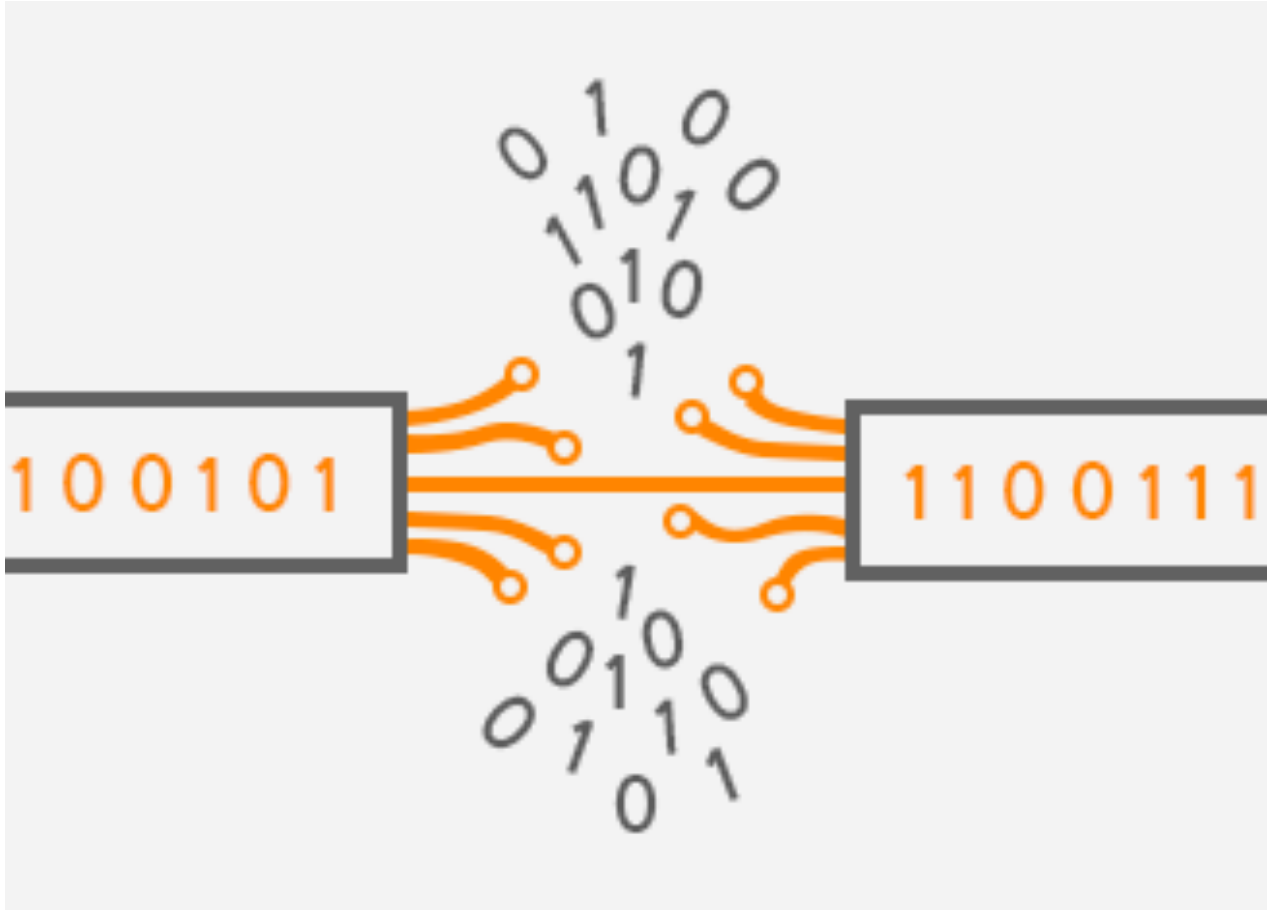
- Latency (or RTT - Round Trip Time)
- Buffer/Window size.
- Packet loss

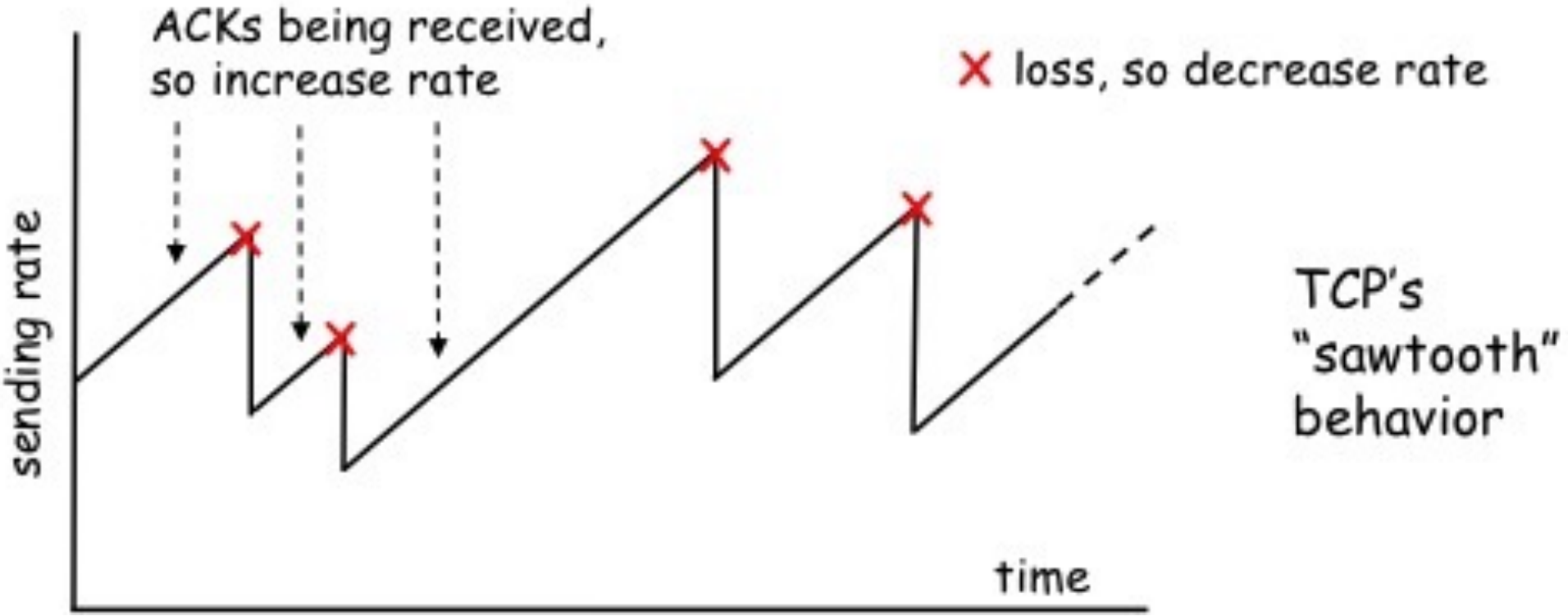
All three are interrelated.



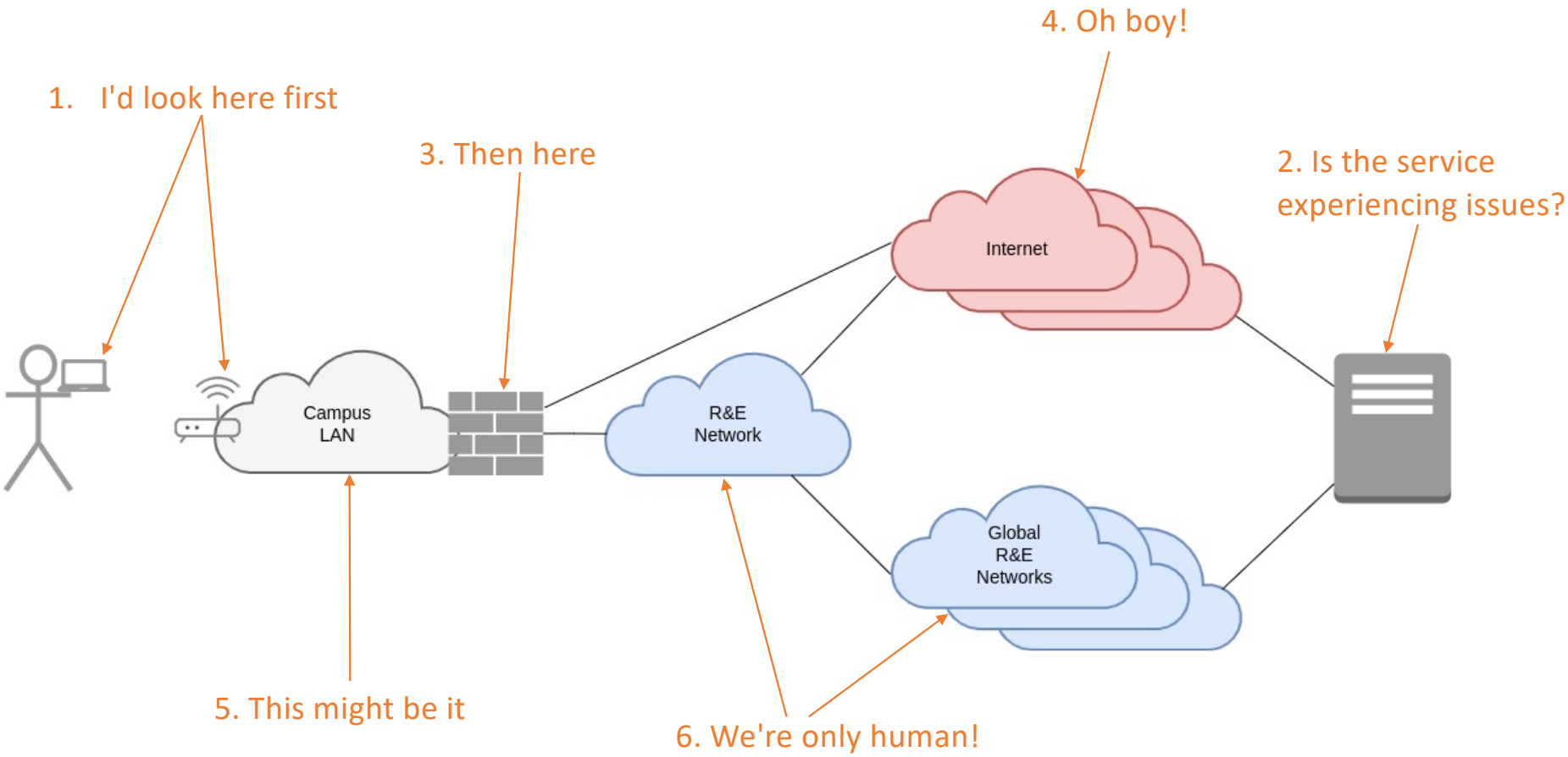


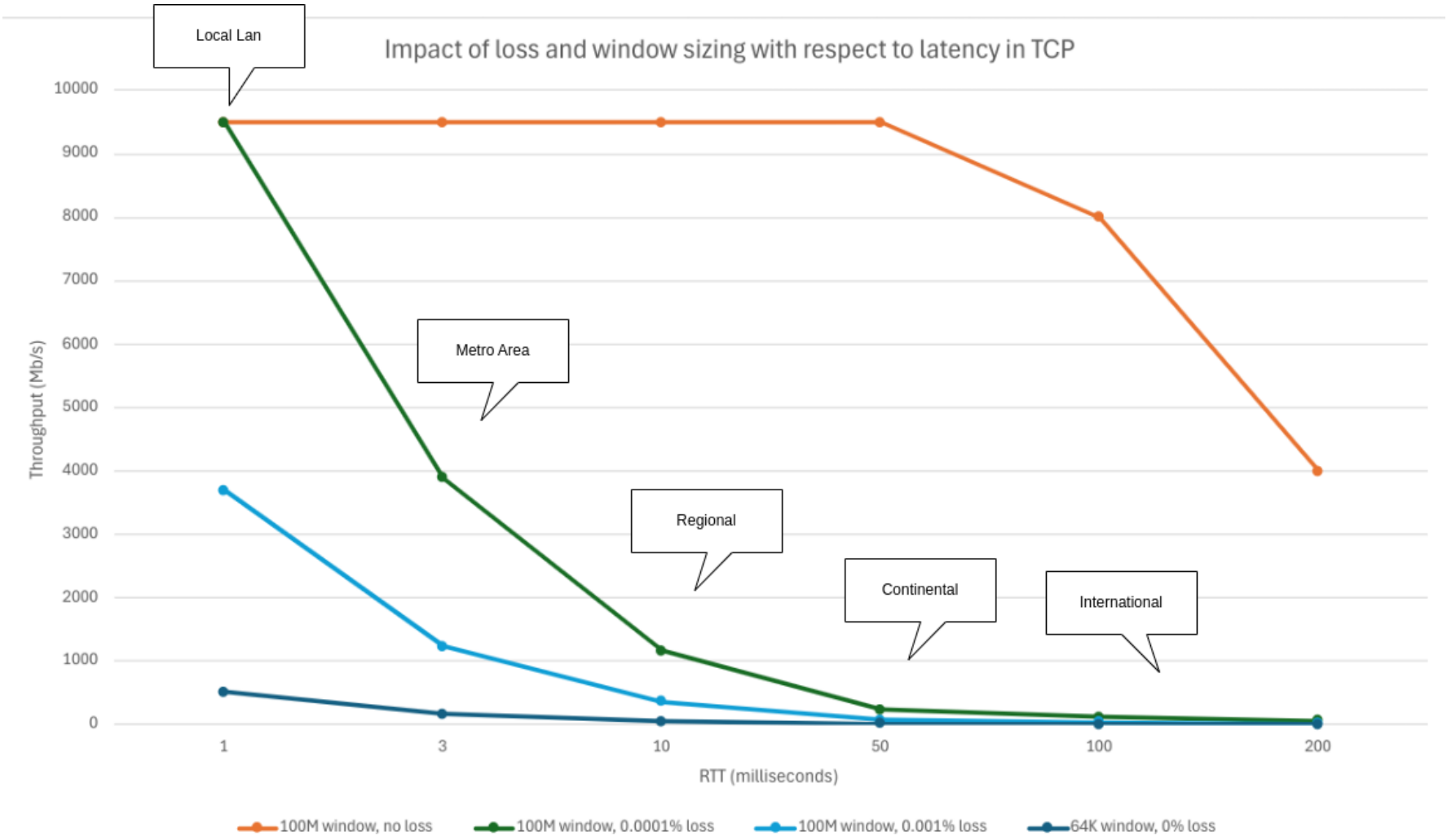
Bandwidth Delay Product


100101
1100111


ACKs being received,
so increase rate
loss, so decrease rate
sending rate
time
TCP's
"sawtooth"
behavior

Where is loss likely to occur?





https://wintelguy.com/wanperf.pl

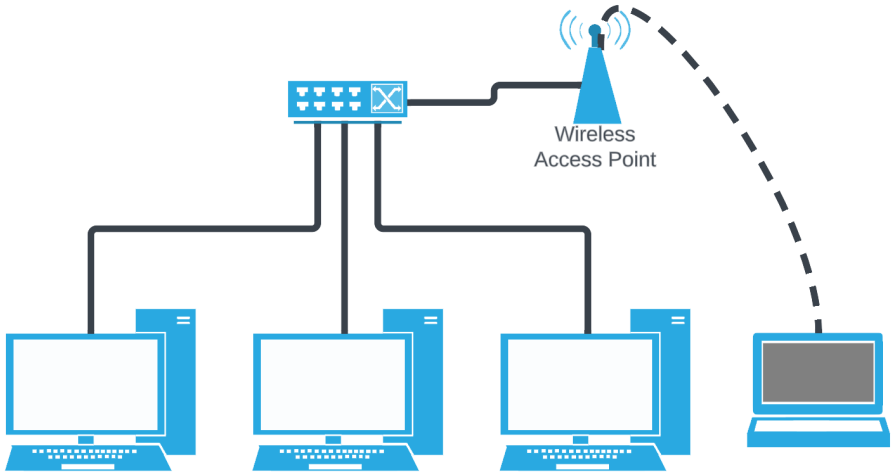
Maximizing network performance

Determine the limiting factor

- ~~Increase TCP window size~~
- Use multiple simultaneous TCP streams
- Avoid lossy network segments
- Change TCP congestion control algorithm (BBR), or
- Switch to UDP transfer
- Use jumboframes (9k MTU)

LAN vs MAN vs WAN

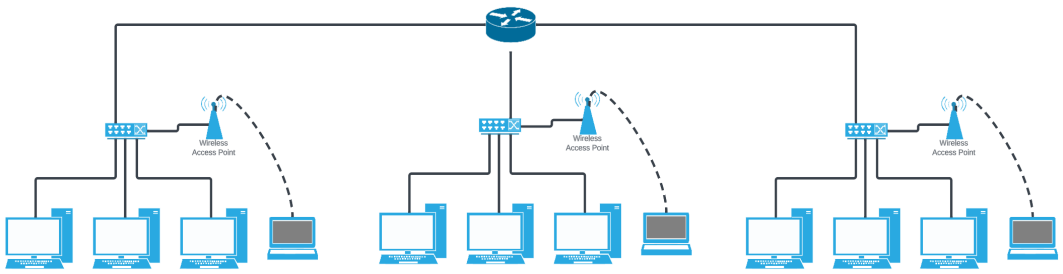
LAN vs MAN vs WAN



- LAN
  - Local Area Network
  - Shorter distances *
  - ”internal” network *
  - Switching and routing *
  - You provide *

* As with all networking the “it depends” rule applies

LAN vs MAN vs WAN



- LAN
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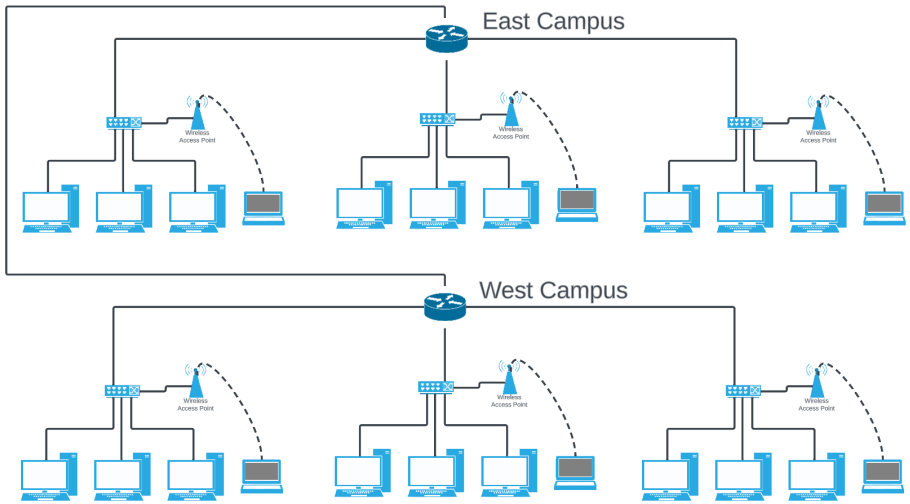
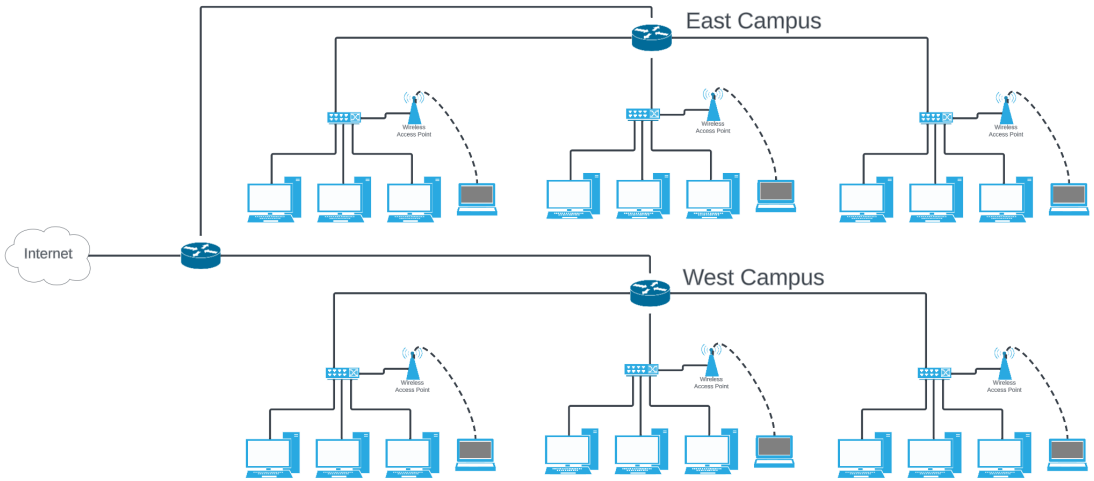
LAN vs MAN vs WAN



- MAN
  - Metropolitan Area Network
  - Connections that are between LAN and WAN
  - University campuses *

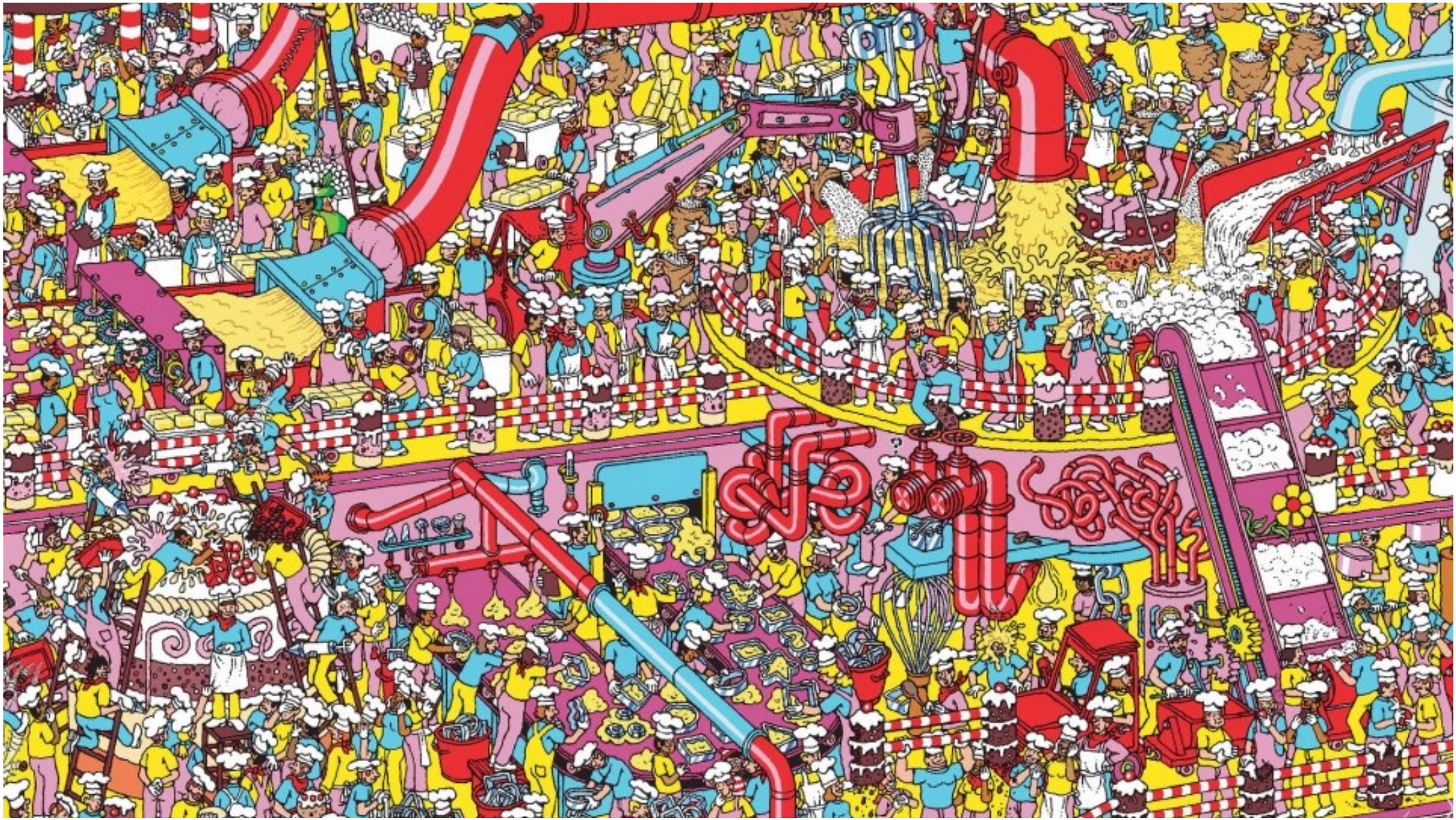
* As with all networking the “it depends” rule applies

LAN vs MAN vs WAN



- WAN
  - Wide Area Network
  - Crosses longer distances *
  - Sometimes considered ”outside” the network *
  - Mostly routing *
  - Someone else provides *

* As with all networking the “it depends” rule applies



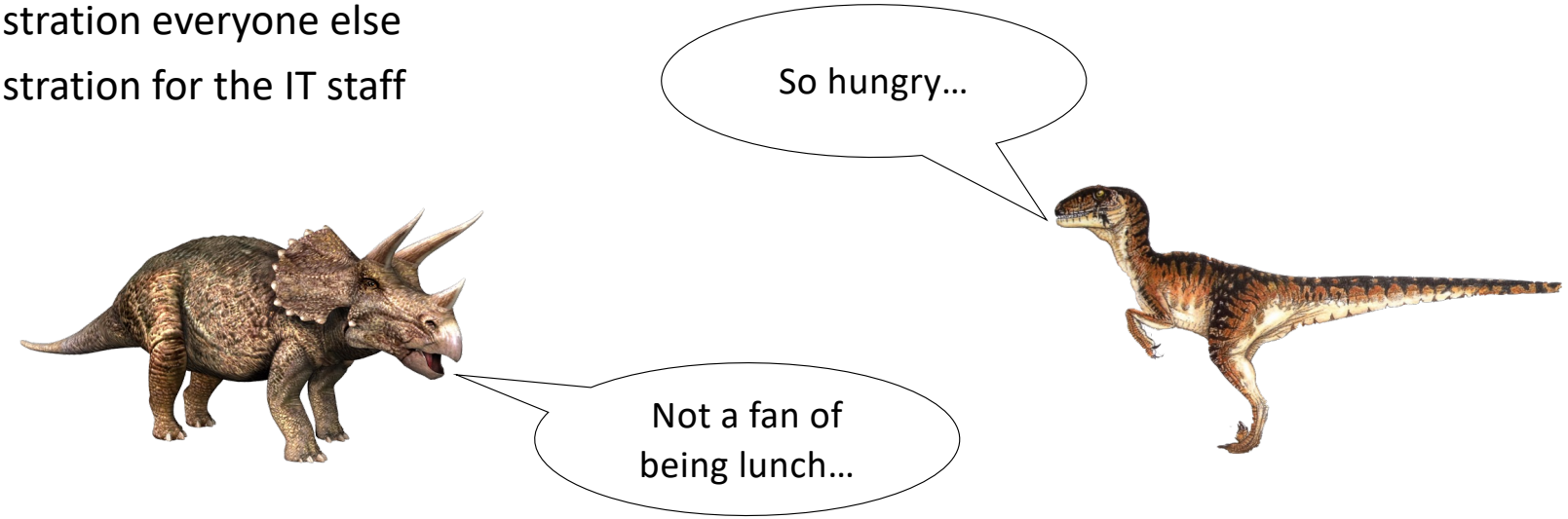
So, what happens when research traffic hits normal networks?


STOP
gifs.com

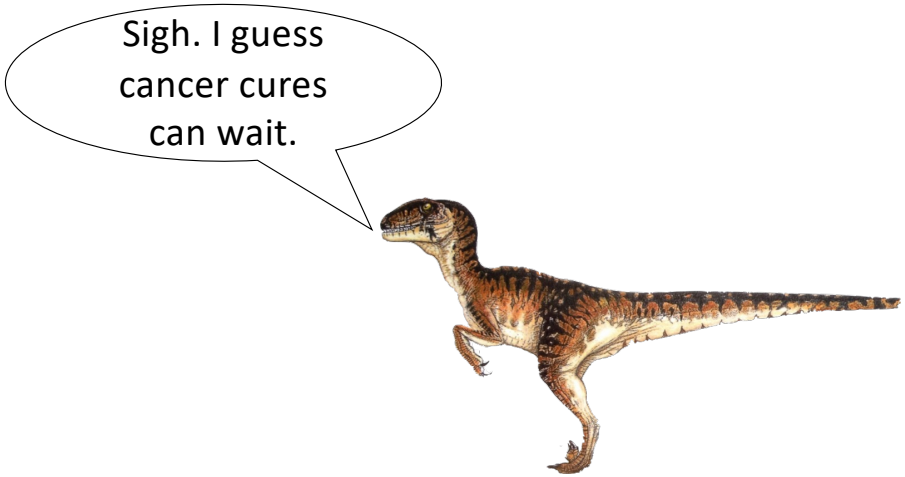
When Data Intensive Science Meets Commercial Commodity Networks

This can result in adverse consequences:

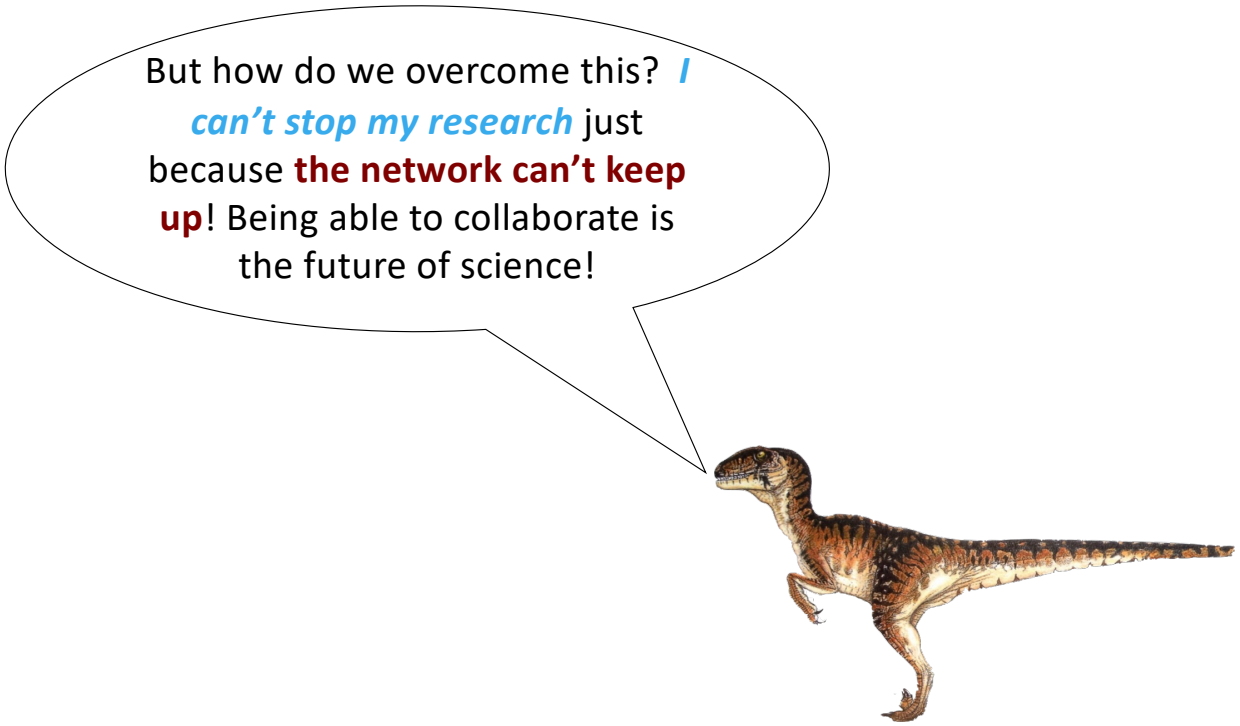
- Performance issues for the researcher
- Performance issues for everyone else
- Frustration for the researcher
- Frustration everyone else
- Frustration for the IT staff



When Data Intensive Science Meets Commercial Commodity Networks



When Data Intensive Science Meets Commercial Commodity Networks



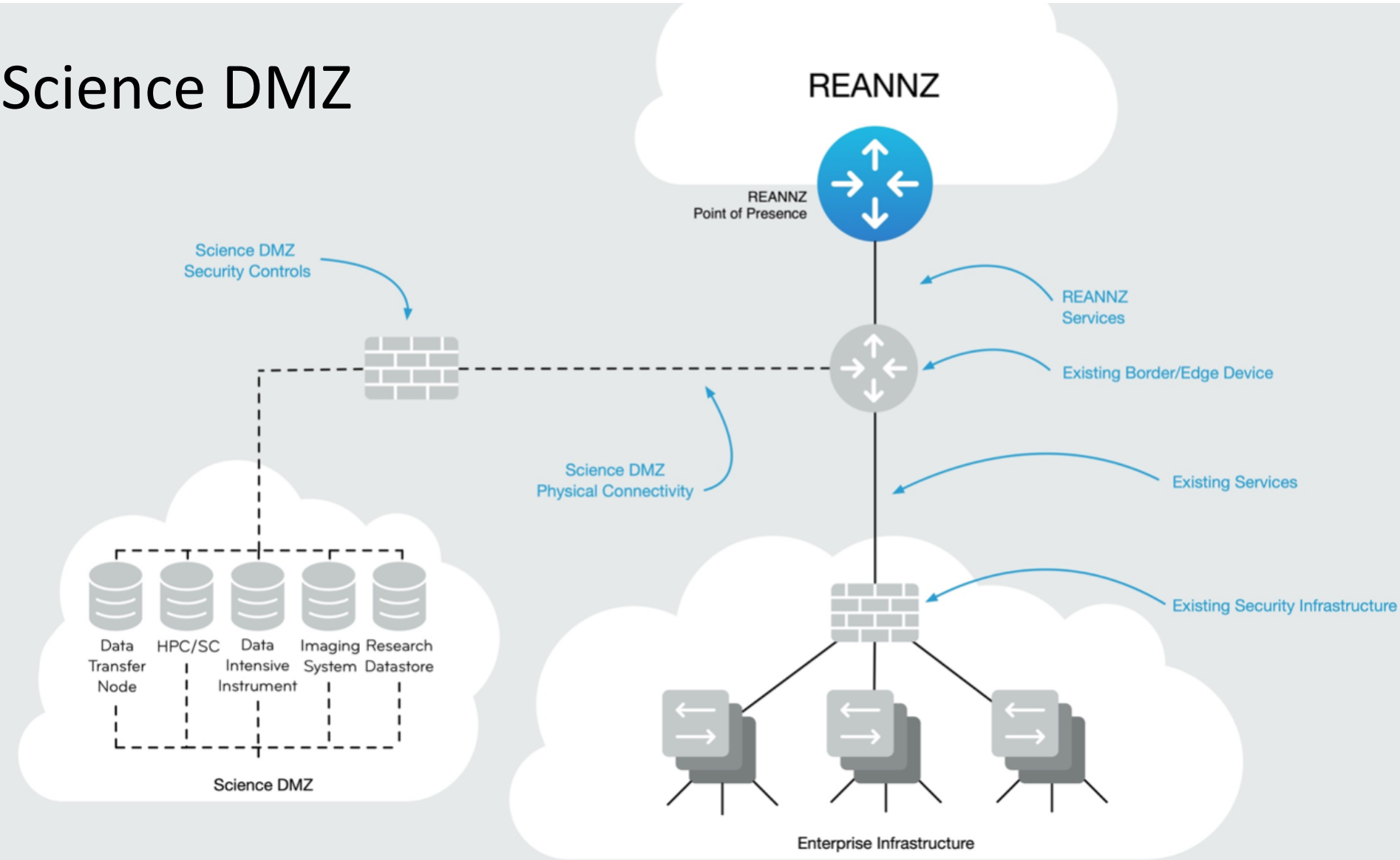
Specialty networks to the rescue!

- Both internally to your organization and externally
- Science DMZ is an example of a specialty network

Parts of the puzzle…

- Science DMZ
- DTN (Data Transfer Node)
- Storage
- Research and Education networks
  - NREN (National Research and Education Network)
  - RON (Regional Optical Network)
  - R&E Network (Research and Education Network)

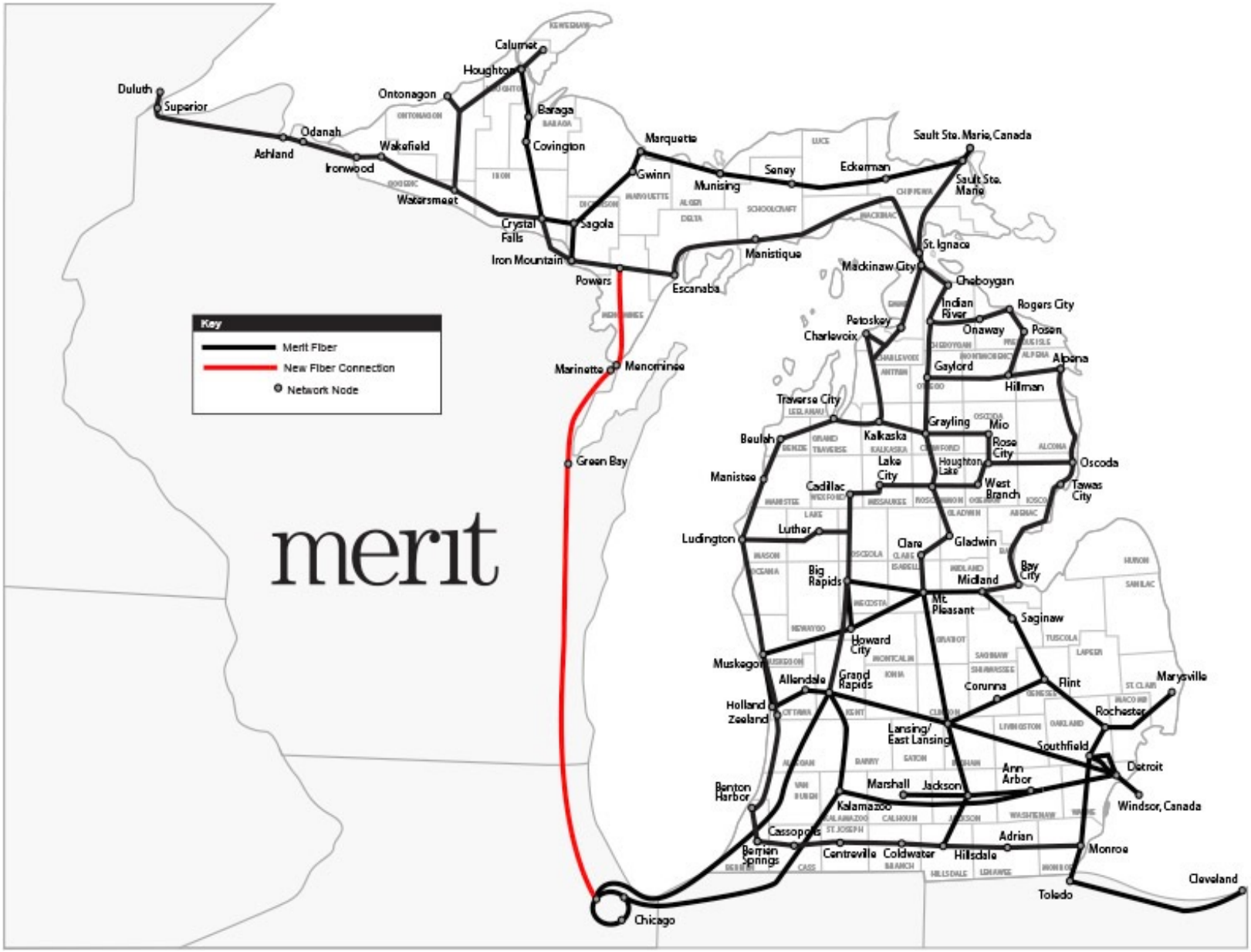
Science DMZ


REANNZ
REANNZ
Point of Presence
Science DMZ
Security Controls
REANNZ
Services
Existing Border/Edge Device
Science DMZ
Physical Connectivity
Existing Services
Existing Security Infrastructure
Data
Transfer
Node
HPC/SC
Data
Intensive
Instrument
Imaging
System
Research
Datastore
Science DMZ
Enterprise Infrastructure

Relationships make the packets flow…

State/regional networks

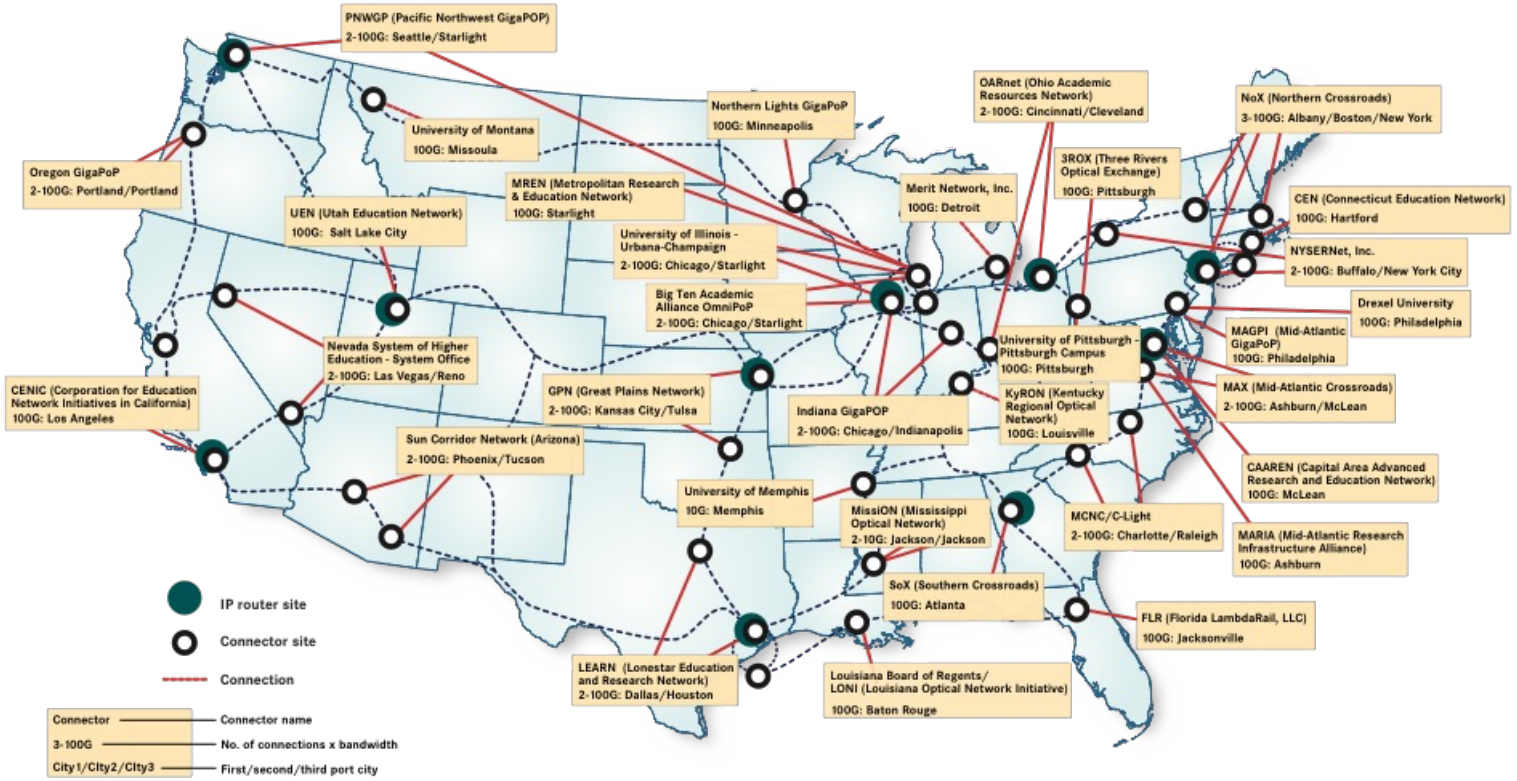
aka “your ISP”


merit
Key
Merit Fiber
New Fiber Connection
Network Node
Duluth
Superior
Ashland
Odanah
Ironwood
Wakefield
Watersmeet
Ontonagon
Houghton
Calumet
Baraga
Covington
Crystal Falls
Sagola
Iron Mountain
Powers
Marquette
Gwinn
Munising
Seney
Eckerman
Sault Ste. Marie, Canada
Sault Ste. Marie
Manistique
Escanaba
Marinette
Menominee
Green Bay
Chicago
St. Ignace
Mackinaw City
Cheboygan
Indian River
Rogers City
Petoskey
Charlevoix
Onaway
Posen
Alpena
Gaylord
Hillman
Traverse City
Grayling
Mio
Kalkaska
Rose City
Houghton Lake
Oscoda
Lake City
Beulah
Manistee
Cadillac
West Branch
Tawas City
Luther
Ludington
Clare
Gladwin
Bay City
Big Rapids
Midland
Mt. Pleasant
Saginaw
Howard City
Muskegon
Allendale
Grand Rapids
Corunna
Flint
Marysville
Holland
Zeeland
Rochester
Lansing/ East Lansing
Southfield
Detroit
Ann Arbor
Marshall
Jackson
Benton Harbor
Kalamazoo
Windsor, Canada
Cassopolis
Adrian
Berrien Springs
Centreville
Coldwater
Hillsdale
Monroe
Toledo
Cleveland

National Networks (US)

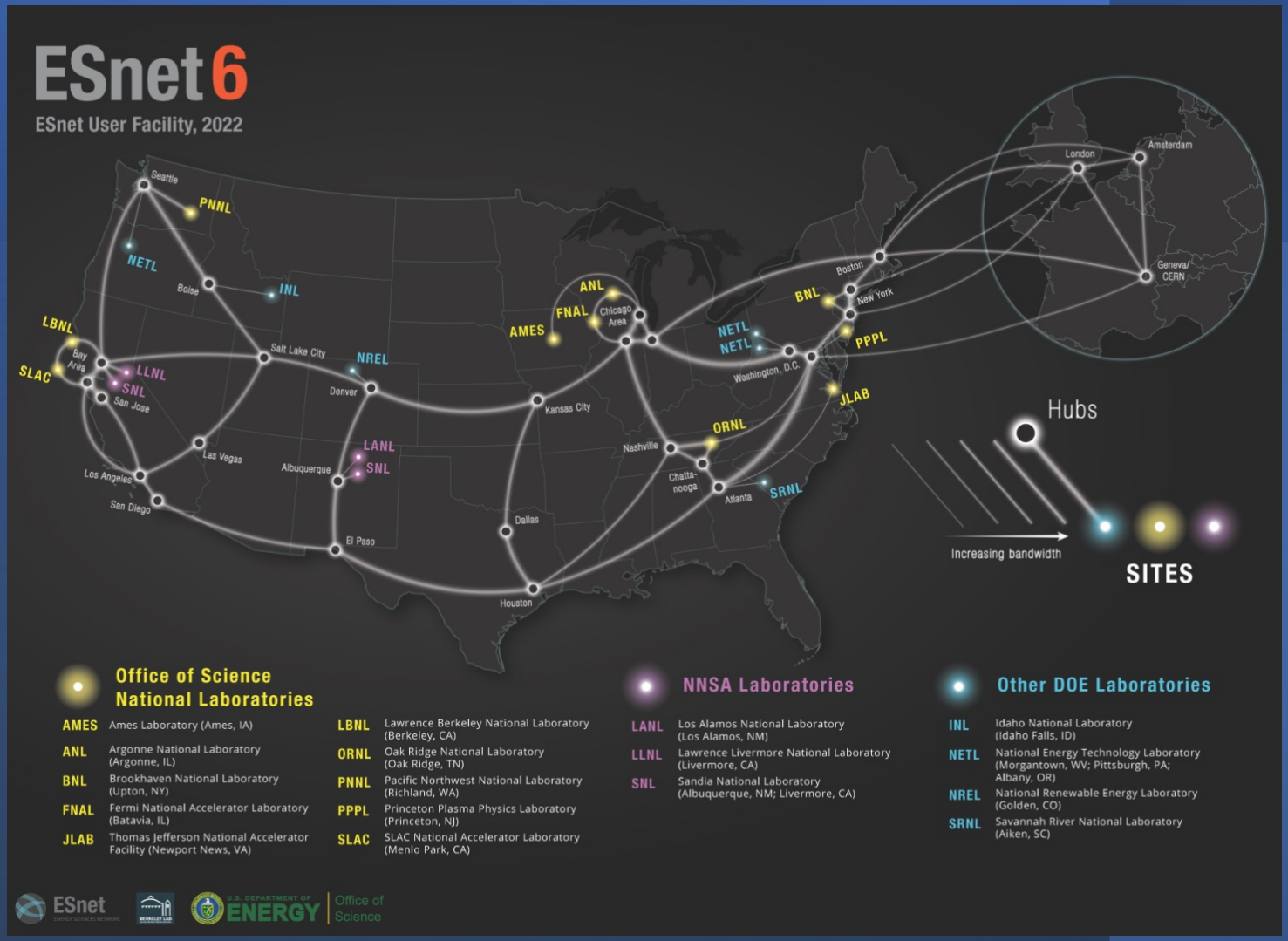
INTERNET2 NETWORK CONNECTIONS

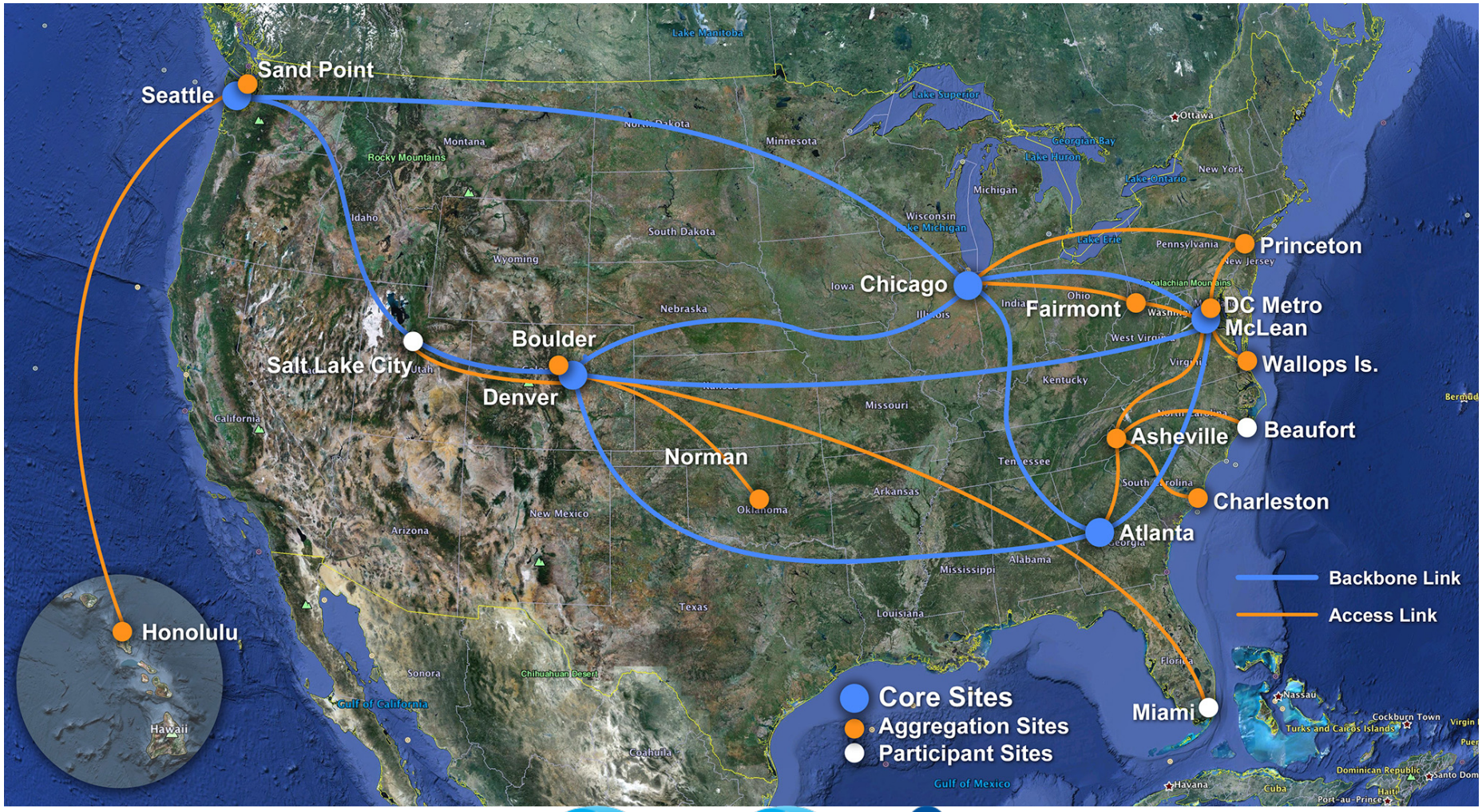
WWW.INTERNET2.EDU/CONNECTORS – MARCH OF 2017



NETWORK PARTNERS

ciena · INDIANA UNIVERSITY · BROCADE · JUNIPER NETWORKS · Level(3)

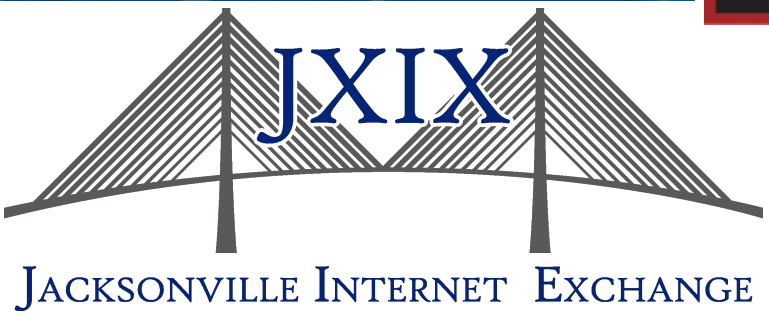

ESnet6
ESnet User Facility, 2022
Seattle
PNNL
NETL
Boise
INL
LBNL
Bay Area
SLAC
LLNL
SNL
San Jose
Salt Lake City
NREL
Denver
Las Vegas
Los Angeles
San Diego
Albuquerque
LANL
SNL
El Paso
Dallas
Houston
Kansas City
AMES
ANL
FNAL
Chicago Area
Nashville
ORNL
Chatta-nooga
Atlanta
SRNL
JLAB
Washington, D.C.
NETL
NETL
PPPL
BNL
Boston
New York
London
Amsterdam
Geneva/ CERN
Hubs
Increasing bandwidth
SITES
Office of Science National Laboratories
AMES Ames Laboratory (Ames, IA)
ANL Argonne National Laboratory (Argonne, IL)
BNL Brookhaven National Laboratory (Upton, NY)
FNAL Fermi National Accelerator Laboratory (Batavia, IL)
JLAB Thomas Jefferson National Accelerator Facility (Newport News, VA)
LBNL Lawrence Berkeley National Laboratory (Berkeley, CA)
ORNL Oak Ridge National Laboratory (Oak Ridge, TN)
PNNL Pacific Northwest National Laboratory (Richland, WA)
PPPL Princeton Plasma Physics Laboratory (Princeton, NJ)
SLAC SLAC National Accelerator Laboratory (Menlo Park, CA)
NNSA Laboratories
LANL Los Alamos National Laboratory (Los Alamos, NM)
LLNL Lawrence Livermore National Laboratory (Livermore, CA)
SNL Sandia National Laboratory (Albuquerque, NM; Livermore, CA)
Other DOE Laboratories
INL Idaho National Laboratory (Idaho Falls, ID)
NETL National Energy Technology Laboratory (Morgantown, WV; Pittsburgh, PA; Albany, OR)
NREL National Renewable Energy Laboratory (Golden, CO)
SRNL Savannah River National Laboratory (Aiken, SC)
ESnet
U.S. DEPARTMENT OF ENERGY
Office of Science

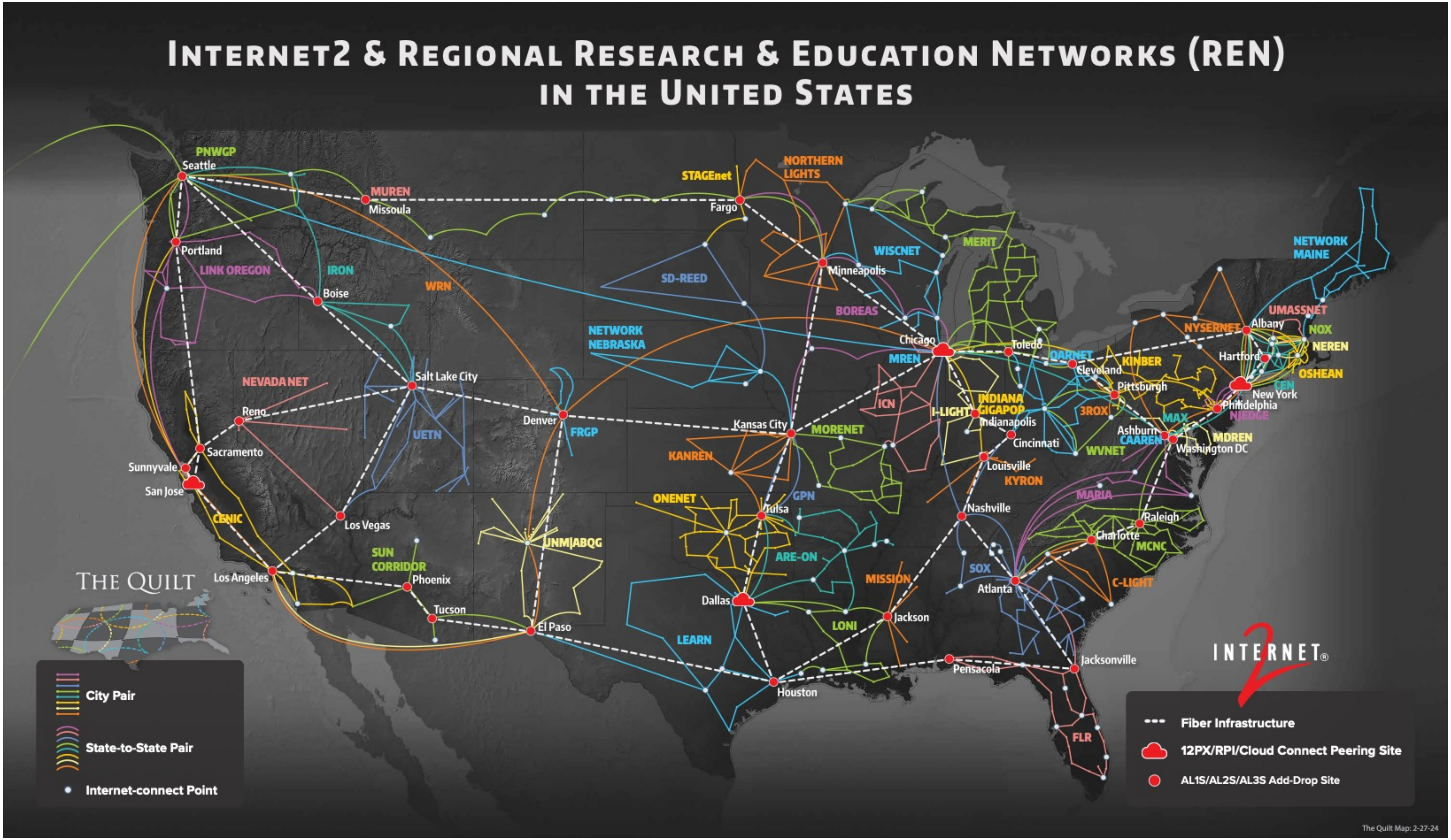


n-wave

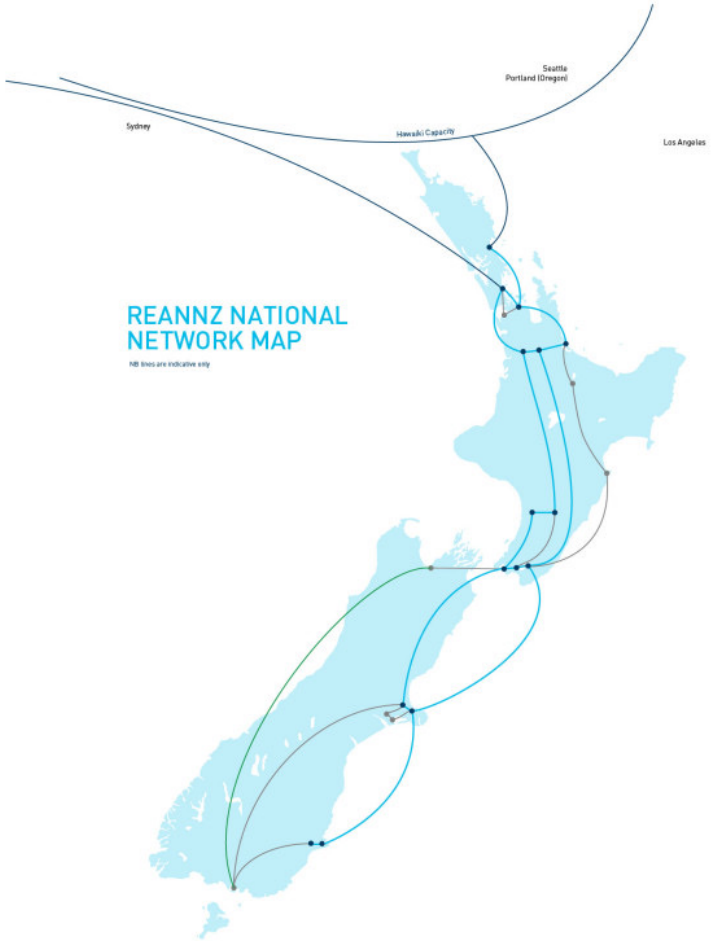
NOAA ENTERPRISE NETWORK

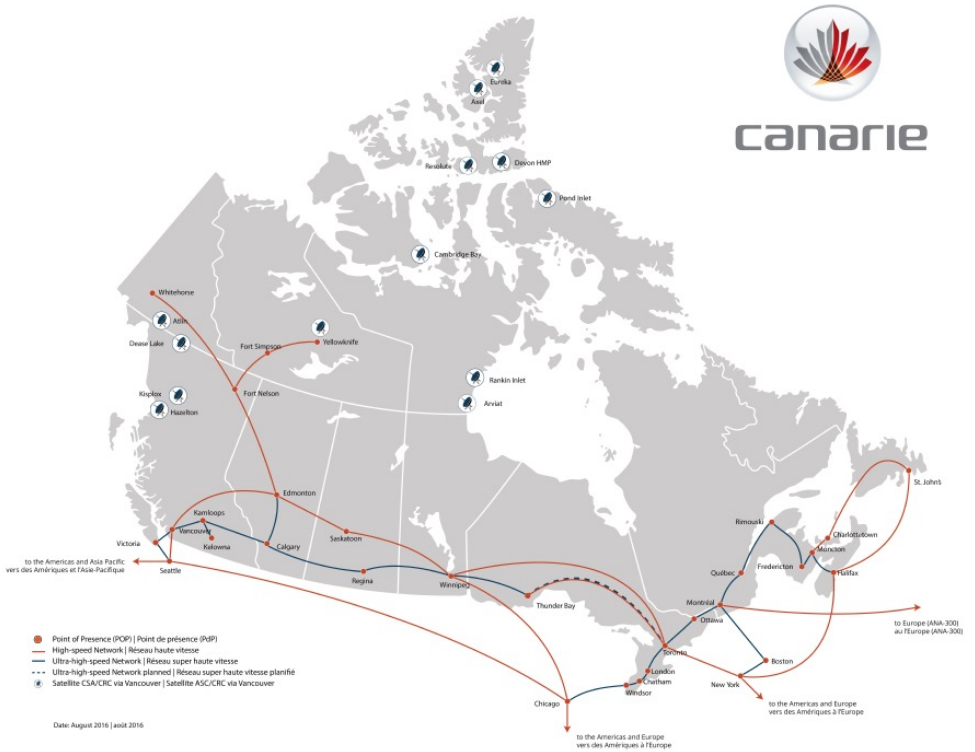
Exchanges and PoPs

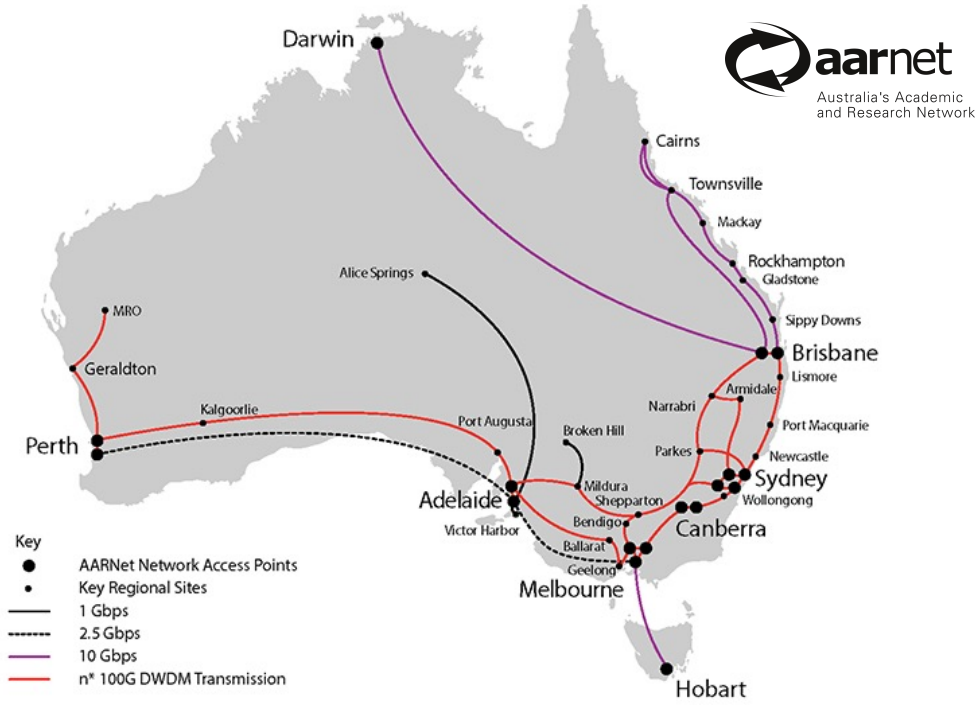


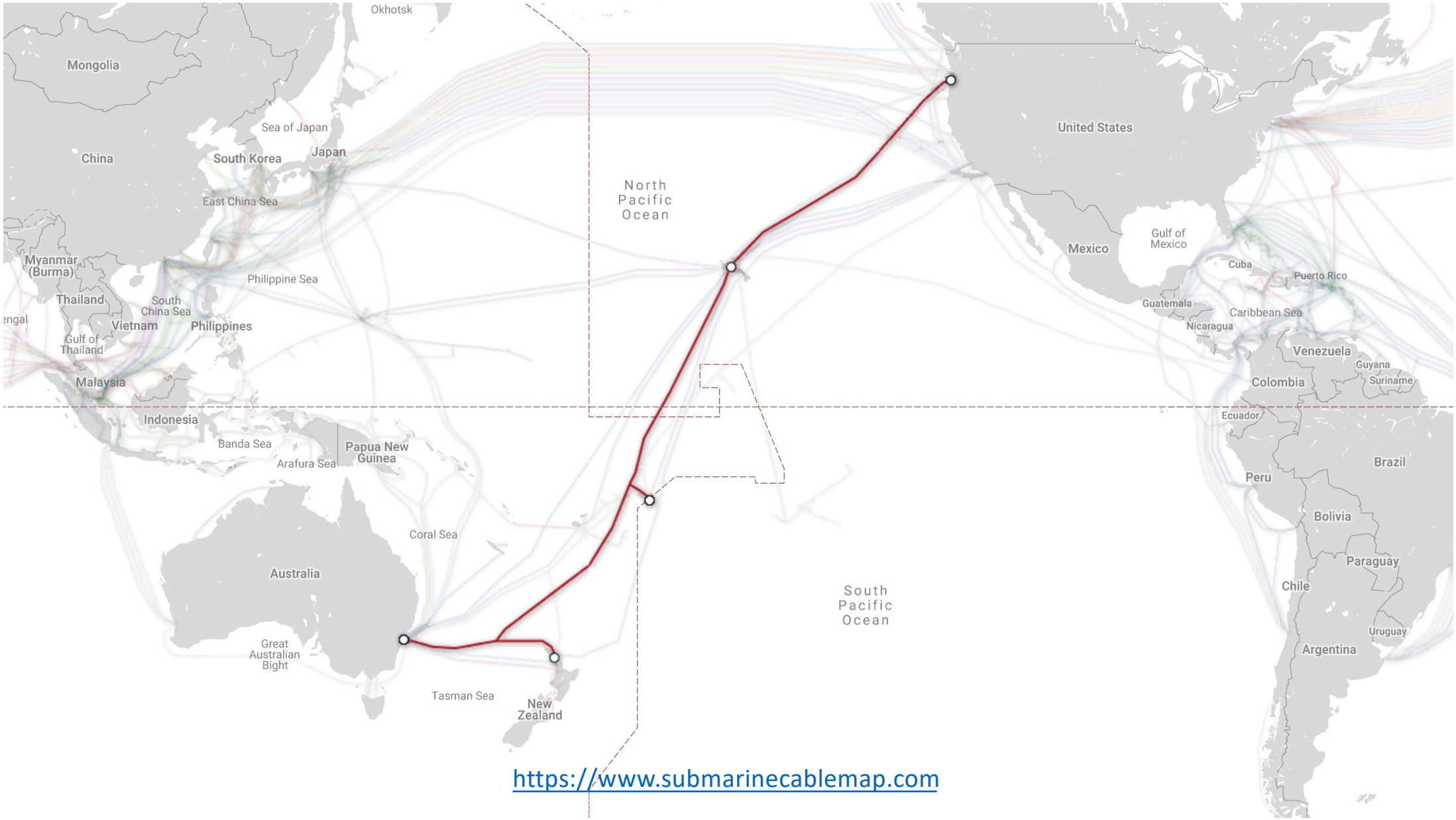

INTERNET2 & REGIONAL RESEARCH & EDUCATION NETWORKS (REN)
IN THE UNITED STATES
PNWGP
Seattle
MUREN
Missoula
STAGEnet
Fargo
NORTHERN LIGHTS
Portland
LINK OREGON
IRON
Boise
WRN
SD-REED
Minneapolis
WISCNET
MERIT
NETWORK MAINE
BOREAS
NETWORK NEBRASKA
UMASSNET
NYSERNET
Albany
NOX
NEREN
Hartford
OSHEAN
Chicago
Toledo
MREN
OARNET
Cleveland
KINBER
CEN
New York
Pittsburgh
Philadelphia
NJEDGE
Salt Lake City
NEVADA NET
Reno
UETN
Denver
FRGP
Kansas City
MORENET
ICN
I-LIGHT
INDIANA GIGAPOP
Indianapolis
3ROX
MAX
Ashburn
CAAREN
Washington DC
MDREN
Cincinnati
WVNET
Sacramento
Sunnyvale
San Jose
KANREN
Louisville
KYRON
CENIC
Los Vegas
ONENET
GPN
Tulsa
Nashville
MARIA
Raleigh
UNM|ABQG
Charlotte
MCNC
SUN CORRIDOR
ARE-ON
SOX
THE QUILT
Los Angeles
Phoenix
MISSION
Atlanta
C-LIGHT
Dallas
Tucson
El Paso
LONI
Jackson
LEARN
Jacksonville
Pensacola
Houston
INTERNET2®
FLR
City Pair
State-to-State Pair
Internet-connect Point
Fiber Infrastructure
12PX/RPI/Cloud Connect Peering Site
AL1S/AL2S/AL3S Add-Drop Site
The Quilt Map: 2-27-24

National Networks

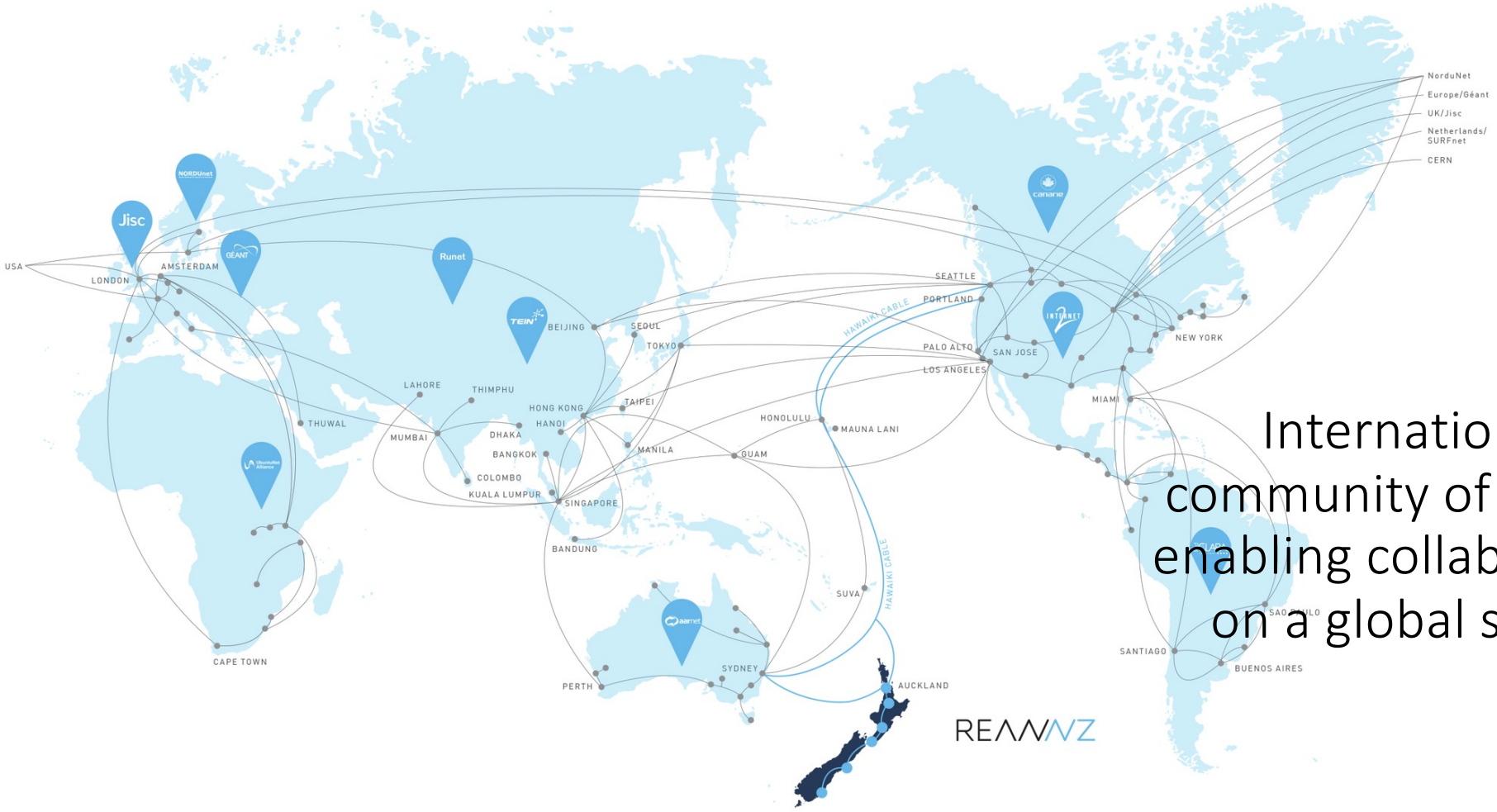

Seattle
Portland (Oregon)
Sydney
Hawaiki Capacity
Los Angeles
REANNZ NATIONAL
NETWORK MAP
NB lines are indicative only


canarie
Eureka
Alert
Resolute
Devon HMP
Pond Inlet
Cambridge Bay
Whitehorse
Aklin
Dease Lake
Fort Simpson
Yellowknife
Kinoloo
Hazelton
Fort Nelson
Rankin Inlet
Arviat
Edmonton
Kamloops
Vancouver
Victoria
Kelowna
Calgary
Saskatoon
Regina
Winnipeg
Thunder Bay
Rimouski
Quebec
Fredericton
Charlottetown
Moncton
Halifax
St. John's
Montreal
Ottawa
Toronto
London
Chatham
Windsor
Boston
New York
Chicago
to the Americas and Asia Pacific
vers des Amériques et l'Asie-Pacifique
Seattle
to Europe (ANA-300)
au l'Europe (ANA-300)
to the Americas and Europe
vers des Amériques à l'Europe
Point of Presence (POP) | Point de présence (PdP)
High-speed Network | Réseau haute vitesse
Ultra-high-speed Network | Réseau super haute vitesse
Ultra-high-speed Network planned | Réseau super haute vitesse planifié
Satellite CSA/CRC via Vancouver | Satellite ASC/CRC via Vancouver
Date: August 2016 | août 2016

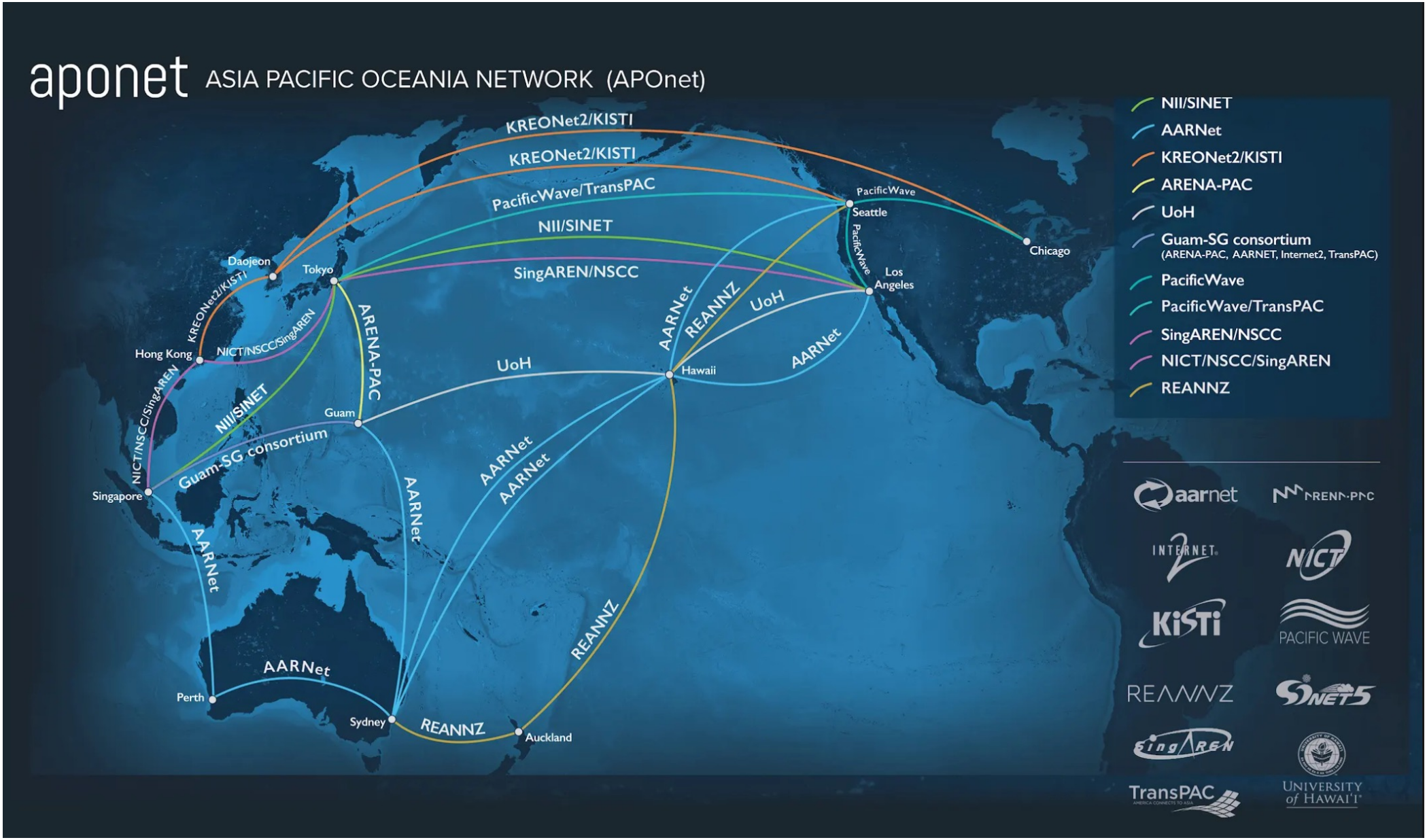

aarnet
Australia's Academic
and Research Network
Darwin
Cairns
Townsville
Mackay
Rockhampton
Gladstone
Alice Springs
MRO
Geraldton
Sippy Downs
Brisbane
Lismore
Armidale
Narrabri
Port Macquarie
Kalgoorlie
Port Augusta
Broken Hill
Perth
Parkes
Newcastle
Sydney
Mildura
Shepparton
Wollongong
Adelaide
Victor Harbor
Bendigo
Canberra
Ballarat
Geelong
Melbourne
Hobart
Key
AARNet Network Access Points
Key Regional Sites
1 Gbps
2.5 Gbps
10 Gbps
n* 100G DWDM Transmission

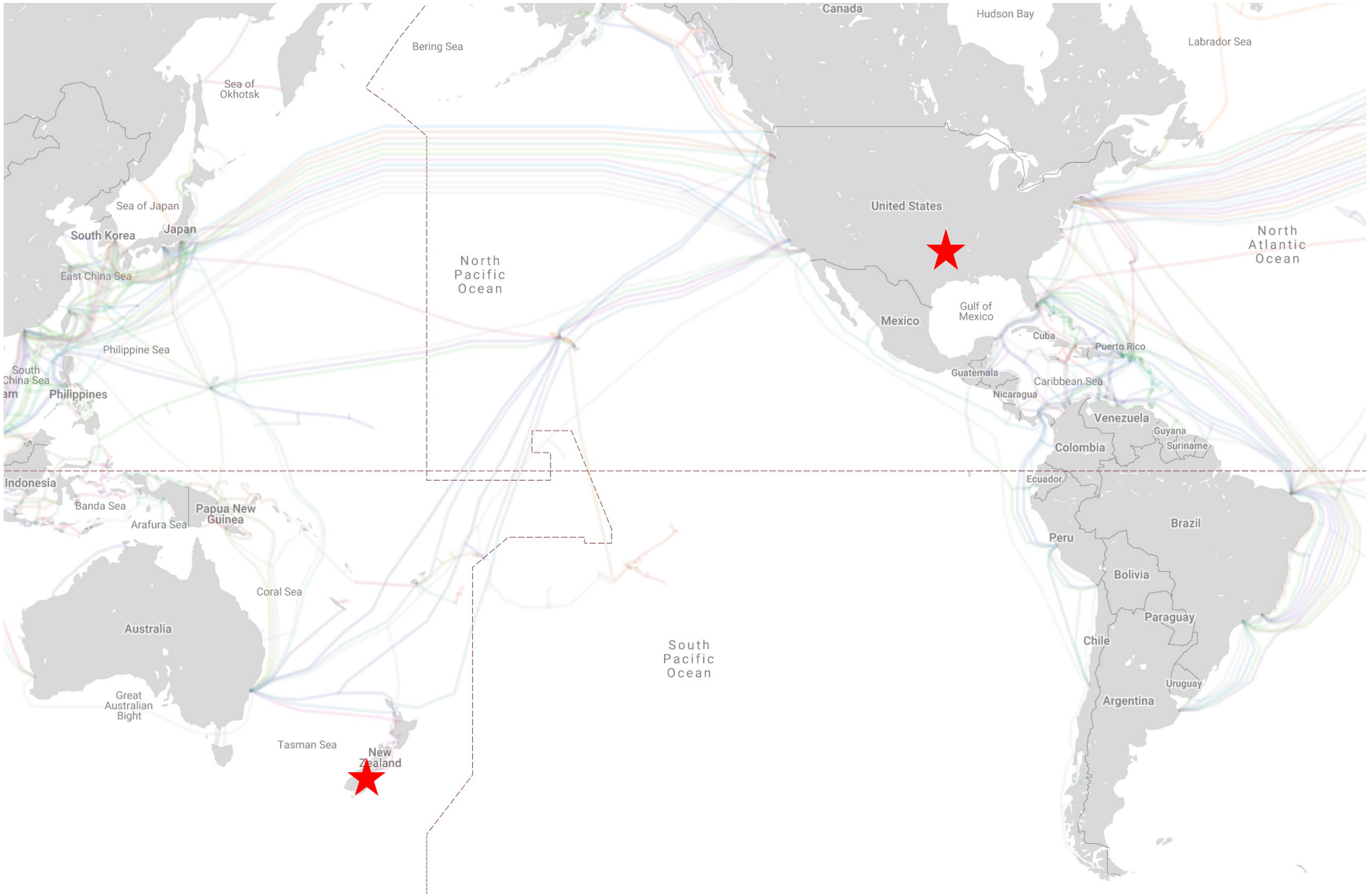


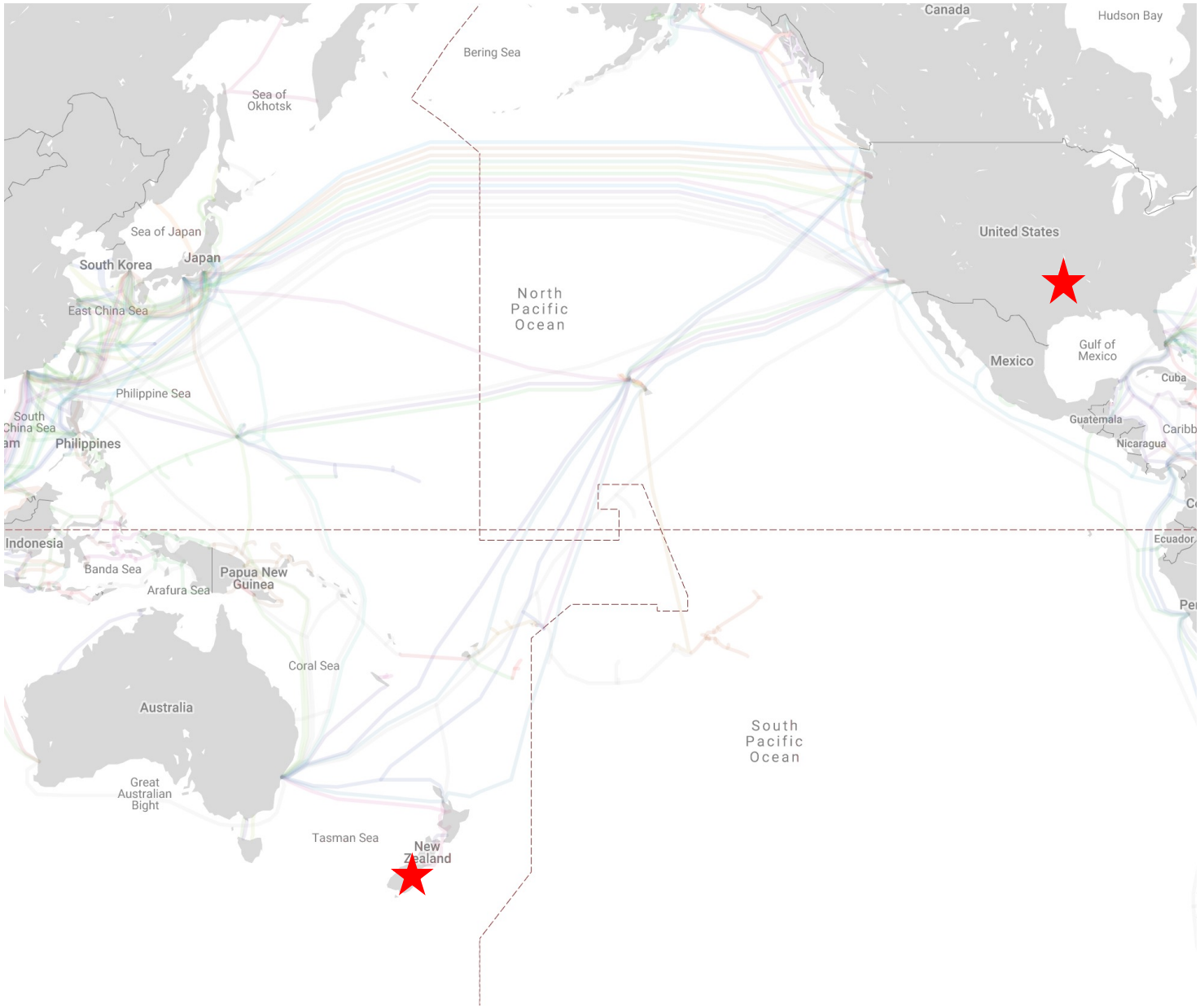
https://www.submarinecablemap.com



International community of NRENs enabling collaboration on a global scale!


aponet
ASIA PACIFIC OCEANIA NETWORK (APOnet)
KREONet2/KISTI
KREONet2/KISTI
PacificWave/TransPAC
NII/SINET
SingAREN/NSCC
PacificWave
Seattle
Chicago
Los Angeles
Daojeon
Tokyo
Hong Kong
NICT/NSCC/SingAREN
KREONet2/KISTI
ARENA-PAC
AARNet
REANNZ
UoH
AARNet
Hawaii
UoH
Guam
NII/SINET
NICT/NSCC/SingAREN
Guam-SG consortium
Singapore
AARNet
AARNet
AARNet
AARNet
AARNet
REANNZ
Perth
Sydney
REANNZ
Auckland
NII/SINET
AARNet
KREONet2/KISTI
ARENA-PAC
UoH
Guam-SG consortium (ARENA-PAC, AARNET, Internet2, TransPAC)
PacificWave
PacificWave/TransPAC
SingAREN/NSCC
NICT/NSCC/SingAREN
REANNZ
aarnet
INTERNET2
KISTI
REANNZ
SingAREN
TransPAC
NICT
PACIFIC WAVE
SINET5
UNIVERSITY of HAWAI'I


Canada
Hudson Bay
Labrador Sea
Bering Sea
Sea of Okhotsk
Sea of Japan
South Korea
Japan
East China Sea
North Pacific Ocean
United States
North Atlantic Ocean
Gulf of Mexico
Mexico
Cuba
Puerto Rico
Guatemala
Caribbean Sea
Nicaragua
Philippine Sea
South China Sea
Philippines
Venezuela
Guyana
Suriname
Colombia
Ecuador
Indonesia
Banda Sea
Papua New Guinea
Arafura Sea
Brazil
Peru
Bolivia
Coral Sea
Australia
Paraguay
Chile
Uruguay
Argentina
South Pacific Ocean
Great Australian Bight
Tasman Sea
New Zealand



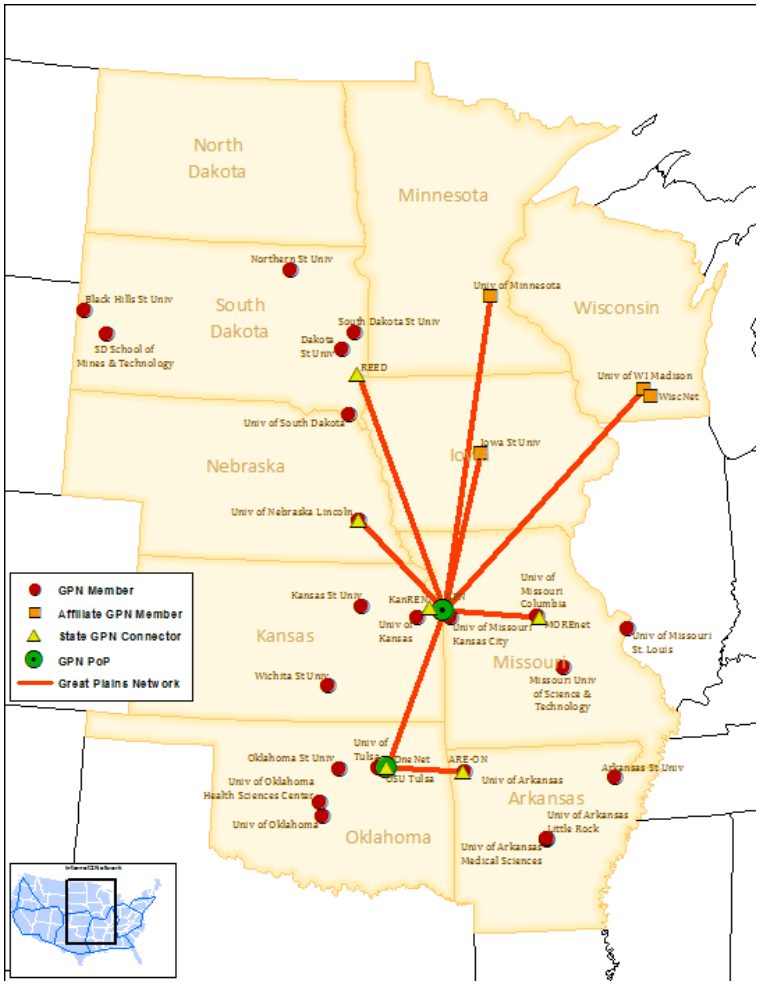
INFORMATION TECHNOLOGY
THE UNIVERSITY OF OKLAHOMA

OU IT INFORMATION TECHNOLOGY
THE UNIVERSITY OF OKLAHOMA

OneNet
Oklahoma's Research & Education Network

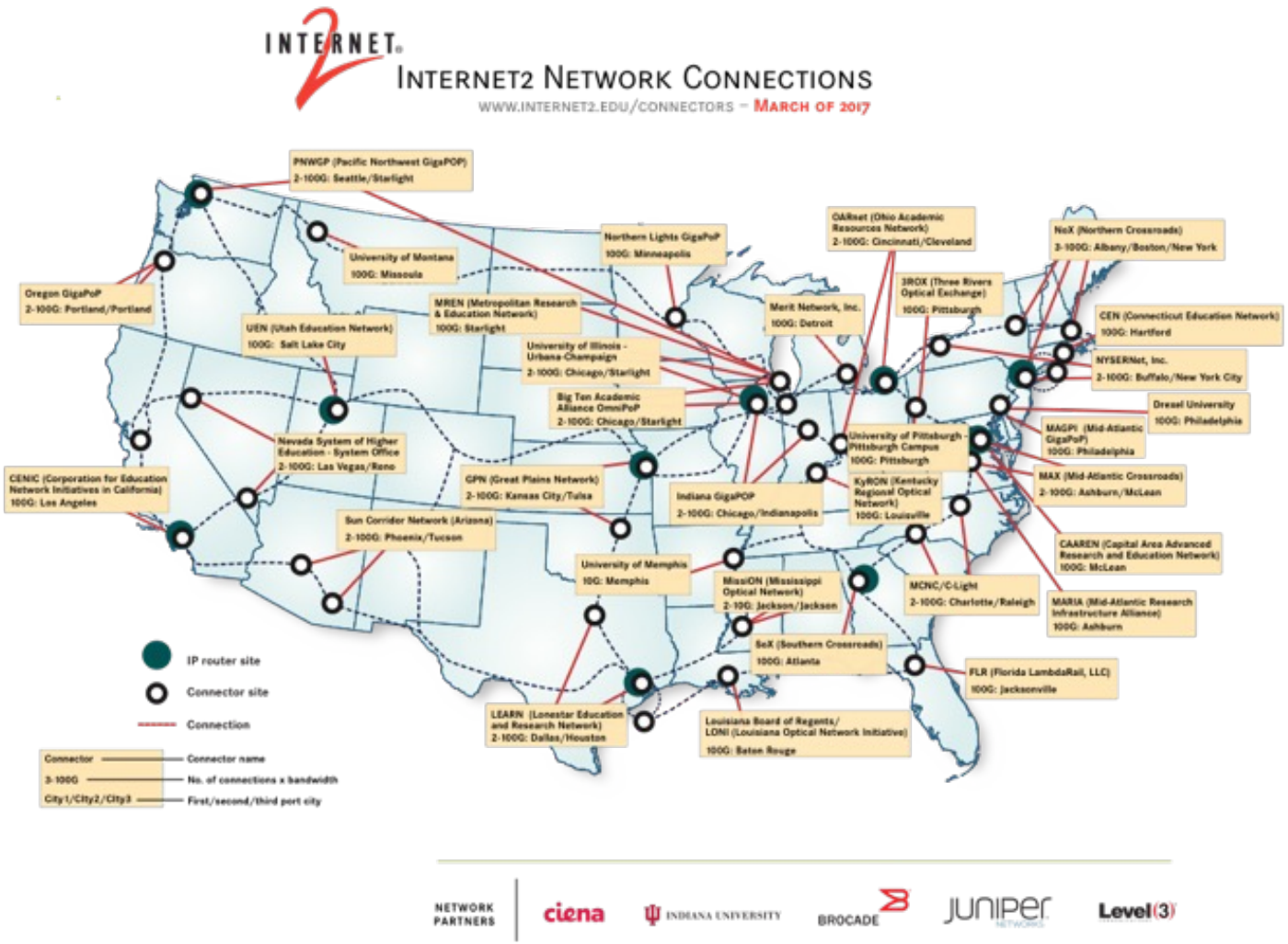
OneNet Points of Presence

Higher Education Campuses | Career Technology Centers | Hospitals | Public Safety Agencies | Other



OneNet
Oklahoma's Research & Education Network

GREAT PLAINS NETWORK

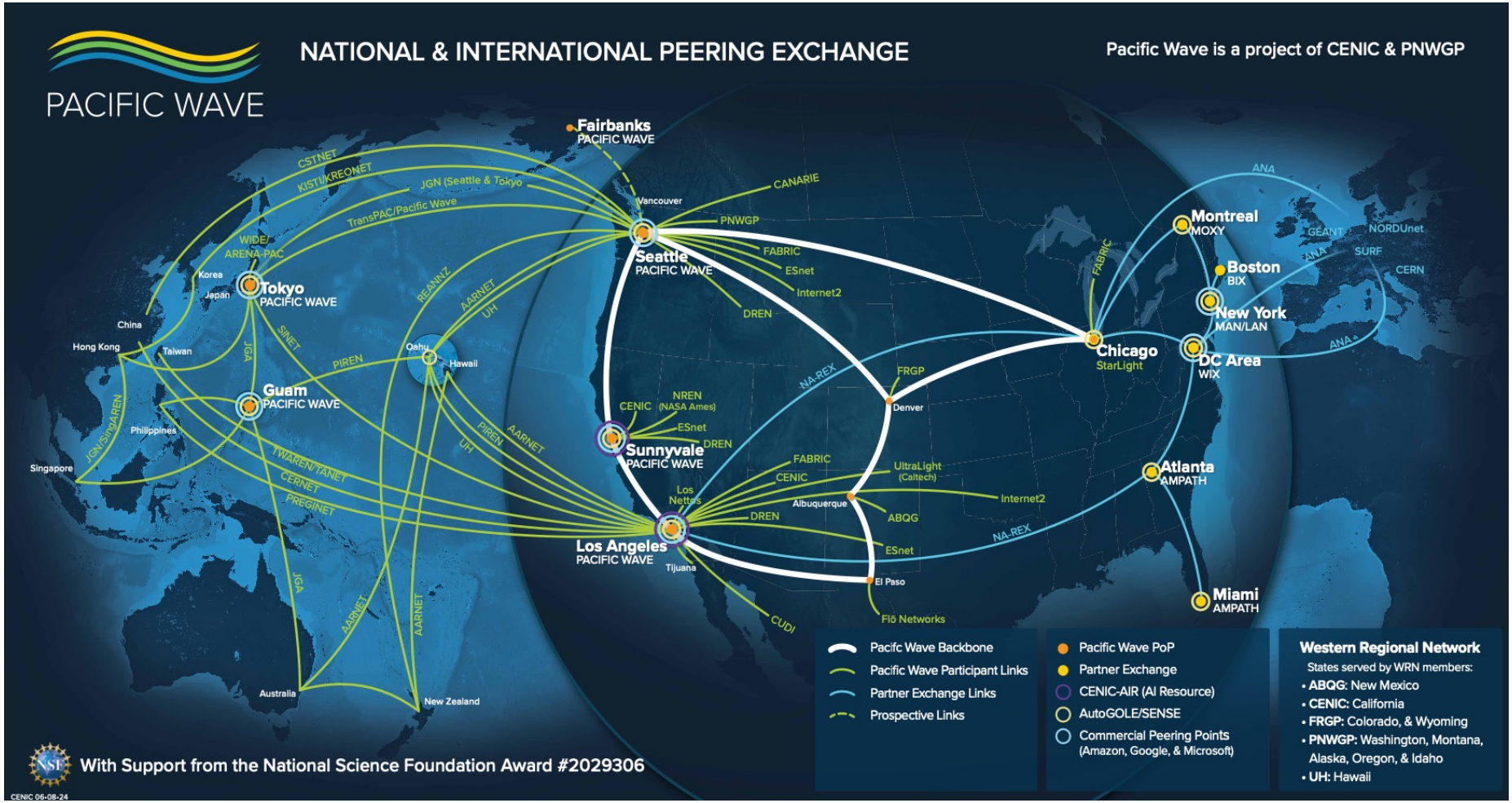


IT INFORMATION TECHNOLOGY
THE UNIVERSITY OF OKLAHOMA

OneNet
Oklahoma's Research & Education Network

GPN
GREAT PLAINS NETWORK

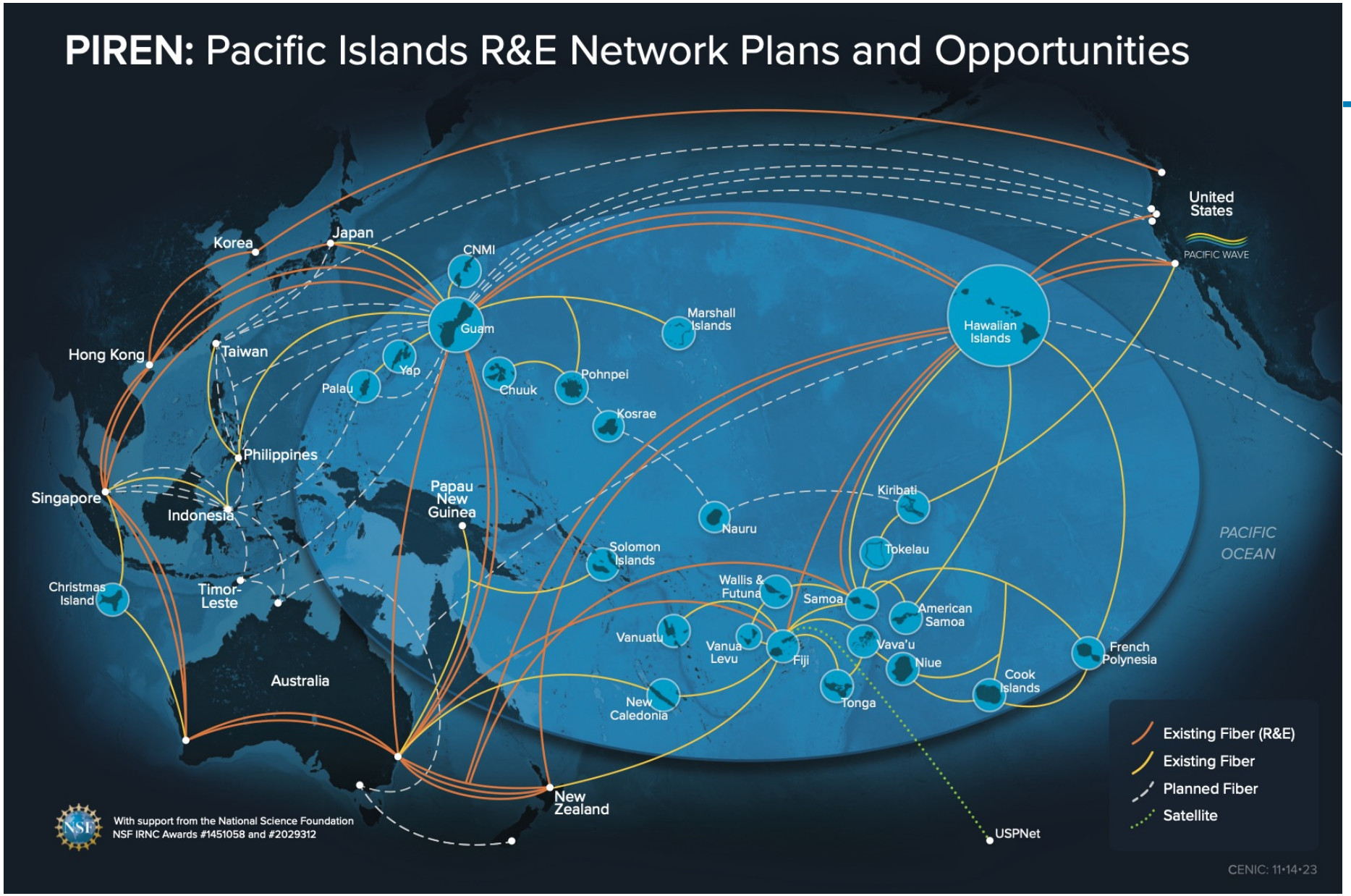
INTERNET®



PACIFIC NORTHWEST GIGAPOP + CENIC

PACIFIC WAVE

PIREN: Pacific Islands R&E Network Plans and Opportunities



OU IT Information Technology, The University of Oklahoma

OneNet
Oklahoma's Research & Education Network

GPN
Great Plains Network

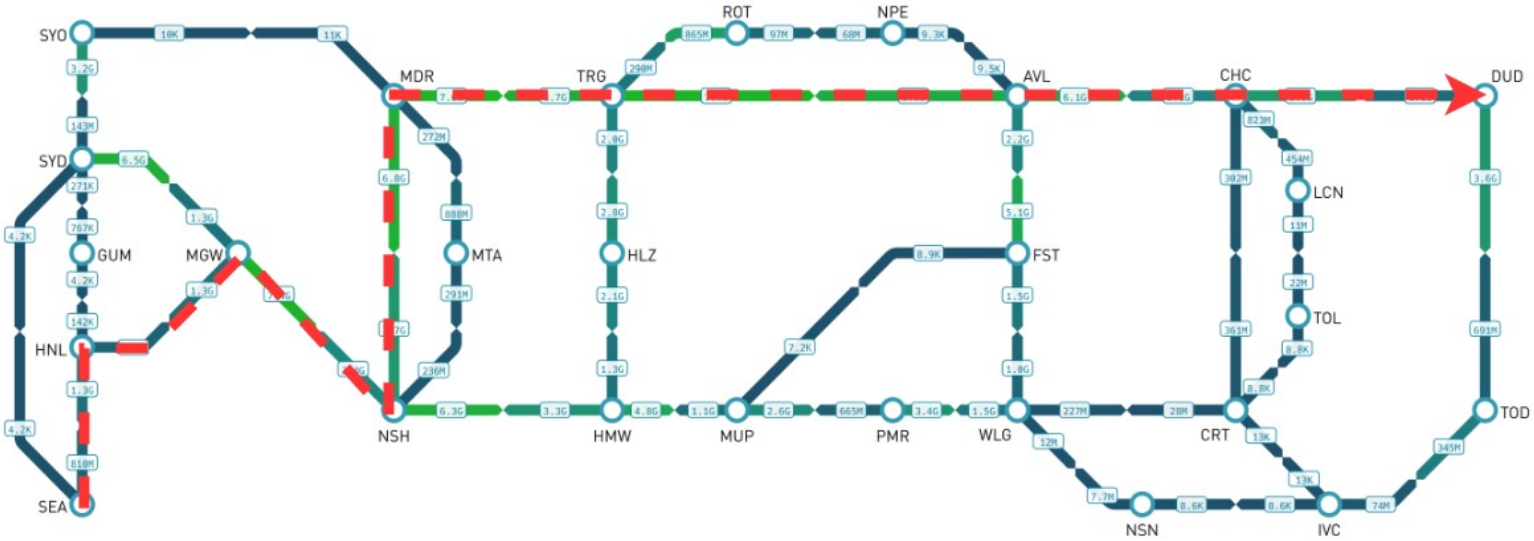
Internet2

Pacific Northwest GigaPop

+

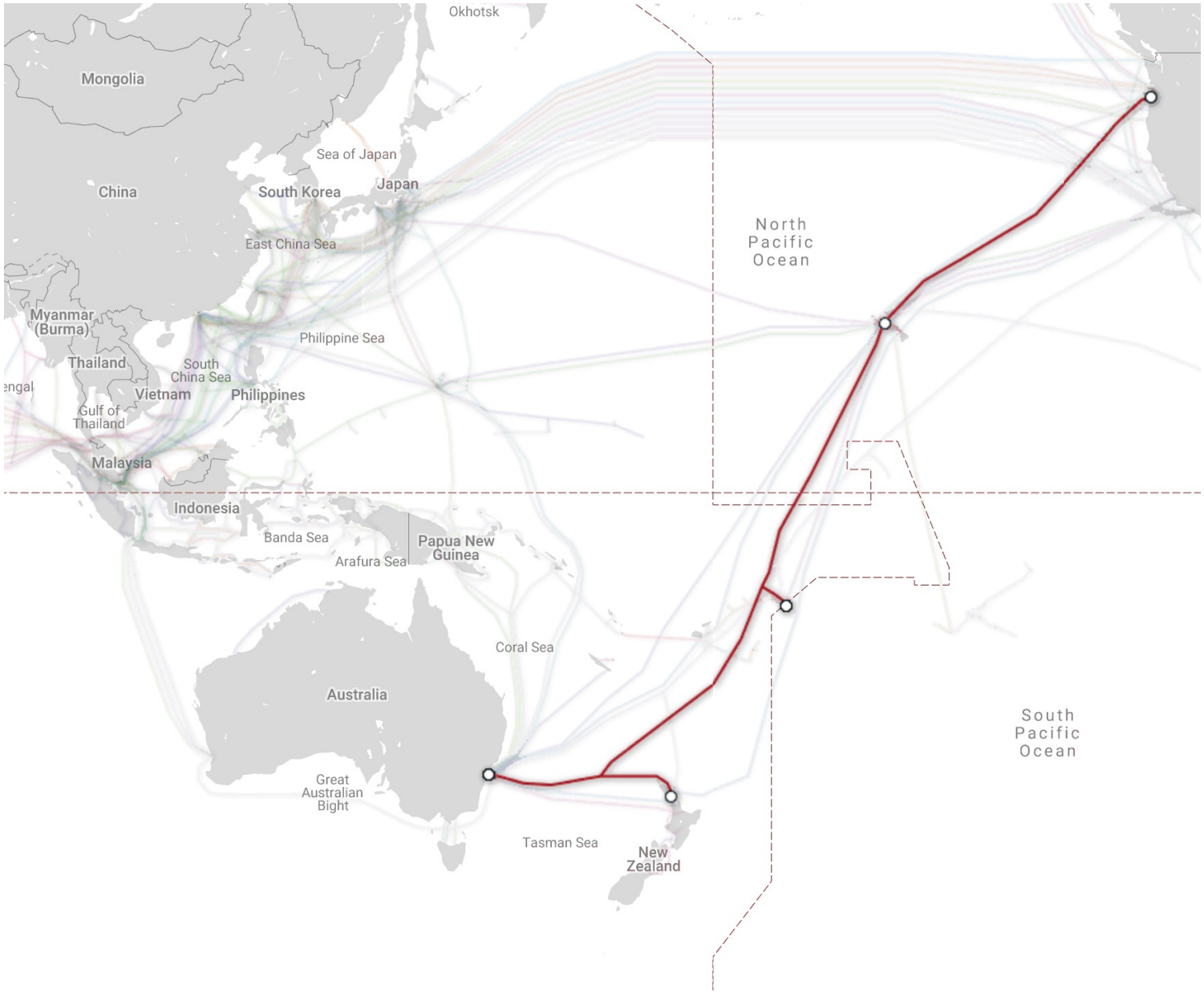
CENIC

Pacific Wave



https://weathermap.reannz.co.nz

REANNZ



OU IT Information Technology, The University of Oklahoma

OneNet
Oklahoma's Research & Education Network

GPN
Great Plains Network

Internet2

Pacific Northwest GigaPop + CENIC

Pacific Wave

REANNZ

OU IT Information Technology, The University of Oklahoma

OneNet
Oklahoma's Research & Education Network

GPN
Great Plains Network

Internet2

Pacific Northwest GigaPop + CENIC

Pacific Wave

REANNZ

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OneNet
Oklahoma's Research & Education Network

GPN
Great Plains Network

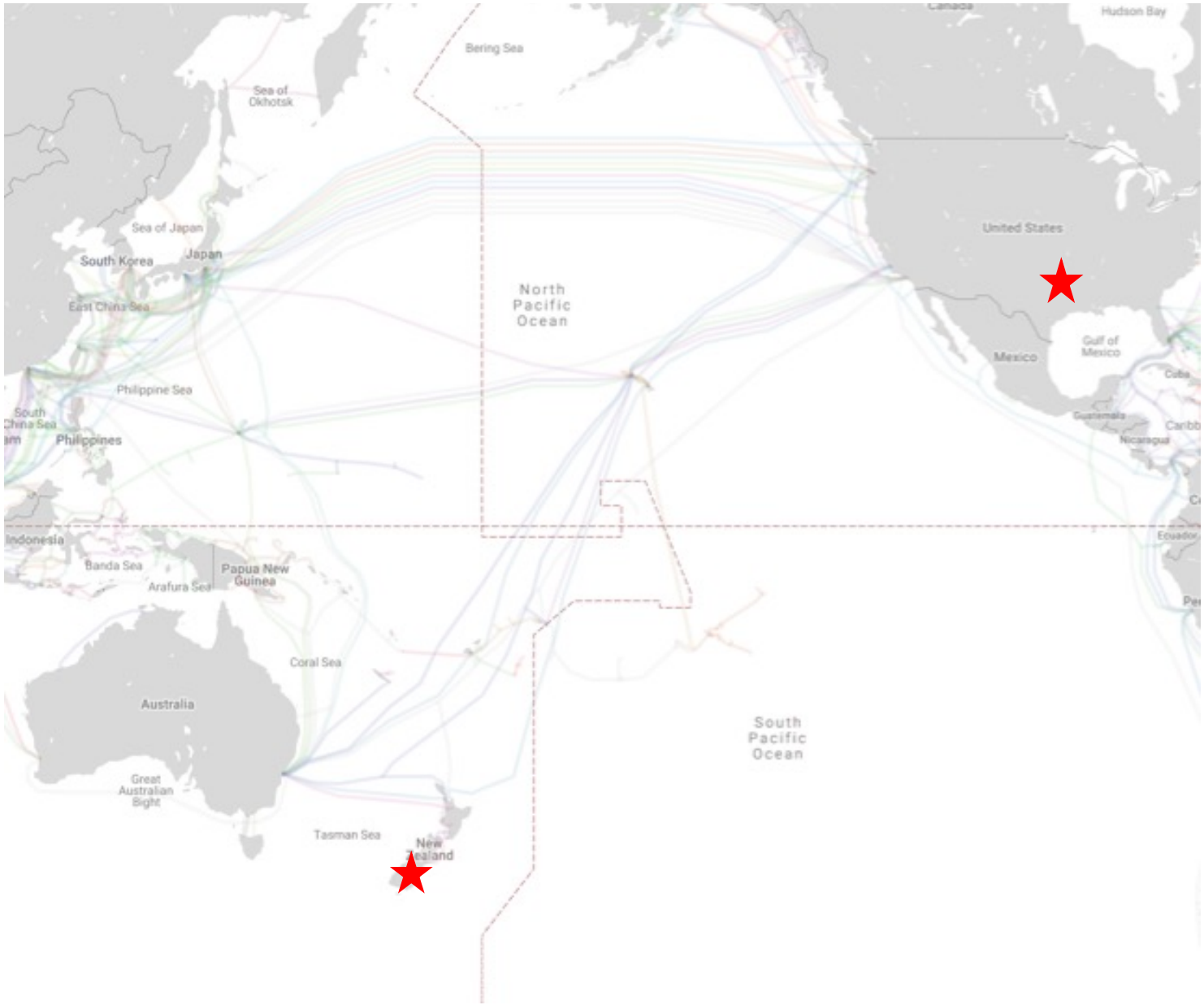
Internet2®

Pacific Northwest GigaPop + CENIC

Pacific Wave

REANNZ

University of Otago
Te Whare Wānanga o Otāgo
New Zealand
Sapere Aude



OU IT Information Technology, The University of Oklahoma

OneNet, Oklahoma's Research & Education Network

GPN, Great Plains Network

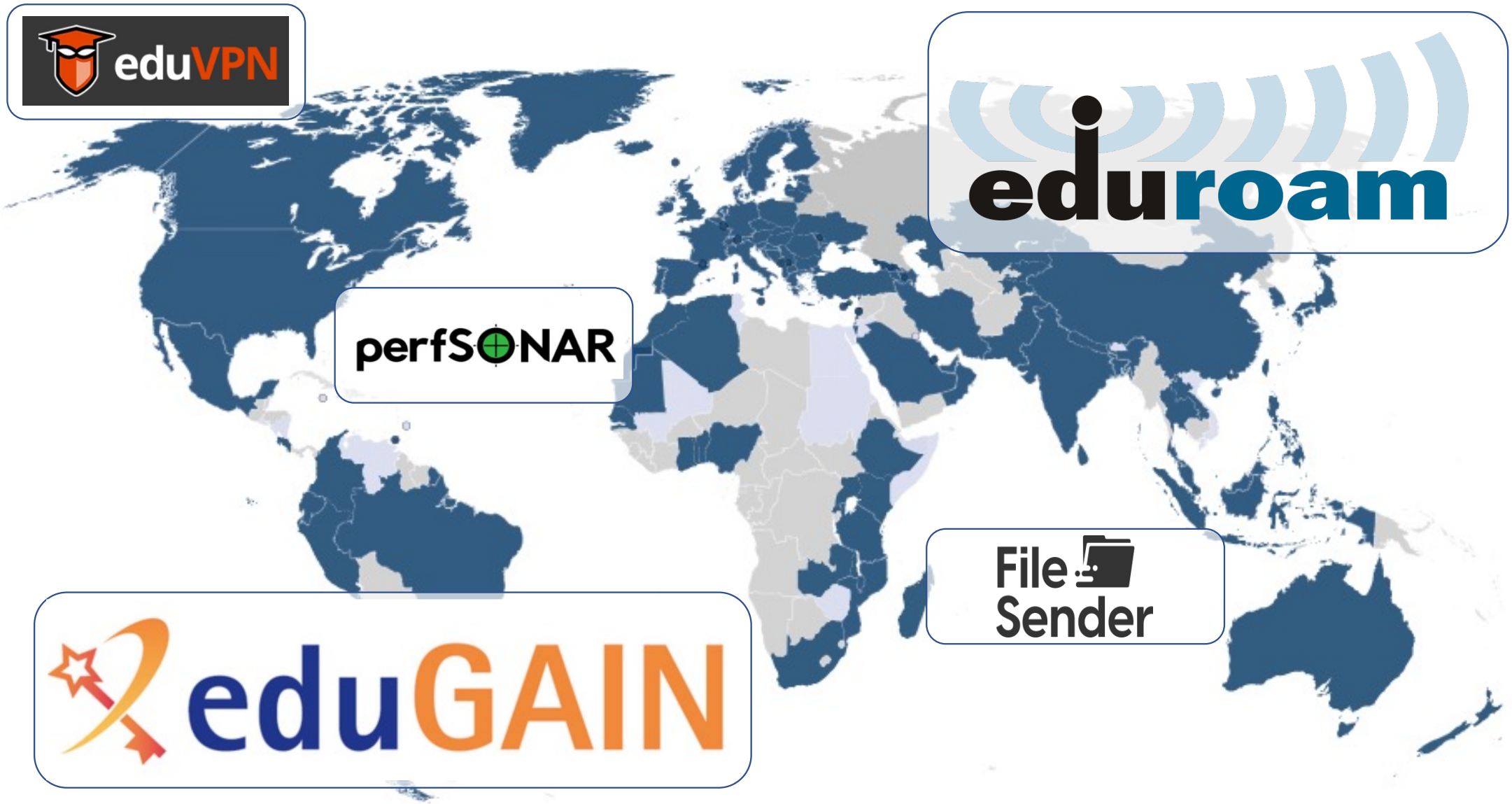
Internet2

Pacific Northwest GigaPop + CENIC

Pacific Wave

REANNZ

University of Otago, Te Whare Wānanga o Otāgo, New Zealand


eduVPN
eduroam
perfSONAR
File Sender
eduGAIN

So… what does all this mean for me?

- The requirements of the data intensive researcher and the service profile of the traditional campus computer network (or commercial networks) do not always align!
- Networks interconnect to networks to networks to networks…
- Networks get exponentially complex the more connections you have
- NRENs are at the core of an international community supporting data intensive science!

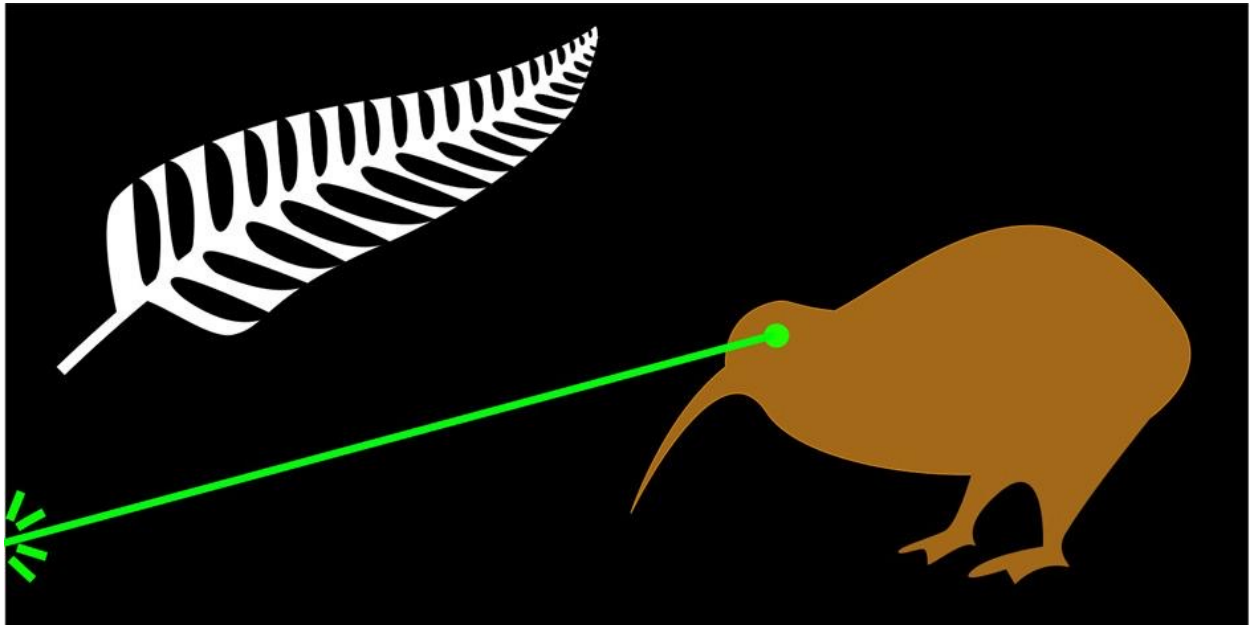
- Research networks are there for YOUR transfers. If it's not working - ask for help!

If your data must transit it - it's “your” network!

Our goal.

Our goal.

NZ edition...



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