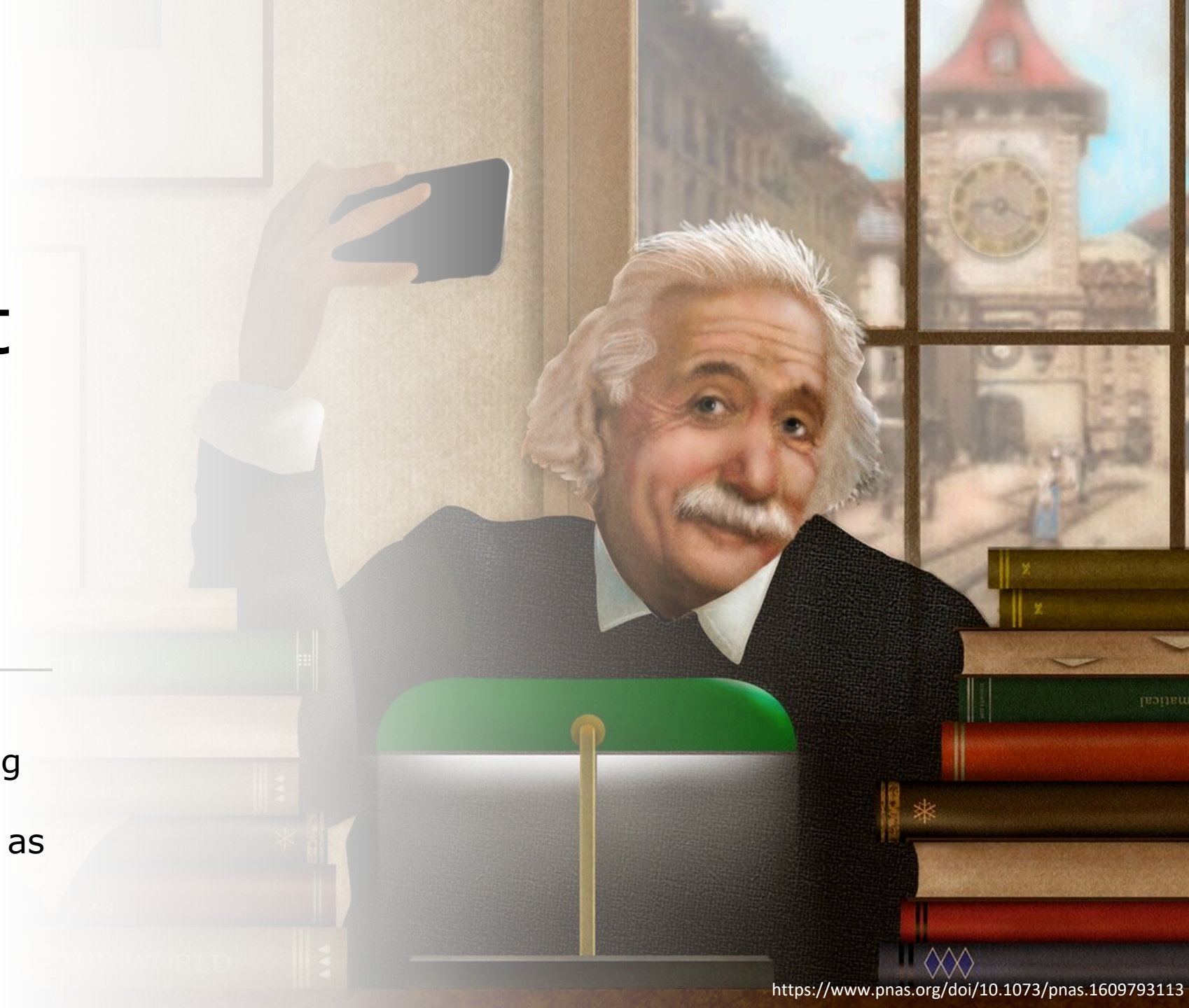
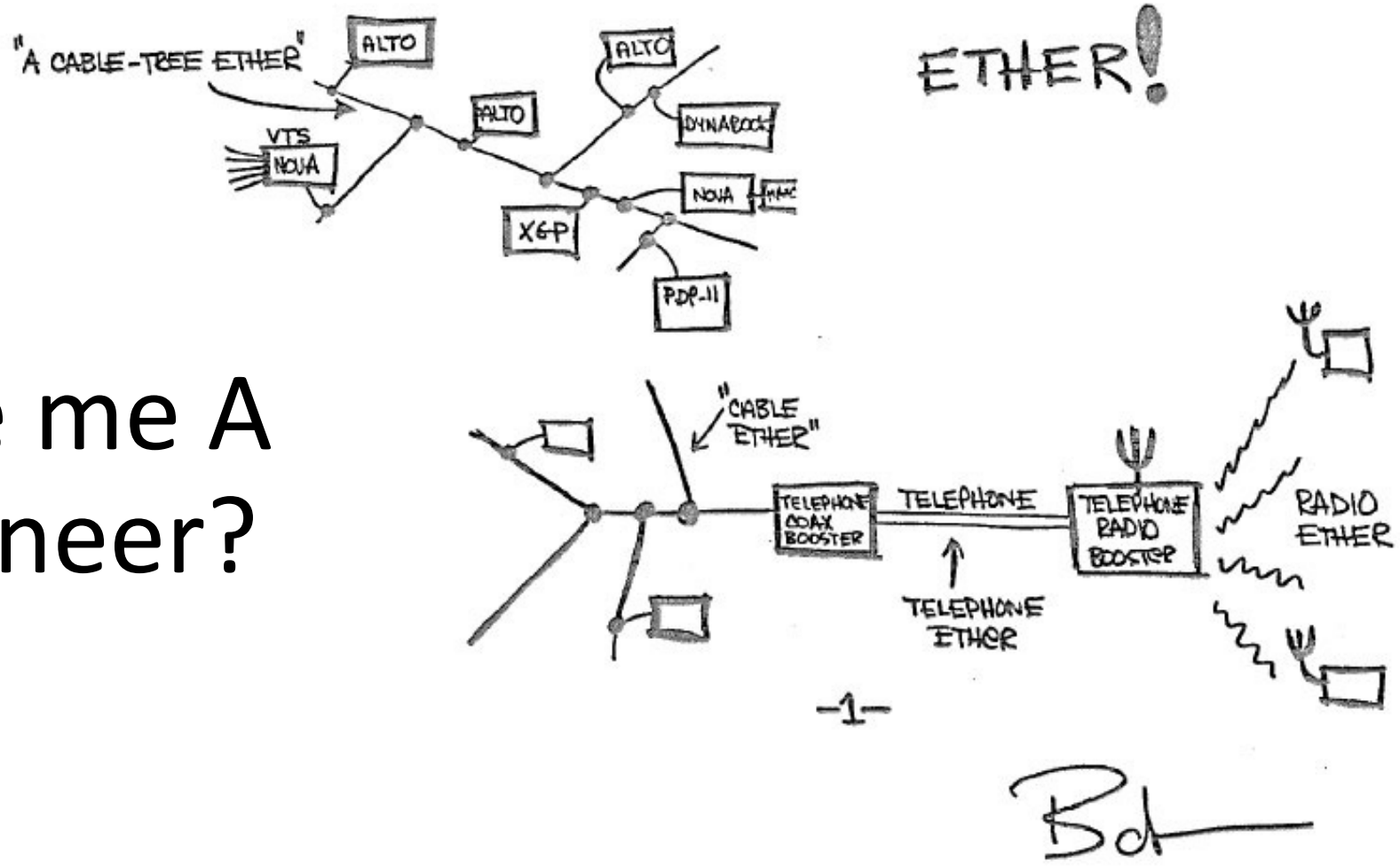
“The internet is fine – I'm on Facebook right now!”

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

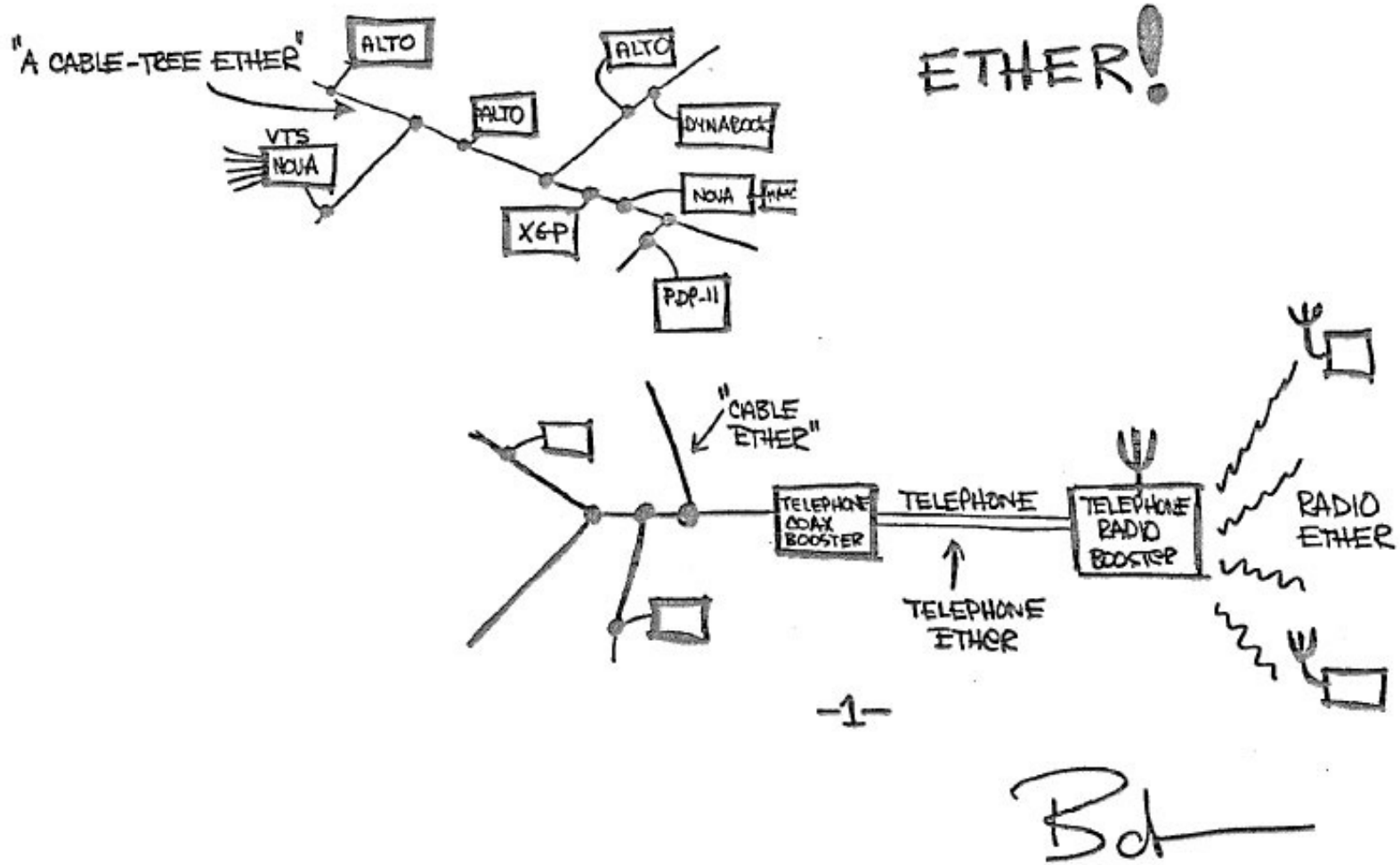


https://www.pnas.org/doi/10.1073/pnas.1609793113

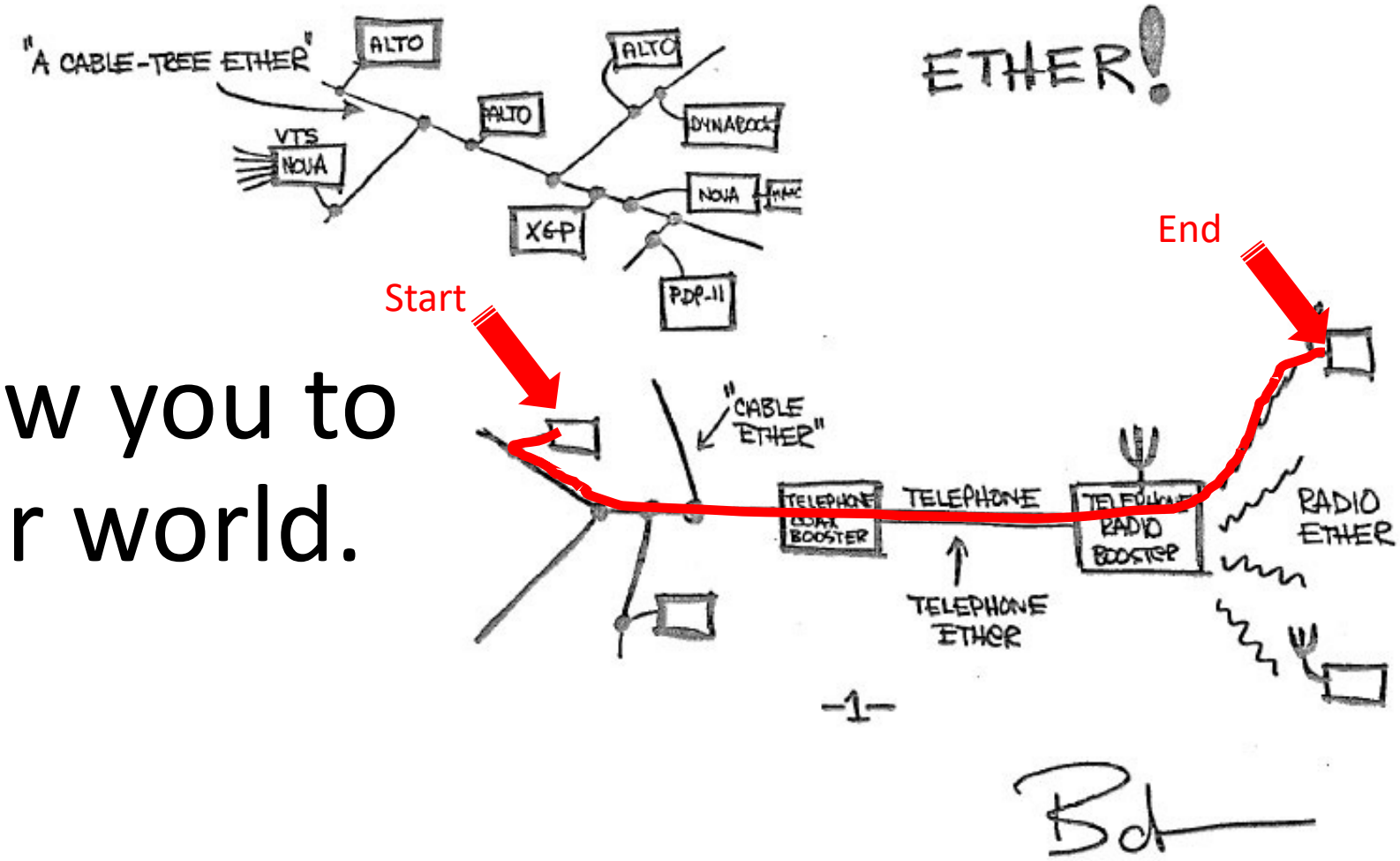
Will this make me A Network Engineer?



No.

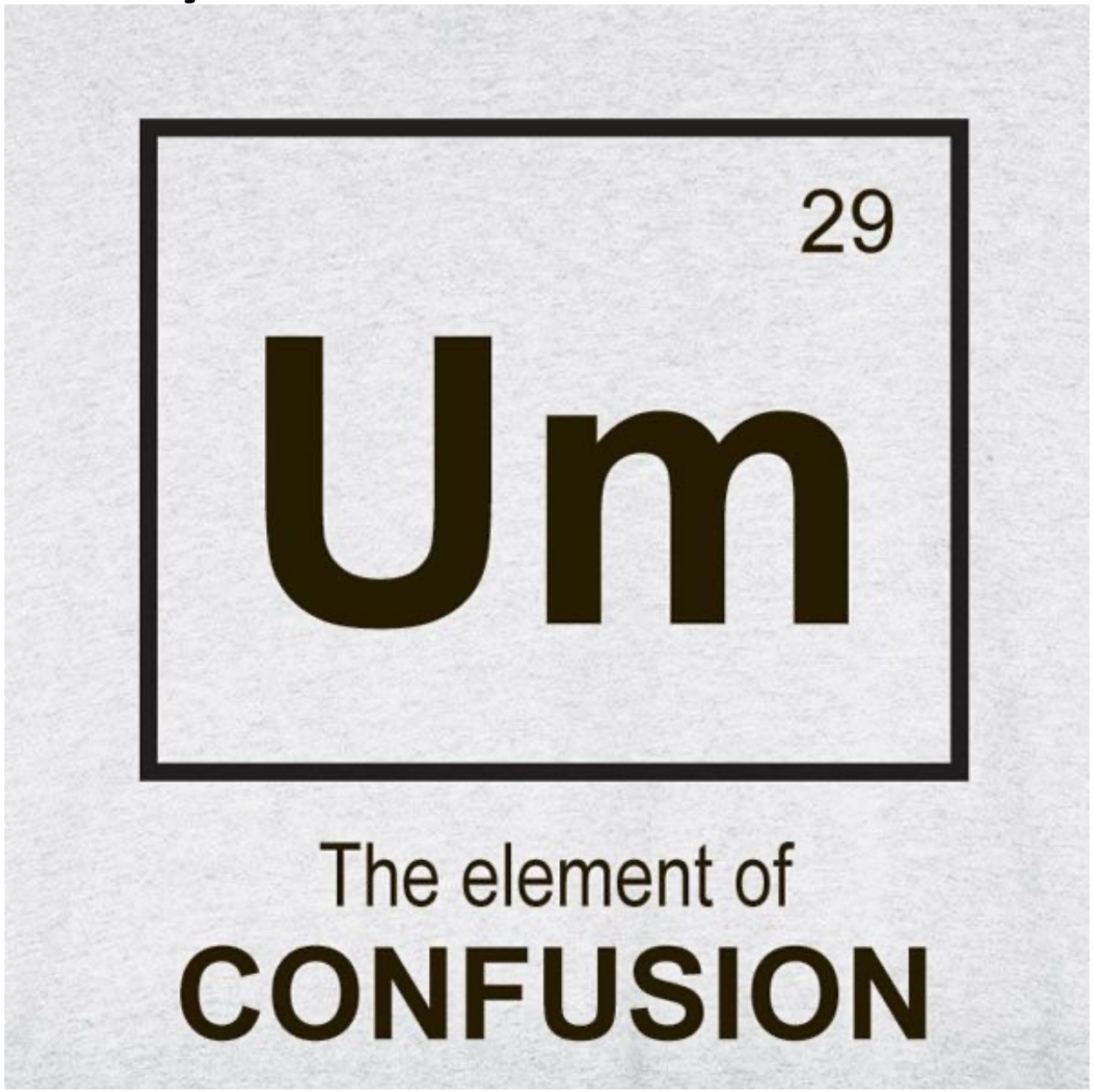

"A CABLE-TREE ETHER"
ALTO
ALTO
ALTO
VT'S
NOVA
DYNABOOK
NOVA
X-P
PDP-11
ETHER!
"CABLE ETHER"
TELEPHONE COAX BOOSTER
TELEPHONE
TELEPHONE RADIO BOOSTER
RADIO ETHER
TELEPHONE ETHER
-1-

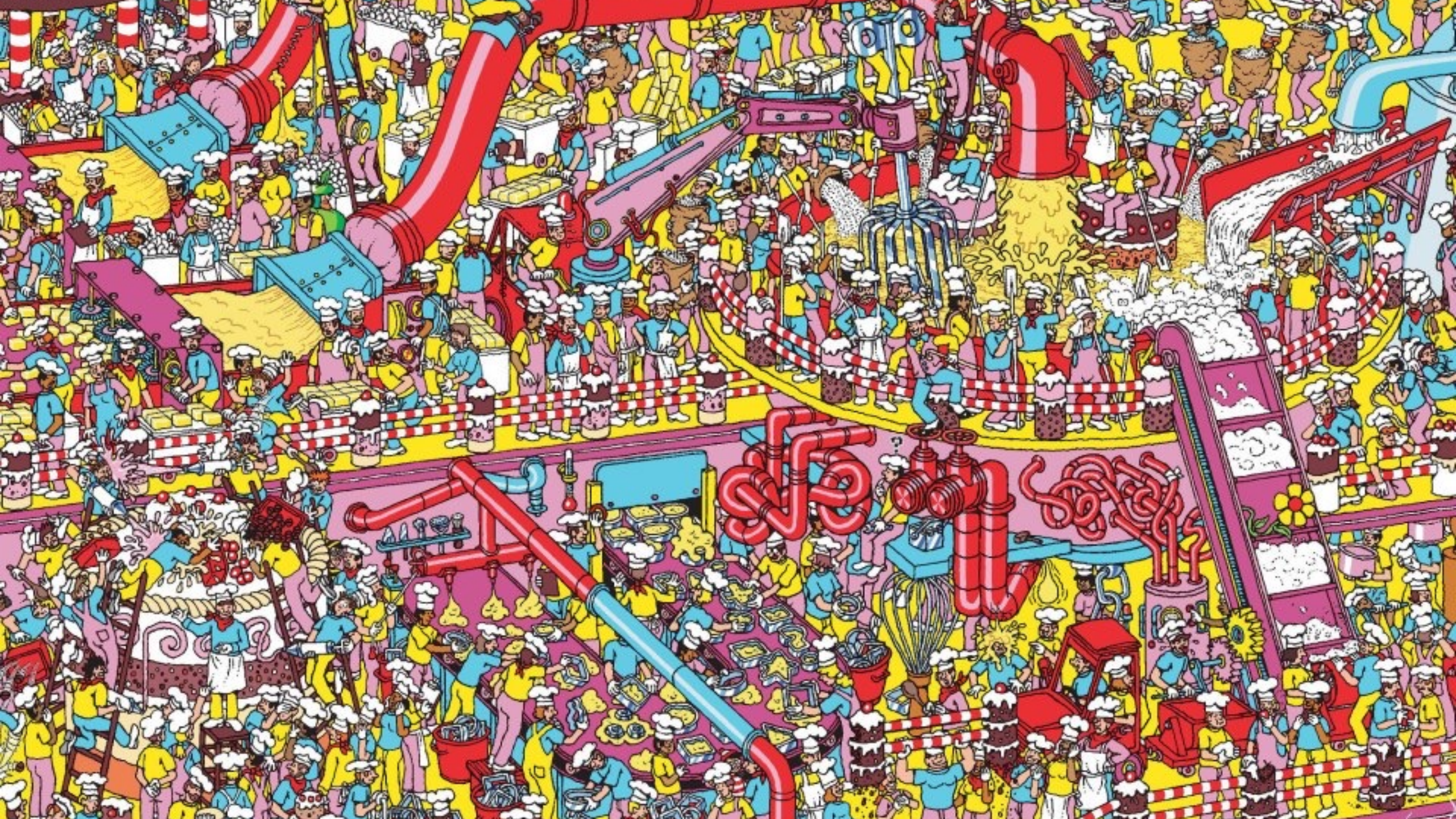
But it will allow you to navigate their world.

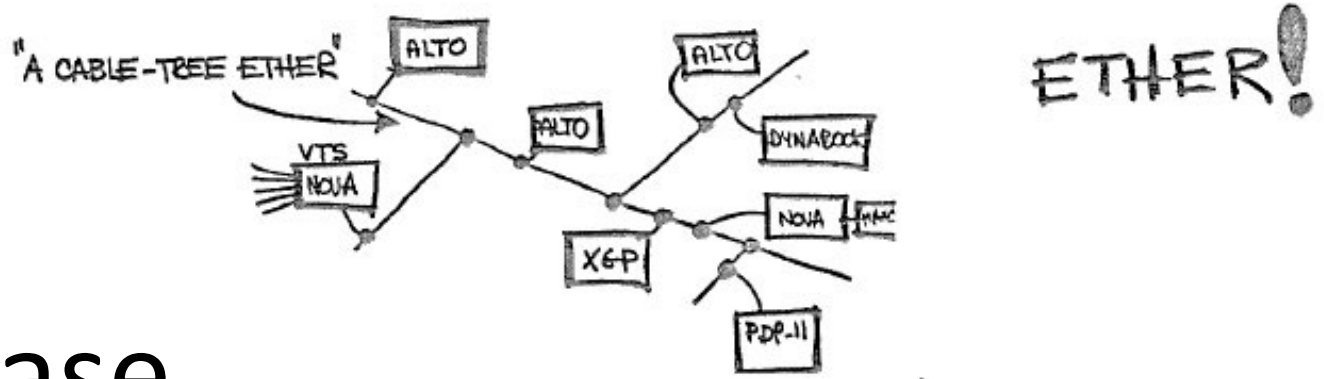


Maybe even understand them…

But why do I need to know this?





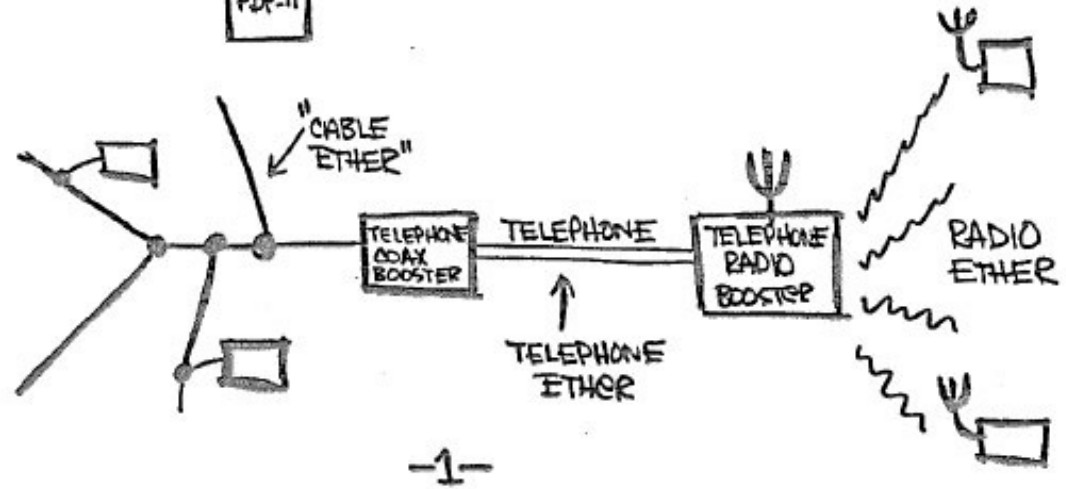


Wallace Chase

Head of Department, ITS

wallace.chase@otago.ac.nz

@bmtfr



SAPERE AUDE

UNIVERSITY of OTAGO

Te Whare Wānanga o Otāgo

NEW ZEALAND

CLEMSON COMPUTING AND INFORMATION TECHNOLOGY

Light R&E Network

REANNZ

WASHINGTON STATE UNIVERSITY

World Class. Face to Face.

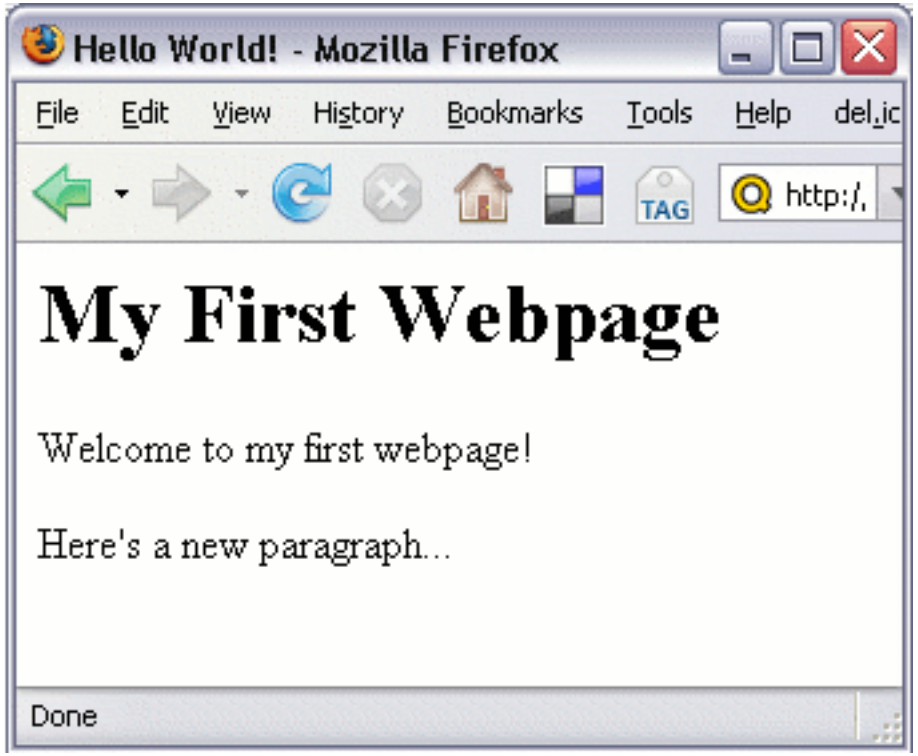
THE GEORGE WASHINGTON UNIVERSITY WASHINGTON, DC

SC LightRail

LSSU LAKE SUPERIOR STATE UNIVERSITY

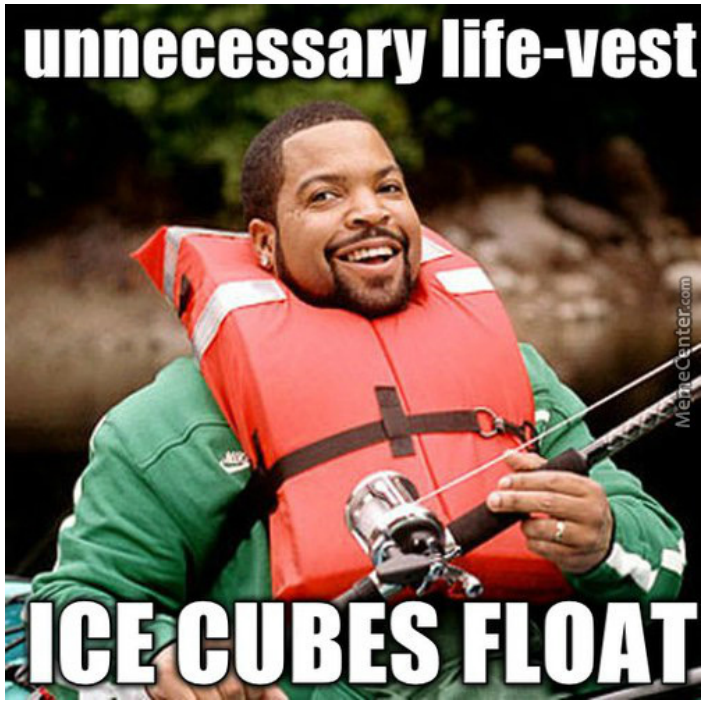
Black Hawk College

So, what is the difference in the data?



twitch

YouTube



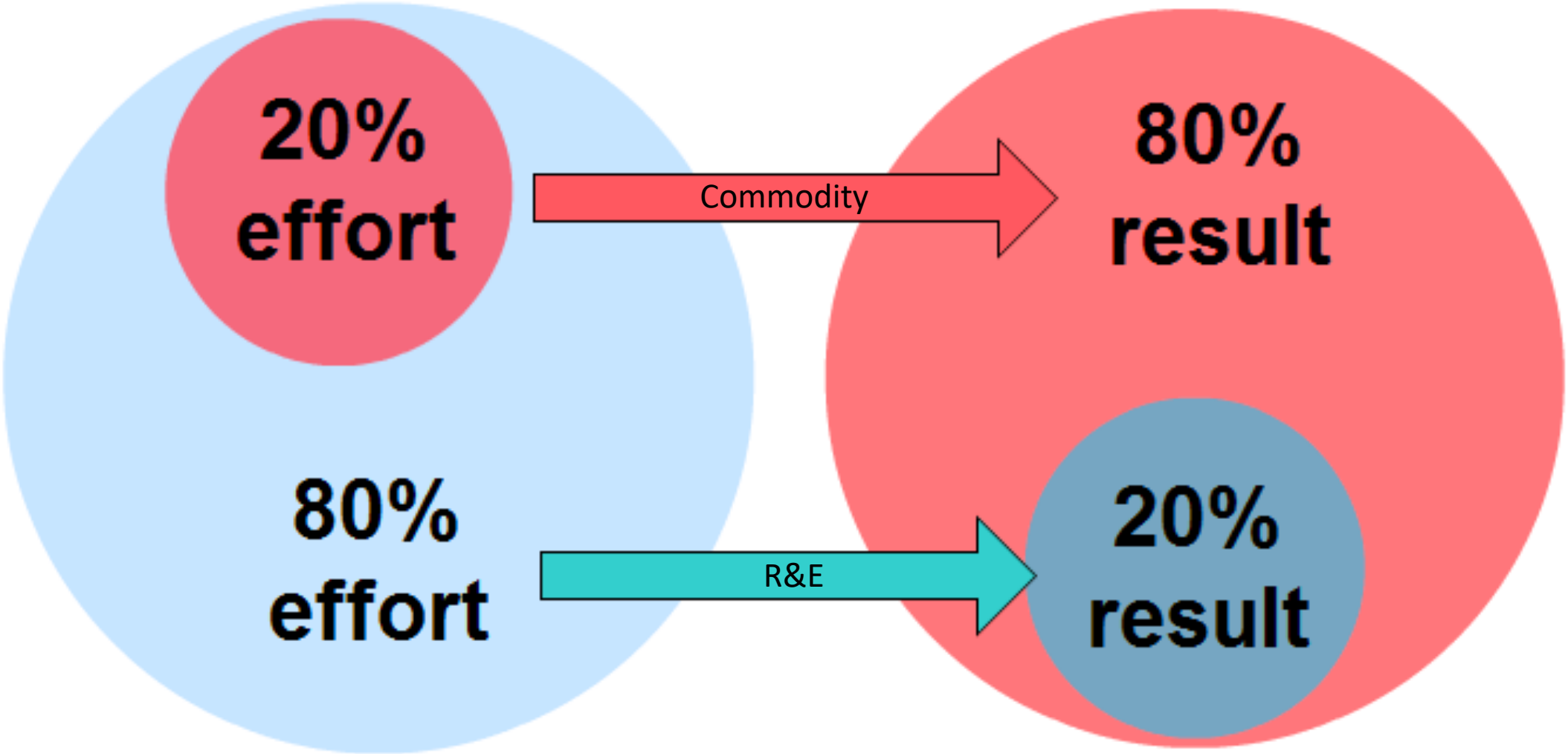
Research data

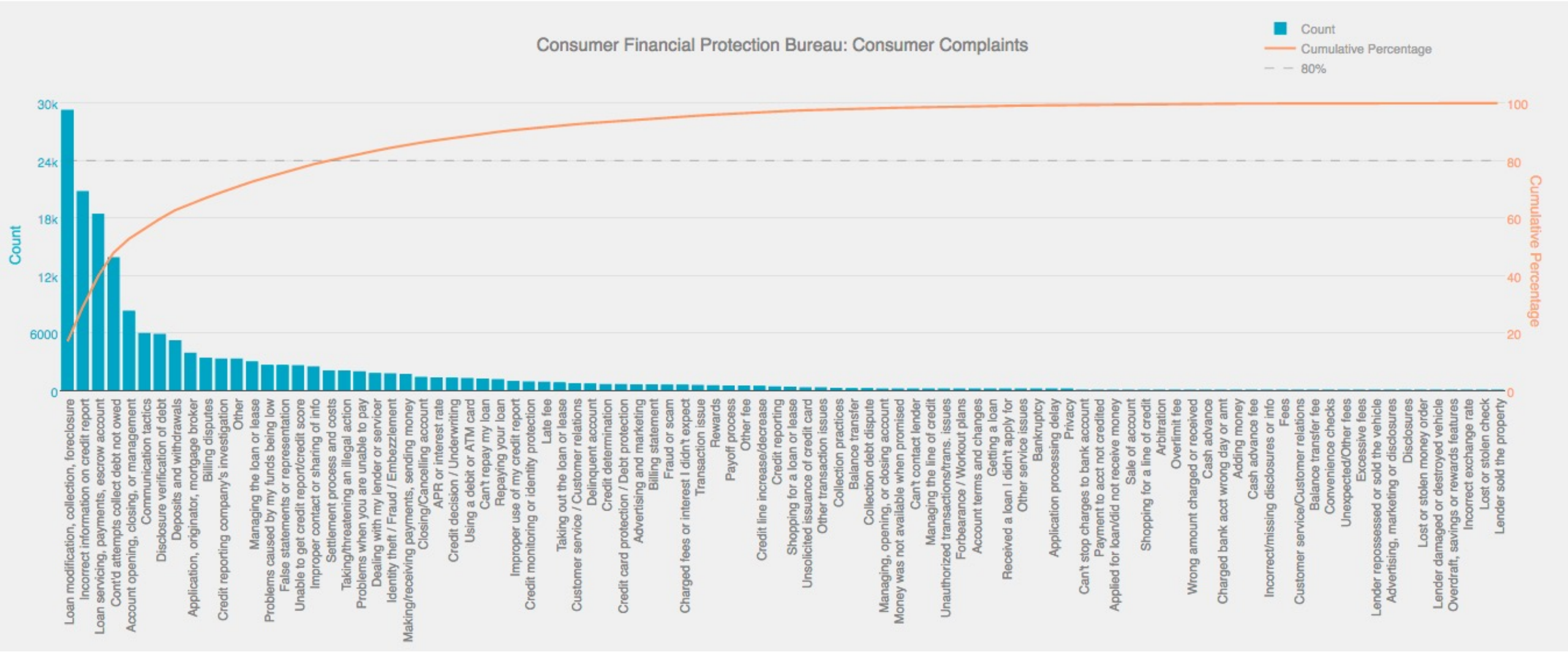
Research data

Who provides the transport?

Commodity/commercial Networks

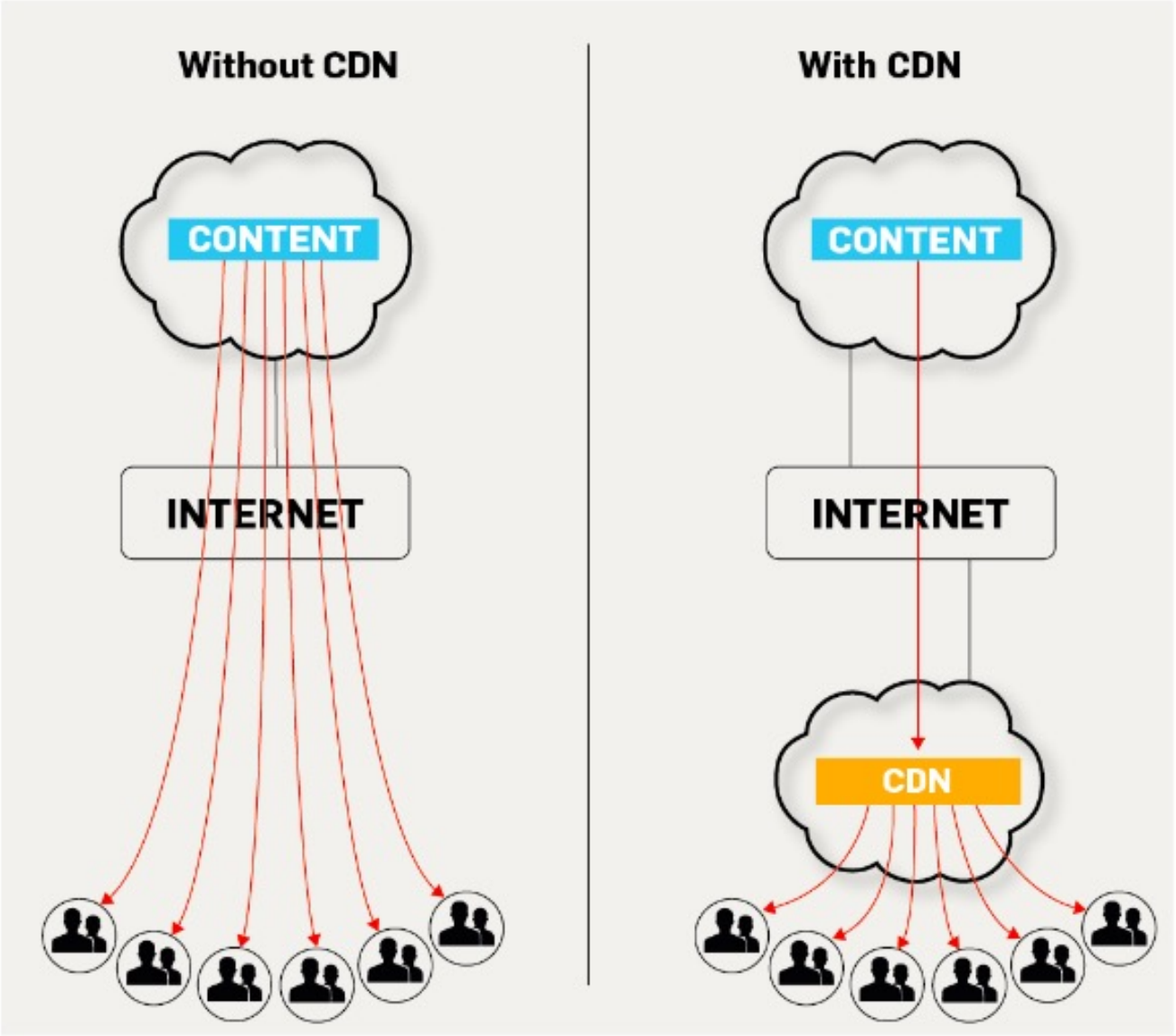
Effort




Consumer Financial Protection Bureau: Consumer Complaints
Count
Cumulative Percentage
80%
30k
24k
18k
12k
6000
0
100
80
60
40
20
0
Count
Cumulative Percentage
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

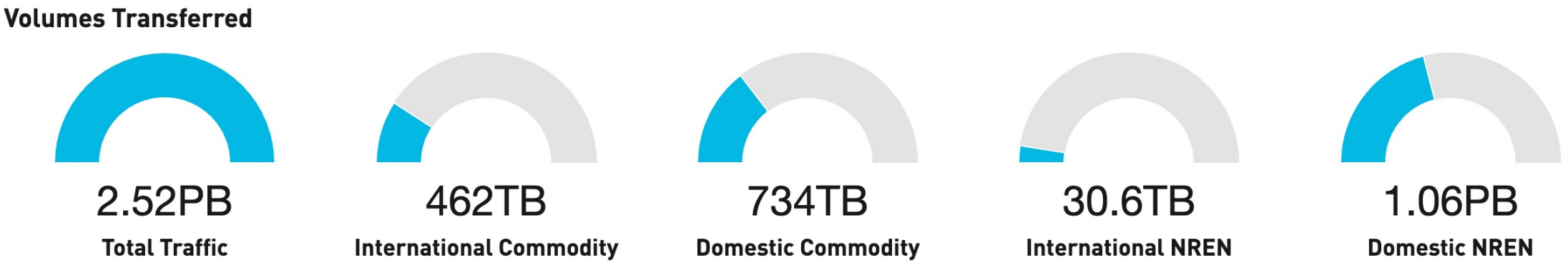
Content Delivery Network

- 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 user can access the data that is stored at a location that is geographically closest to the user.



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

An example of traffic flows…




DEPTH
GAUGE
FROM: DISNEY

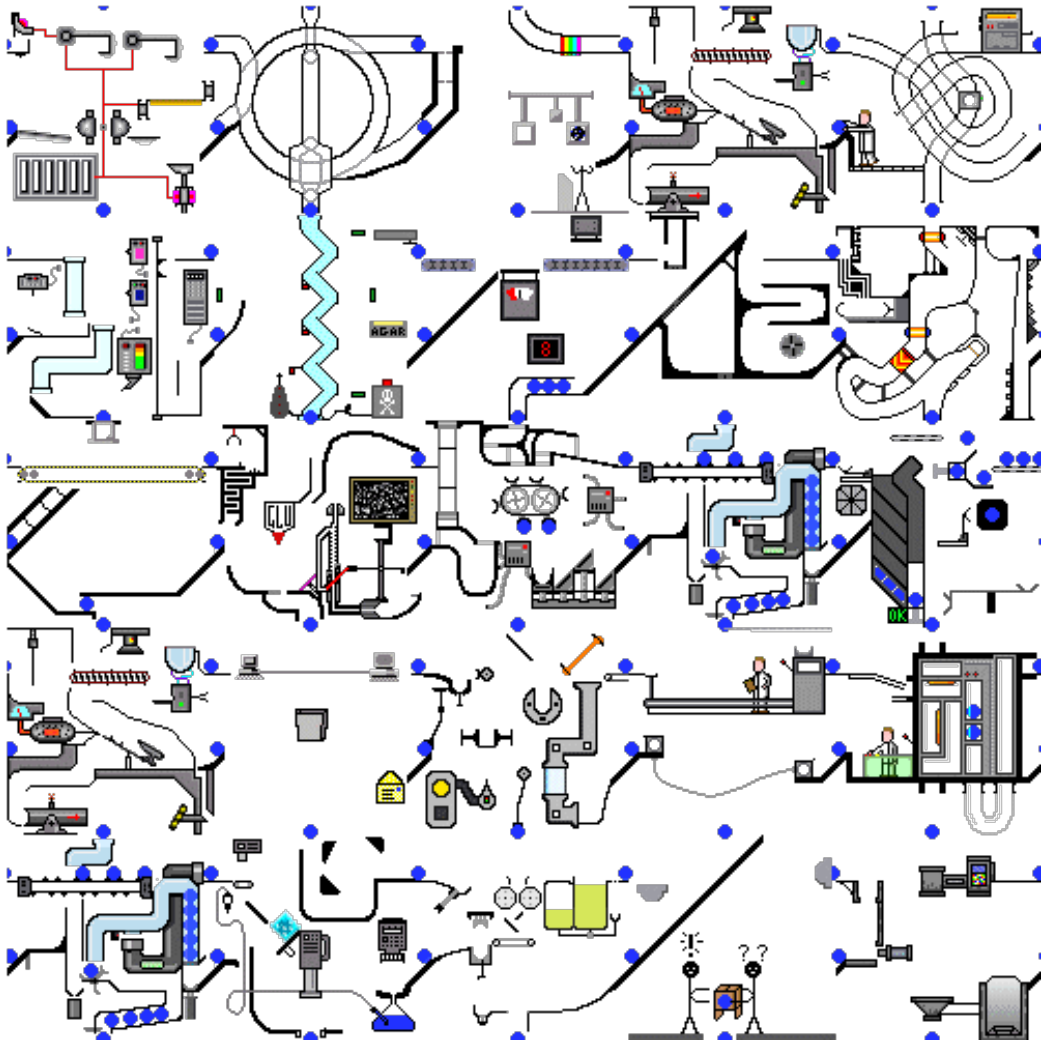
State/regional networks

aka “your ISP”

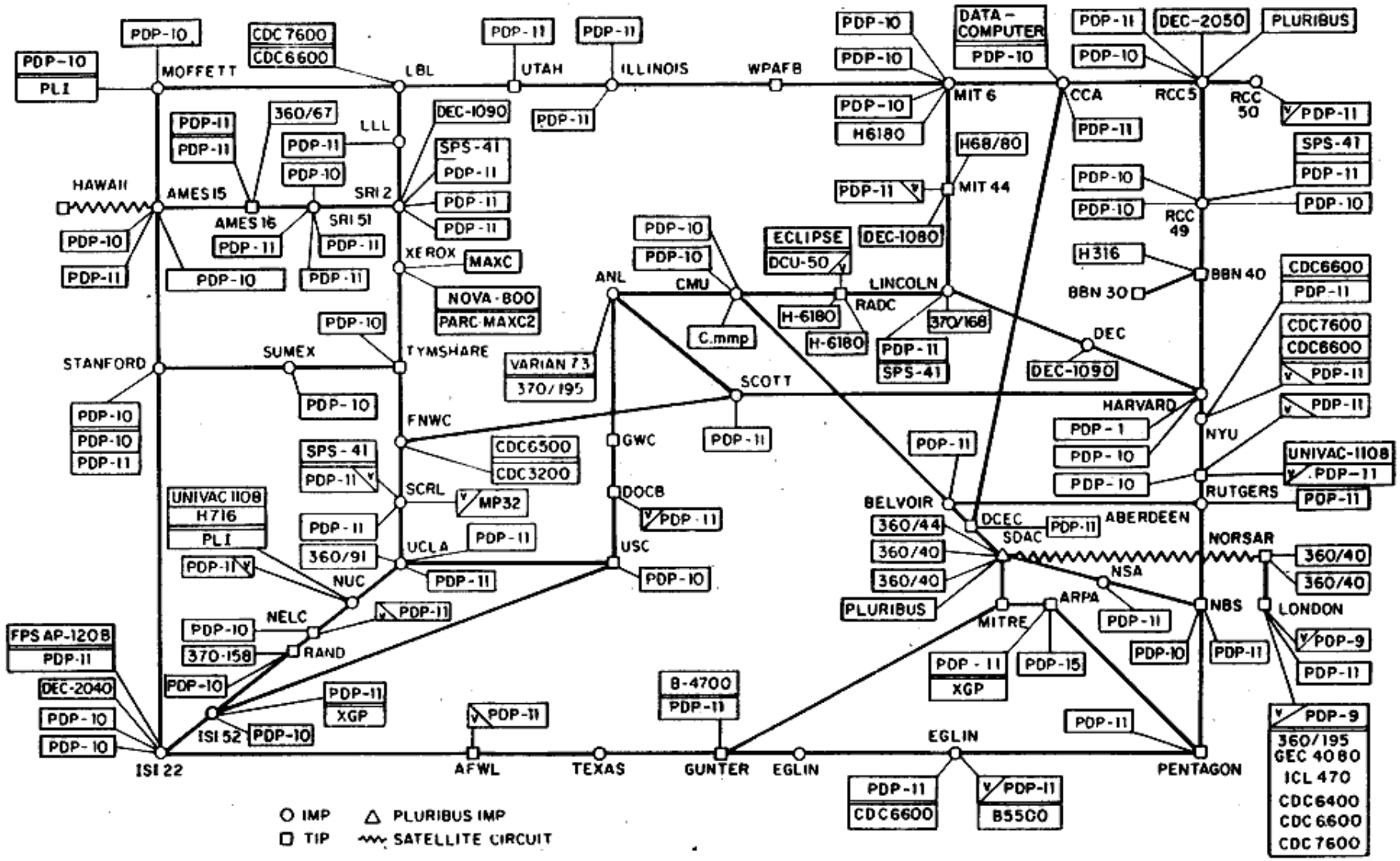
But they go about it in different ways…

They both eat the leaves…

Now to the technical reasons…



ARPANET LOGICAL MAP, MARCH 1977



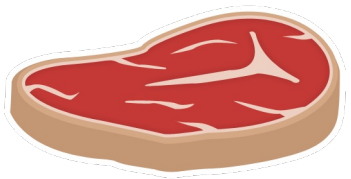
(PLEASE NOTE THAT WHILE THIS MAP SHOWS THE HOST POPULATION OF THE NETWORK ACCORDING TO THE BEST INFORMATION OBTAINABLE, NO CLAIM CAN BE MADE FOR ITS ACCURACY)

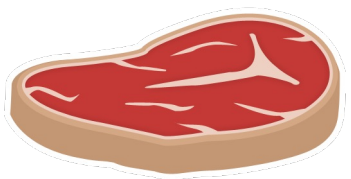
NAMES SHOWN ARE IMP NAMES, NOT (NECESSARILY) HOST NAMES

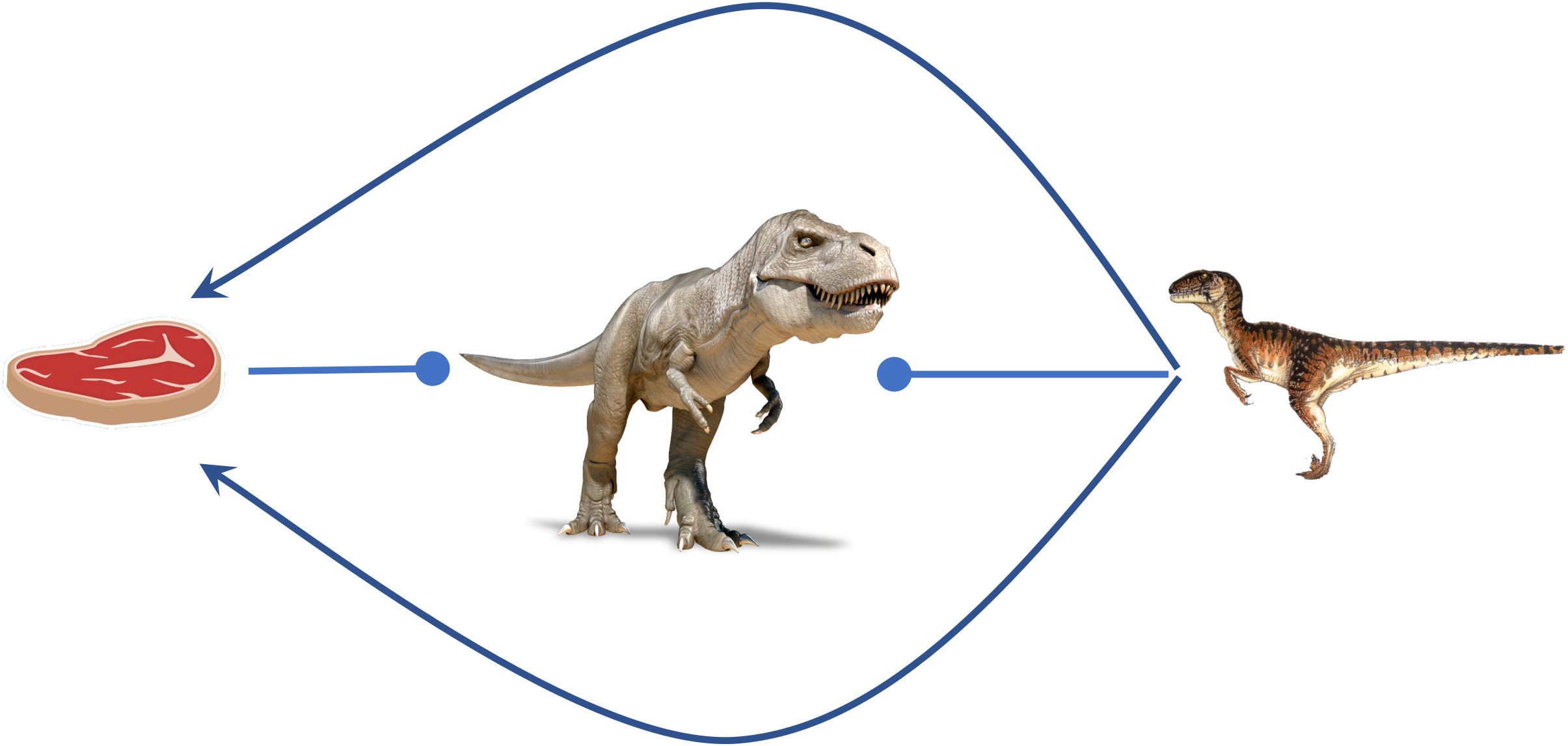
The goal was to exploit new computer technologies to meet the needs of military command and control against nuclear threats, achieve survivable control of US nuclear forces, and improve military tactical and management decision making.

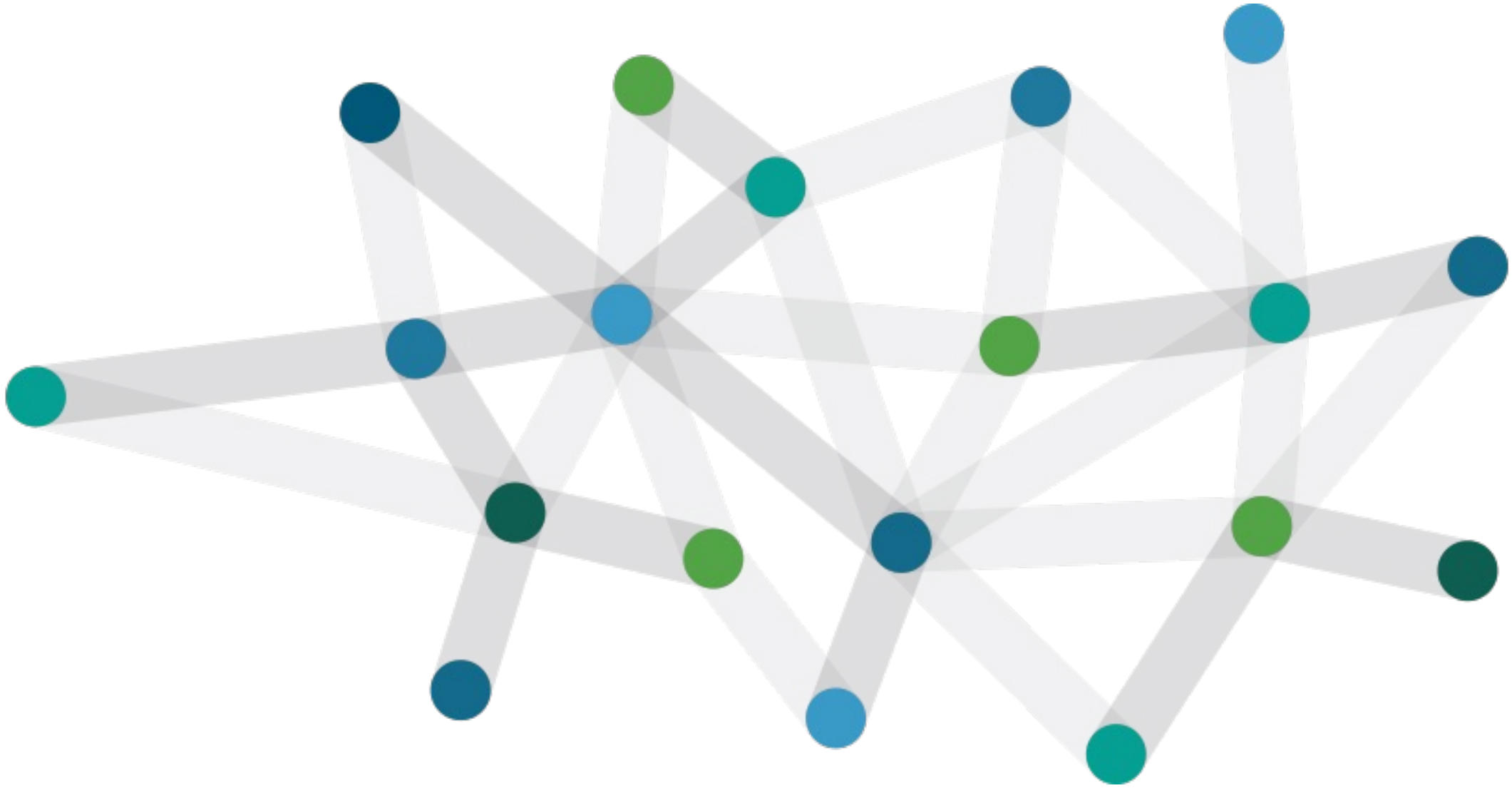
Stephen J. Lukasik

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

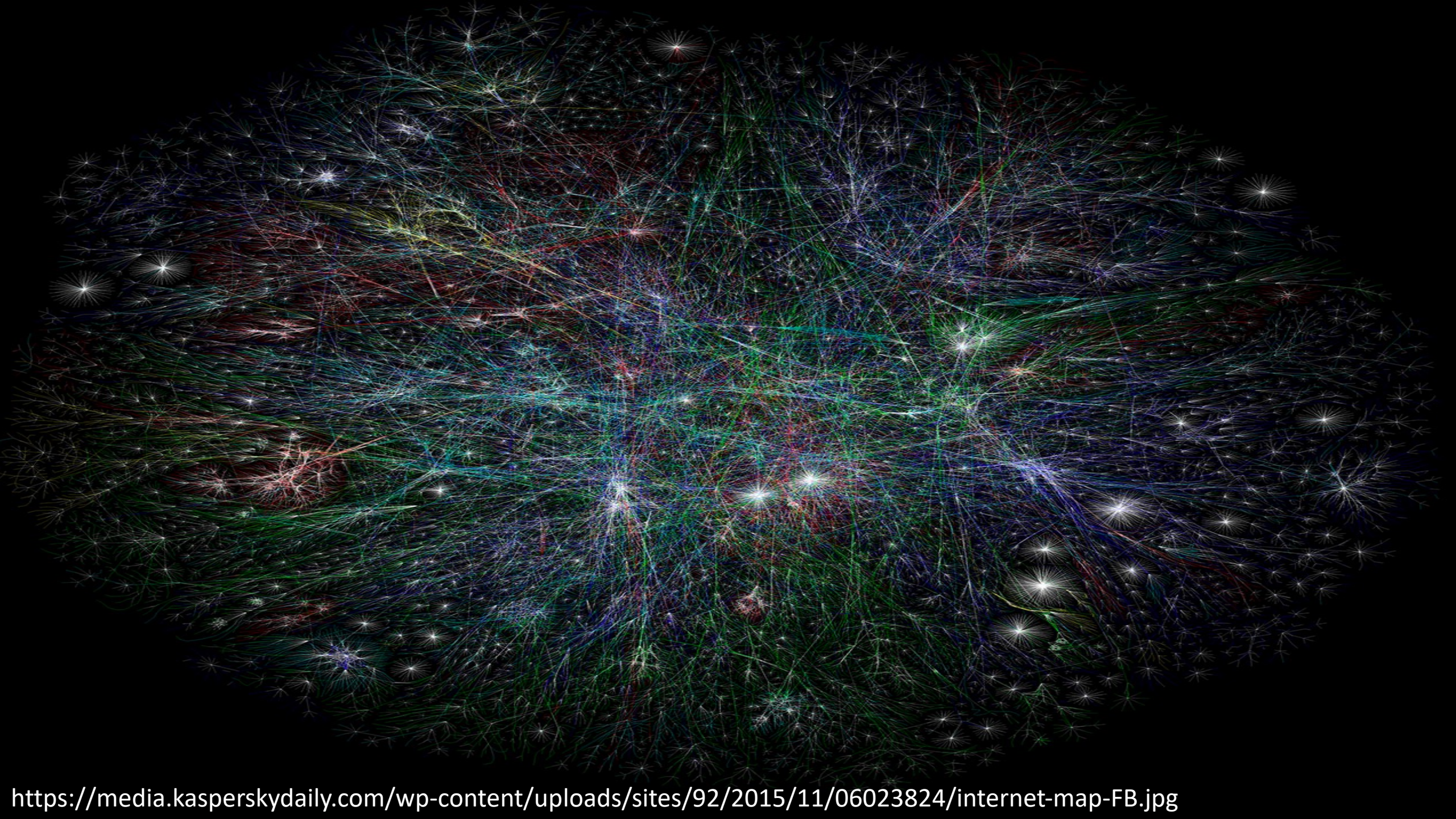




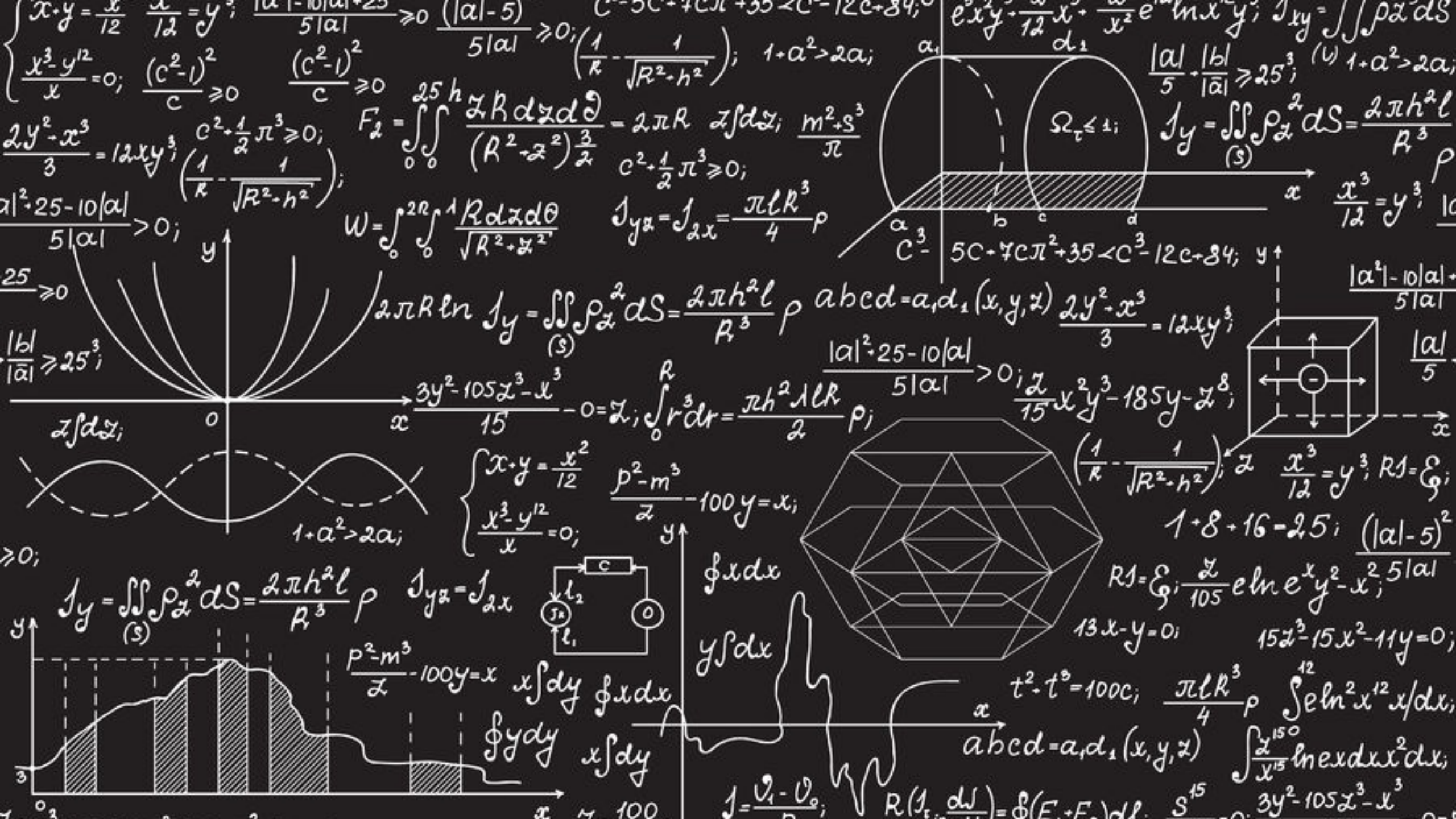


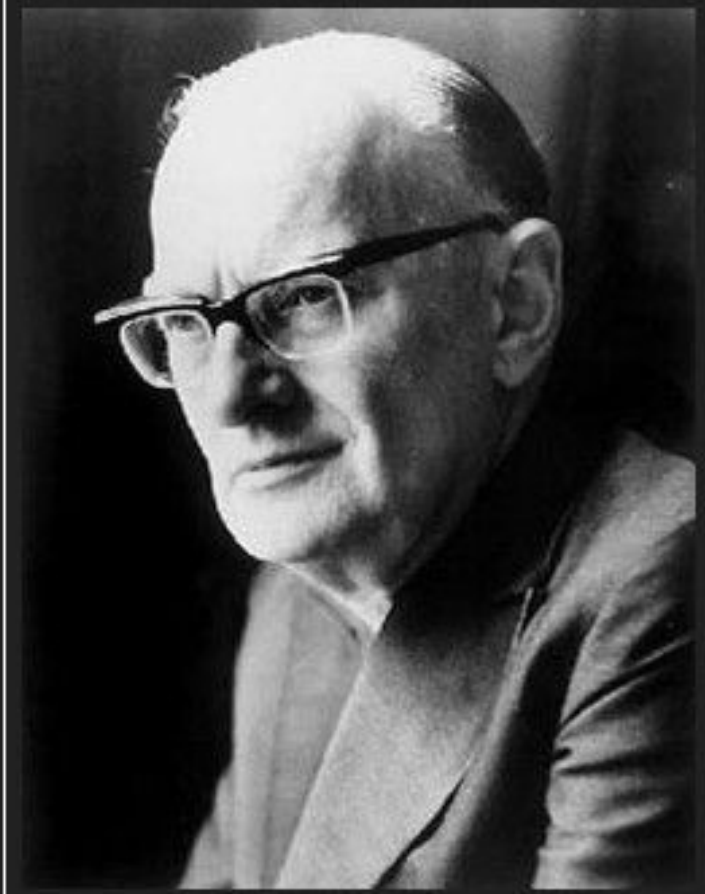


Autonomous systems, interconnecting using standardized protocols…



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


$\frac{x^3-y^{12}}{x}=0;\quad \frac{(c^2-1)^2}{c}\geqslant 0$
$F_z=\int_0^{25}\int_0^{h}\frac{z\,R\,dz\,d\vartheta}{(R^2+z^2)^{\frac{3}{2}}}=2\pi R\int z\,dz;\quad \frac{m^2+s^3}{\pi}$
$\frac{2y^2-x^3}{3}=12xy^3;\quad c^2+\frac{1}{2}\pi^3\geqslant 0;$
$\left(\frac{1}{R}-\frac{1}{\sqrt{R^2+h^2}}\right);$
$W=\int_0^{2R}\int_0^{1}\frac{R\,dz\,d\theta}{\sqrt{R^2+z^2}}$
$J_{yz}=J_{2x}=\frac{\pi l R^3}{4}\rho$
$\frac{|a|^2+25-10|a|}{5|a|}>0;$
$2\pi R\ln J_y=\iint_{(s)}\rho_z^2\,dS=\frac{2\pi h^2 l}{R^3}\rho$
$abcd=a_1d_1(x,y,z)$
$\frac{3y^2-105z^3-x^3}{15}-0=z;\quad \int_0^R r^3dr=\frac{\pi h^2 l l R}{2}\rho;$
$\frac{|a|^2+25-10|a|}{5|a|}>0;\quad \frac{z}{15}x^2y^3-185y-z^8;$
$\begin{cases}x+y=\frac{x^2}{12}\\ \frac{x^3-y^{12}}{x}=0;\end{cases}\quad \frac{p^2-m^3}{z}-100y=x;$
$J_y=\iint_{(s)}\rho_z^2\,dS=\frac{2\pi h^2 l}{R^3}\rho\quad J_{yz}=J_{2x}$
$\frac{p^2-m^3}{z}-100y=x\quad x\int dy\quad \oint x\,dx$
$\oint y\,dy\quad x\int dy$
$\oint x\,dx$
$y\int dx$
$abcd=a_1d_1(x,y,z)$
$J=\frac{U_1-U_2}{R};\quad R\left(I_2\frac{dJ}{dt}\right)=\oint(E_1+E_2)dl;$
$\frac{x^3}{12}=y^3;\quad 1+8+16-25;\quad \frac{(|a|-5)^2}{5|a|}$
$R1=\mathcal{E};\quad \frac{z}{105}e\ln e^x y^2-x^2;$
$13x-y=0;\quad 15z^3-15x^2-11y=0;$
$t^2+t^3=100c;\quad \frac{\pi l R^3}{4}\rho\quad \int e\ln^2 x^{12}\,x\,dx;$
$\int\frac{z^{150}}{x^{15}}\ln ex\,dx\,x^2dx;$
$\frac{3y^2-105z^3-x^3}{15}$



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

(Arthur C. Clarke)

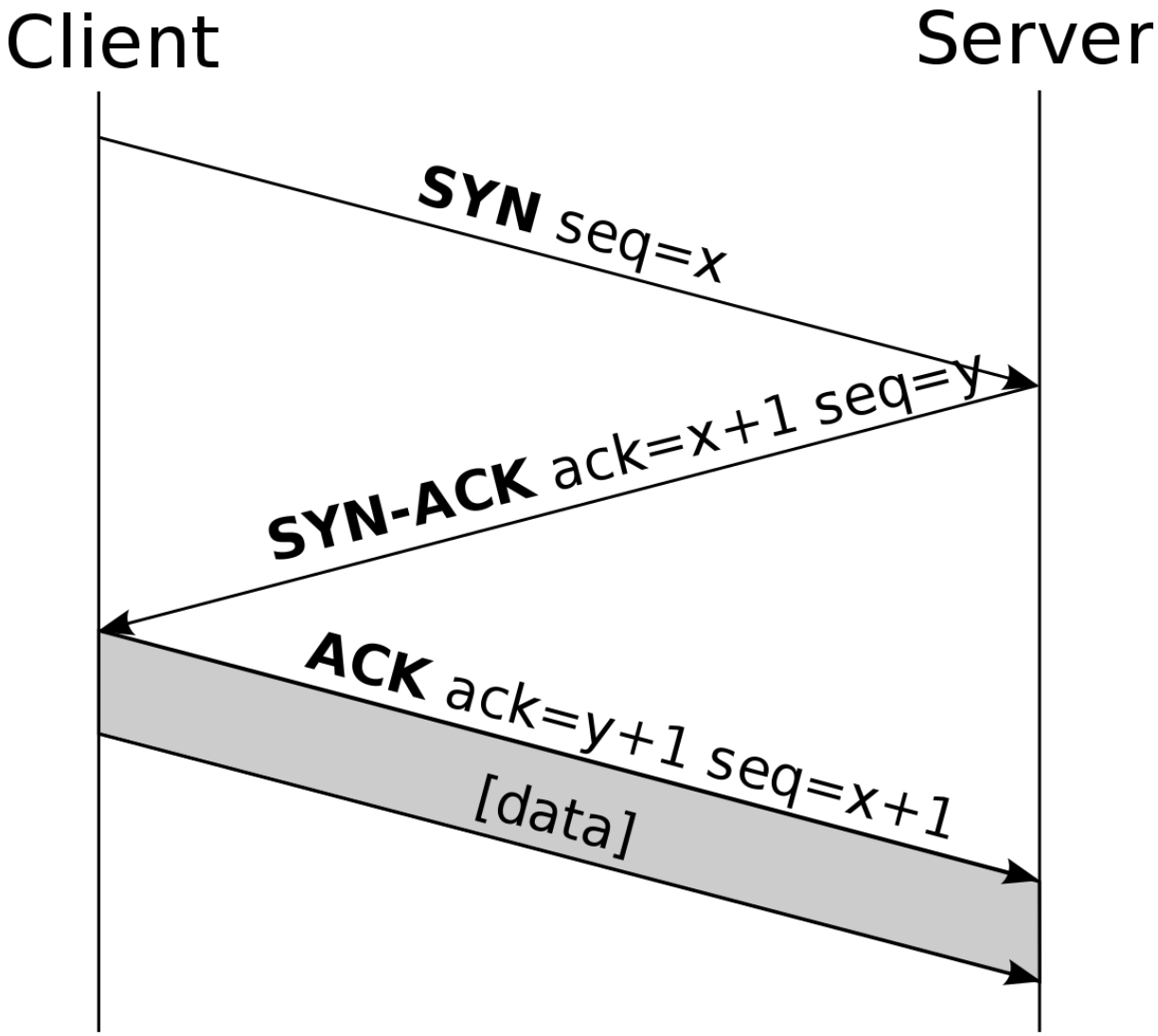
izquotes.com

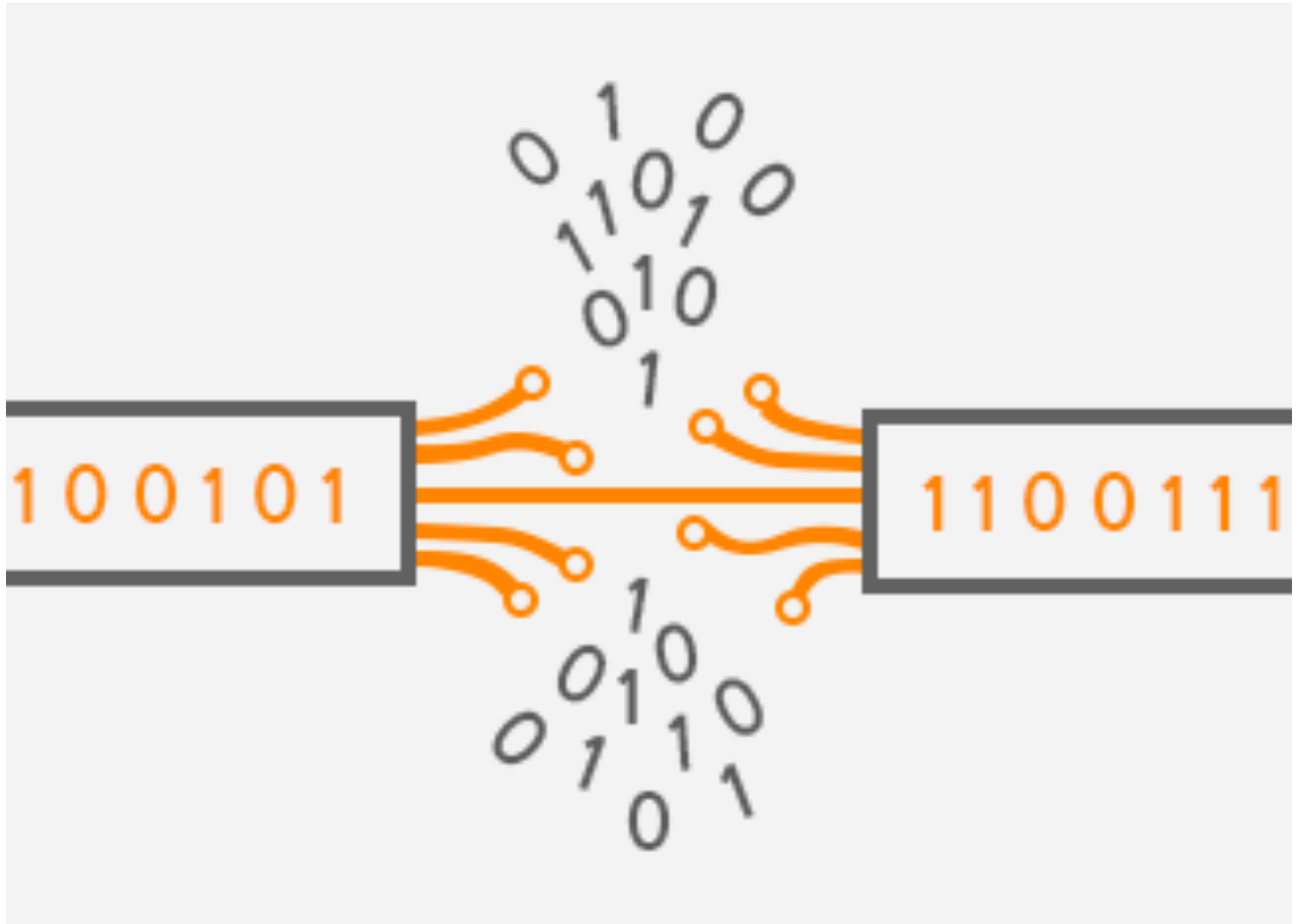
Transmission Control Protocol (TCP)

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

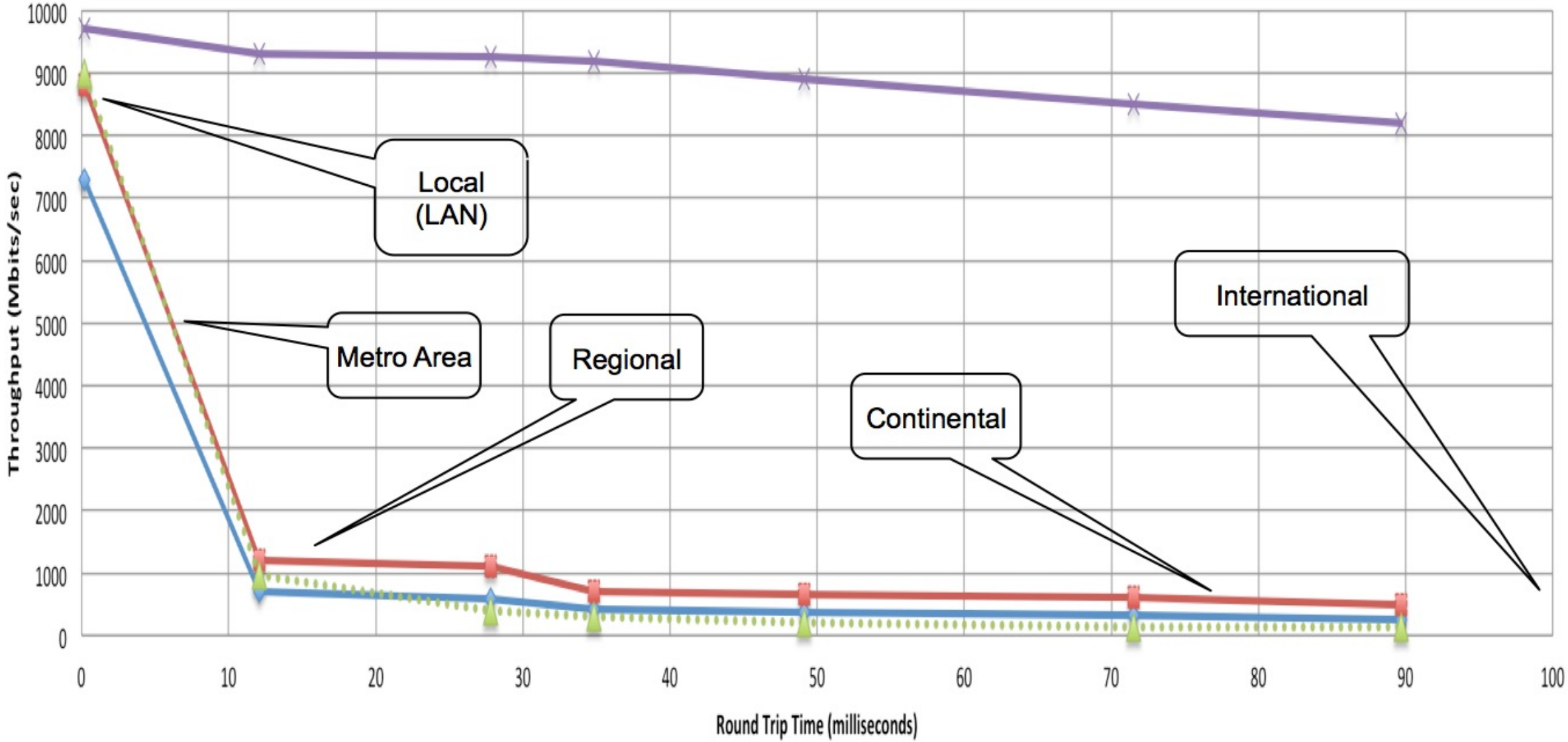
- Latency (or RTT -Round Trip Time)
- Buffer/window size.
- Packet loss

All three are interrelated.




1 0 0 1 0 1
1 1 0 0 1 1 1

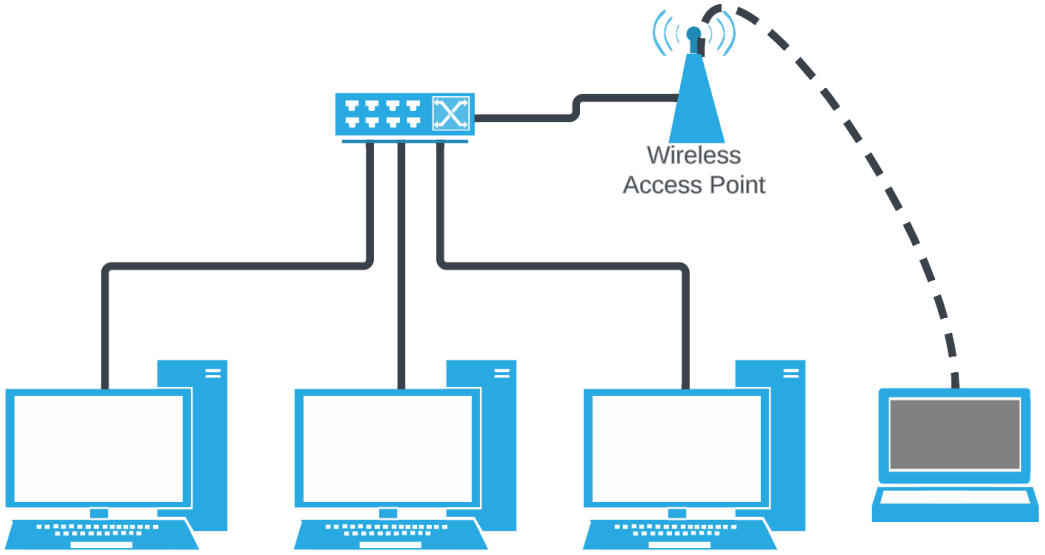
Throughput vs. increasing latency on a 10Gb/s link with *0.0046%* packet loss



Measured (TCP Reno) **Measured (HTCP)** **Theoretical (TCP Reno)** **Measured (no loss)**

WAN vs LAN vs MAN

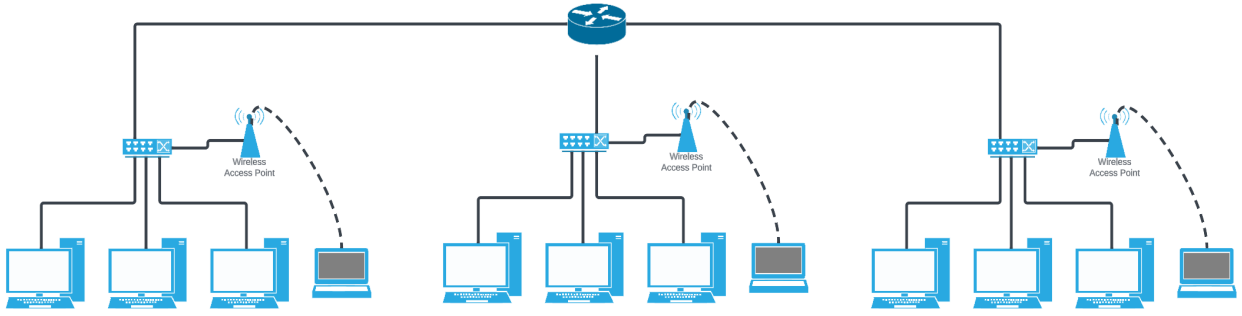
LAN vs MAN vs WAN



- 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



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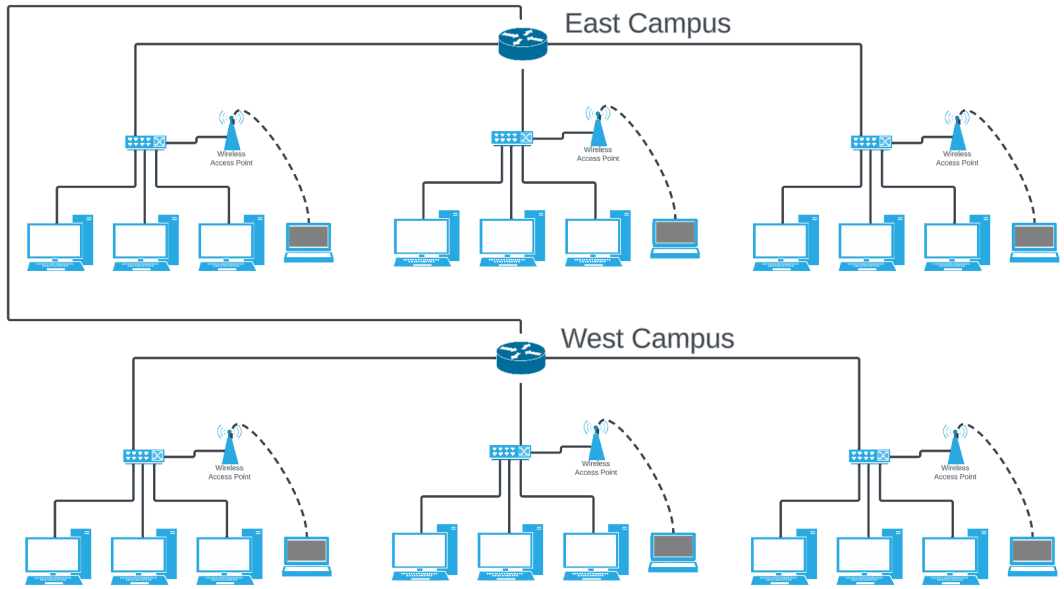
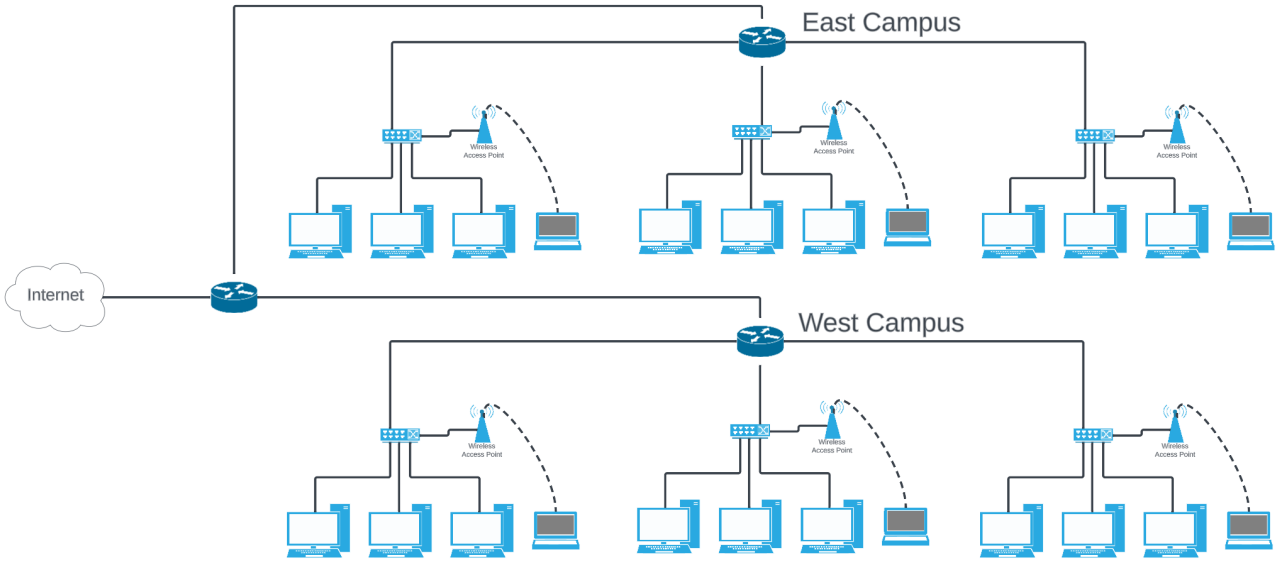
LAN vs MAN vs WAN



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

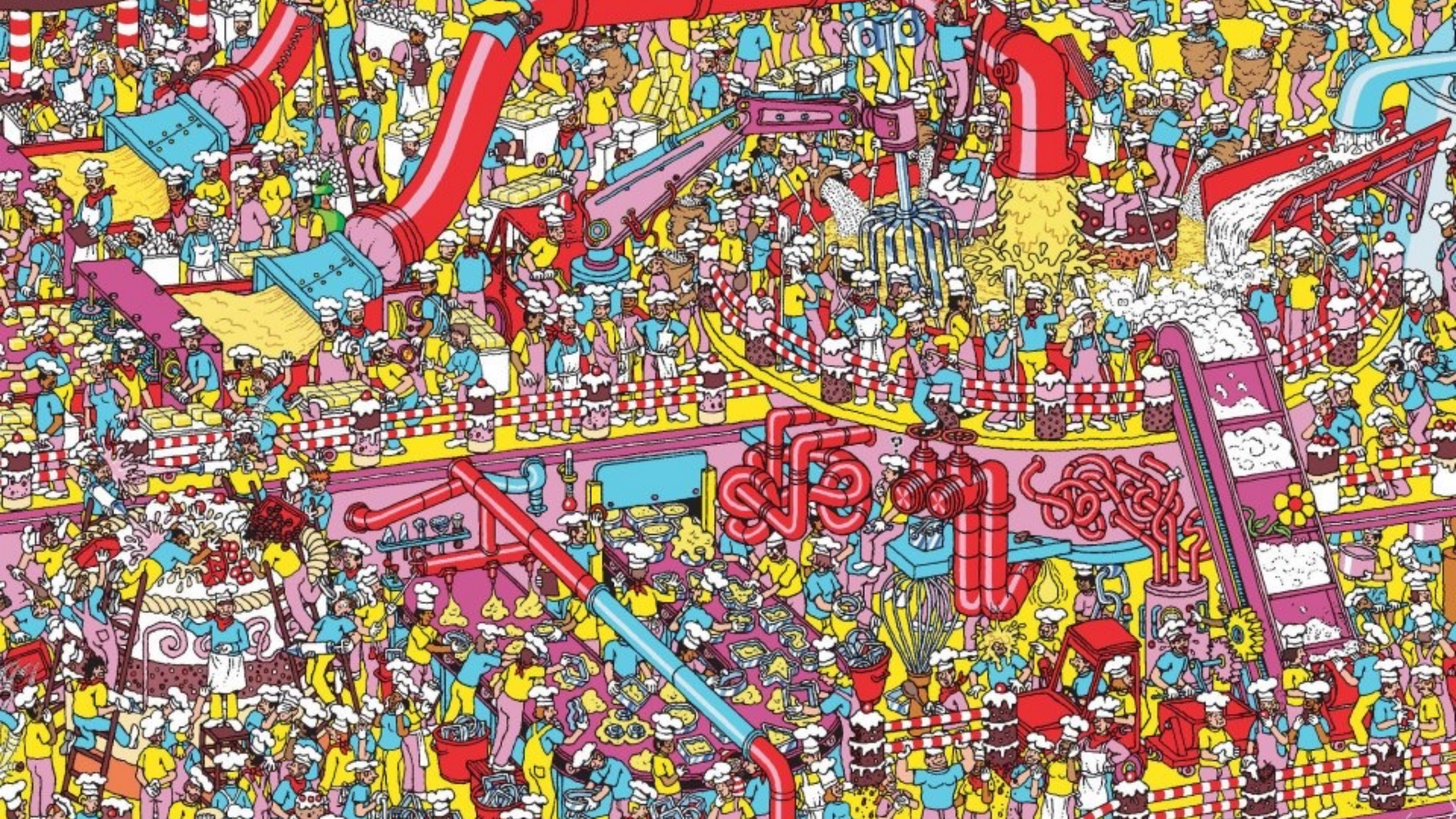
* As with all networking the “it depends” rule applies

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



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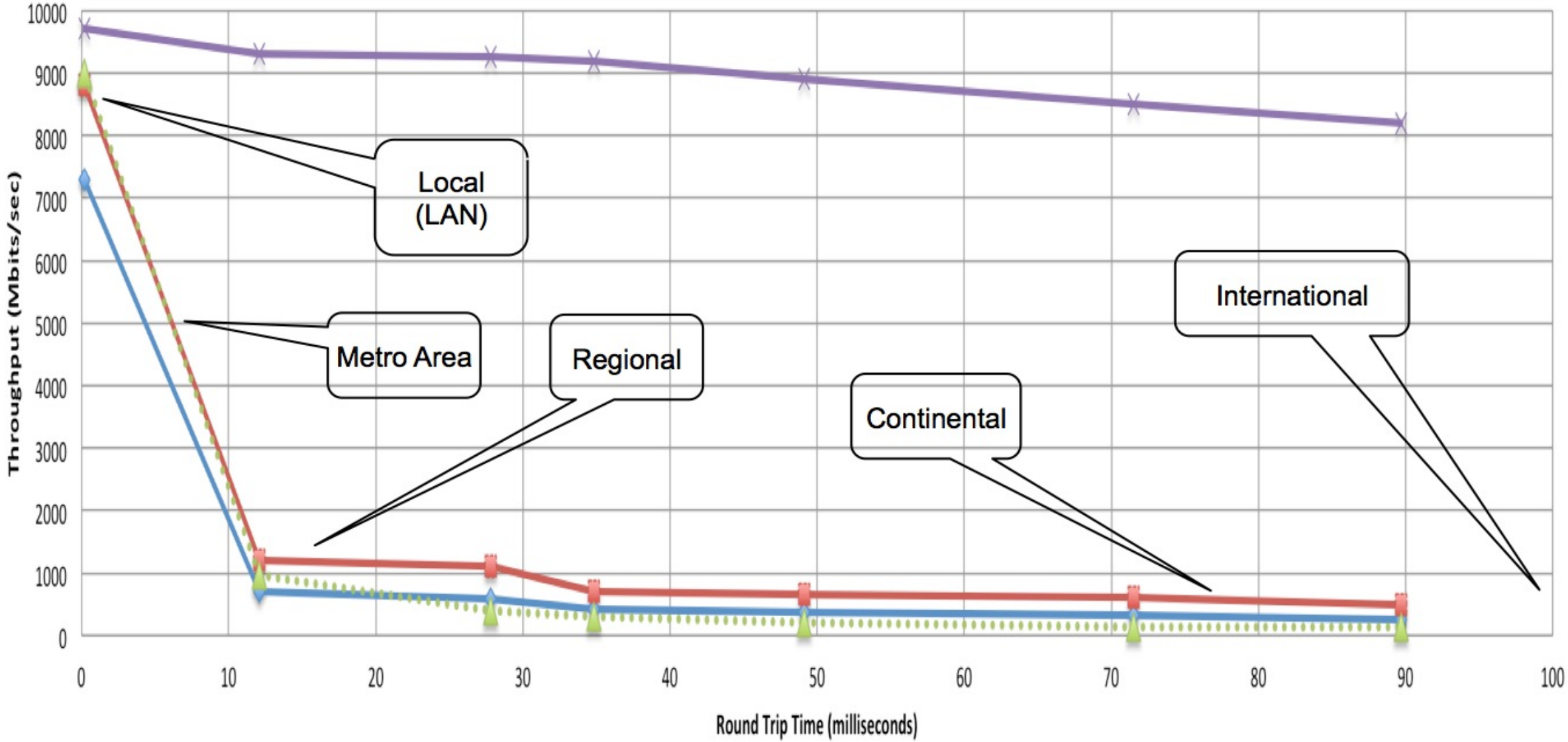


Measured (TCP Reno) **Measured (HTCP)** **Theoretical (TCP Reno)** **Measured (no loss)**

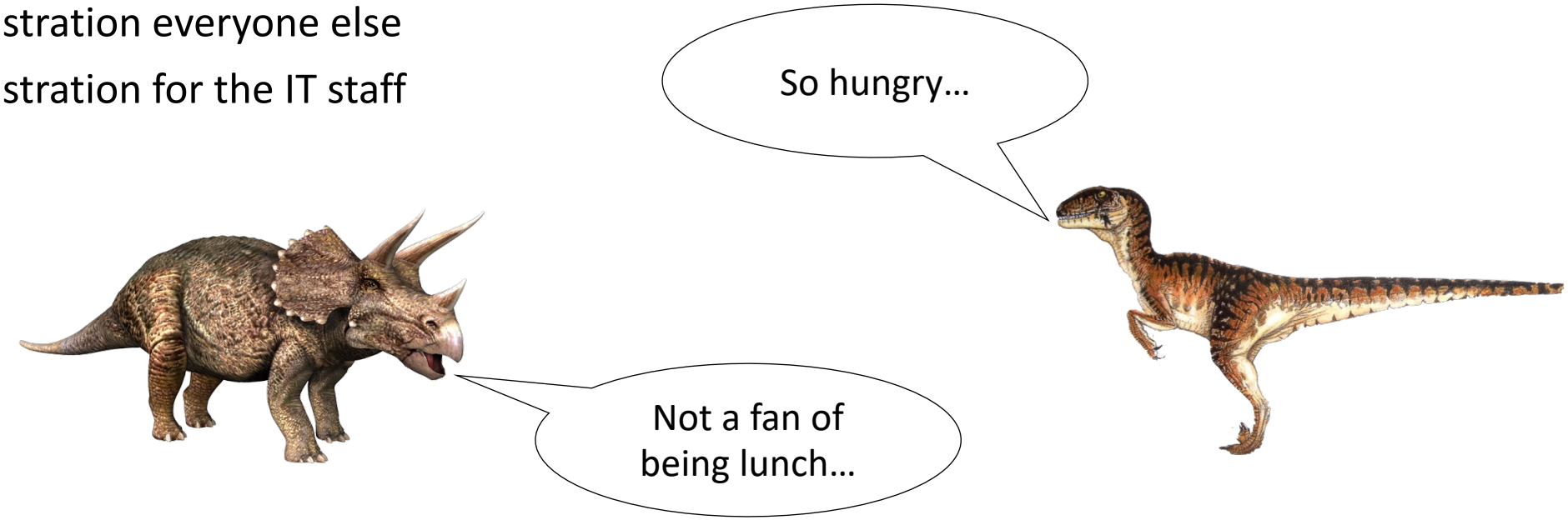
So, what happens when research traffic hits normal networks?


STOP
gifs.com

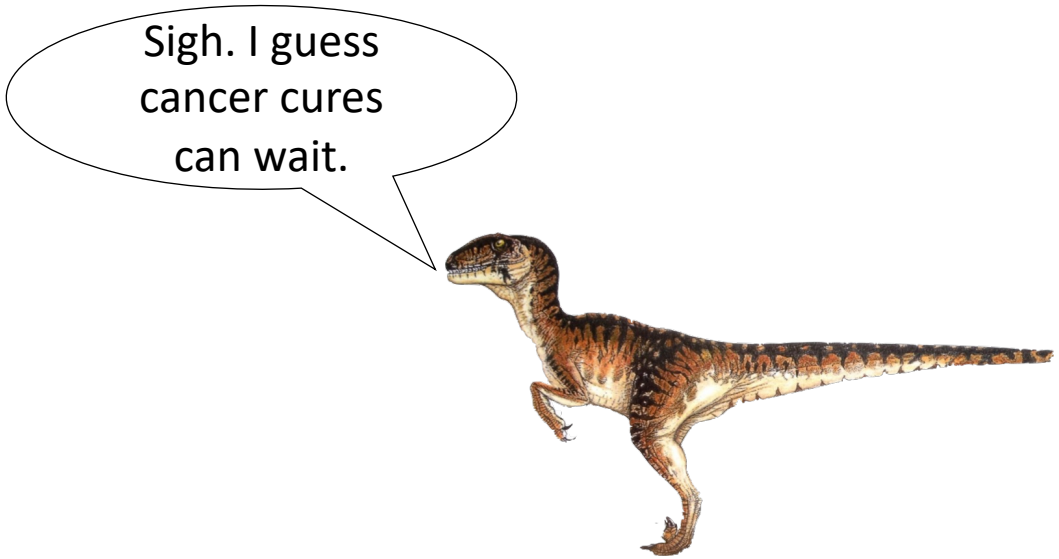
When Data Intensive Science Meets Commercial Commodity Networks

This can result in adverse consequences:

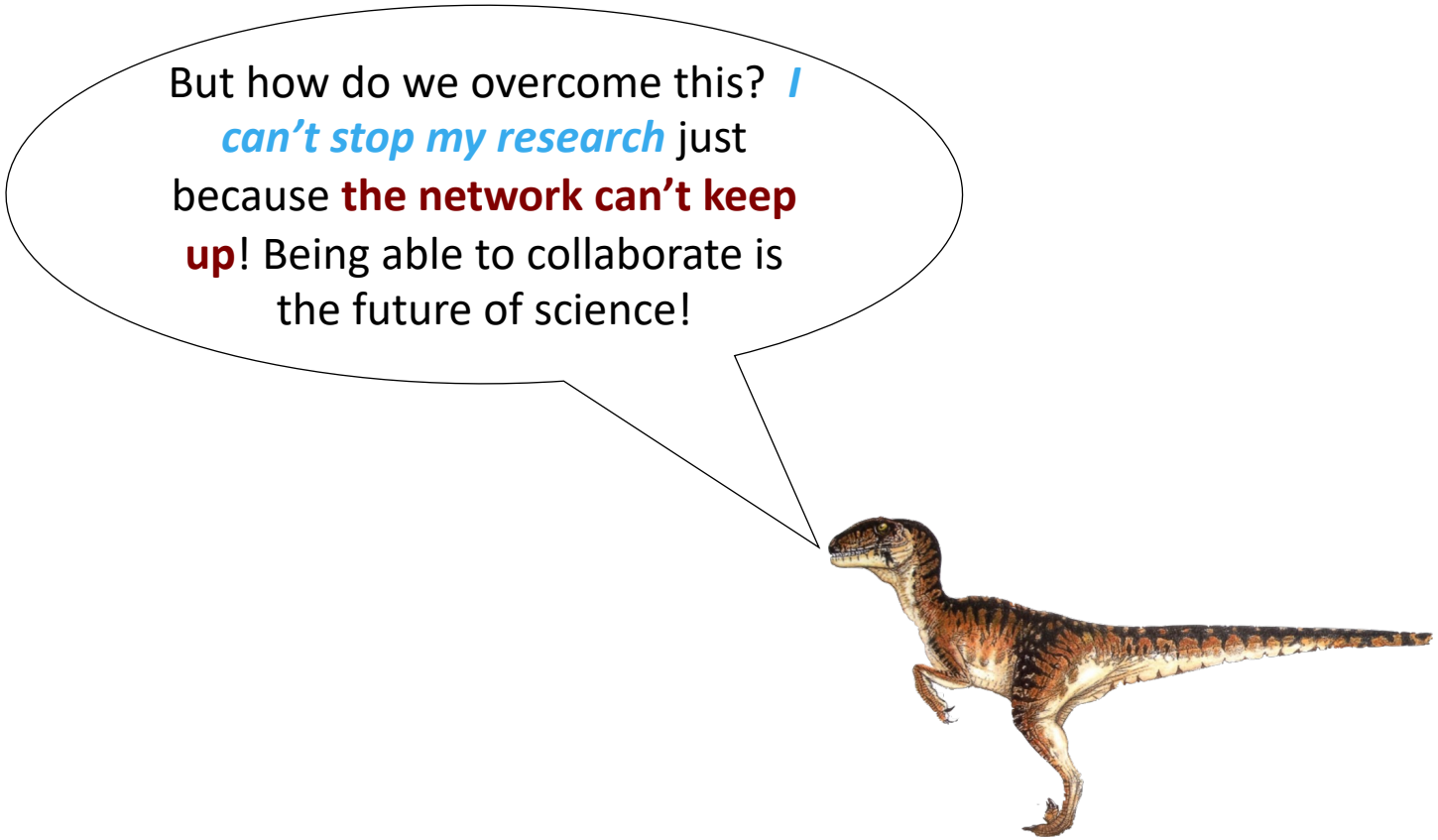
- Performance issues for the researcher
- Performance issues for everyone else
- Frustration for the researcher
- Frustration everyone else
- Frustration for the IT staff



When Data Intensive Science Meets Commercial Commodity Networks

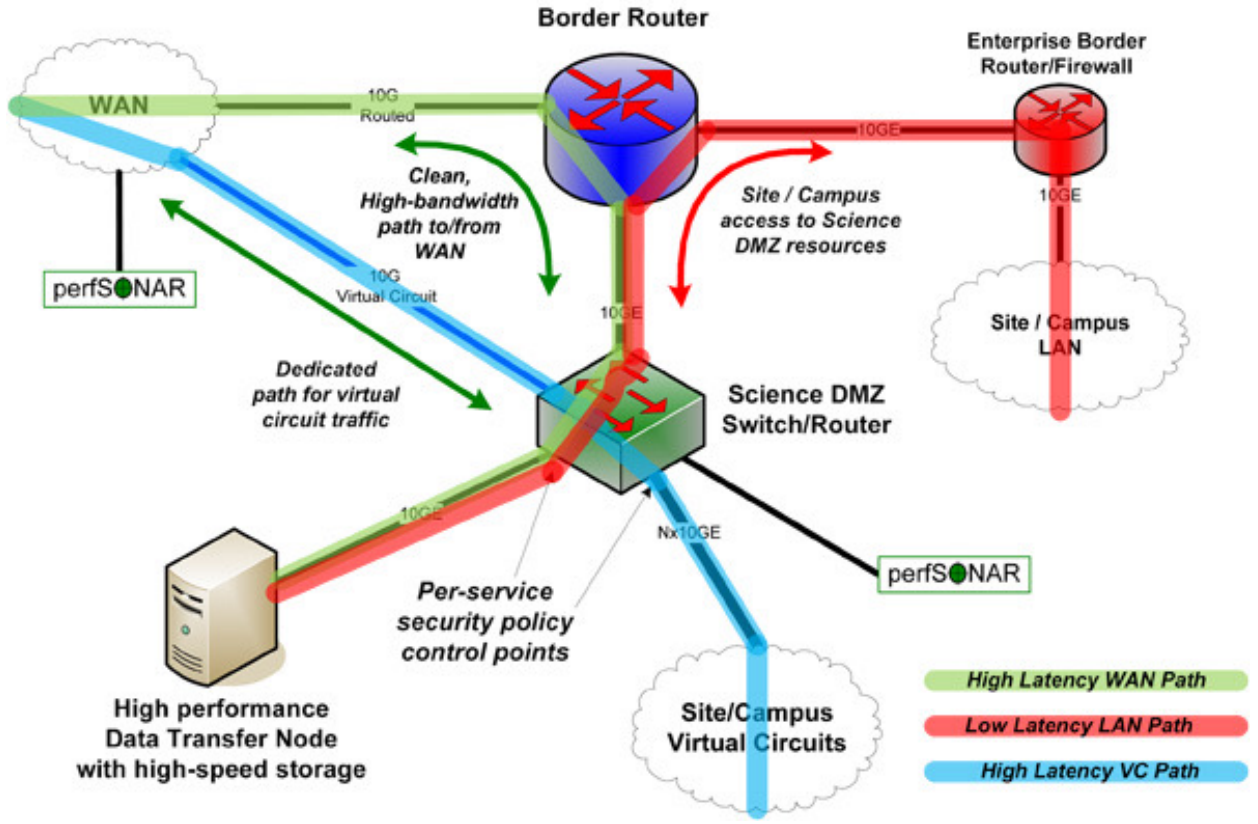


When Data Intensive Science Meets Commercial Commodity Networks



Specialty networks to the rescue!

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

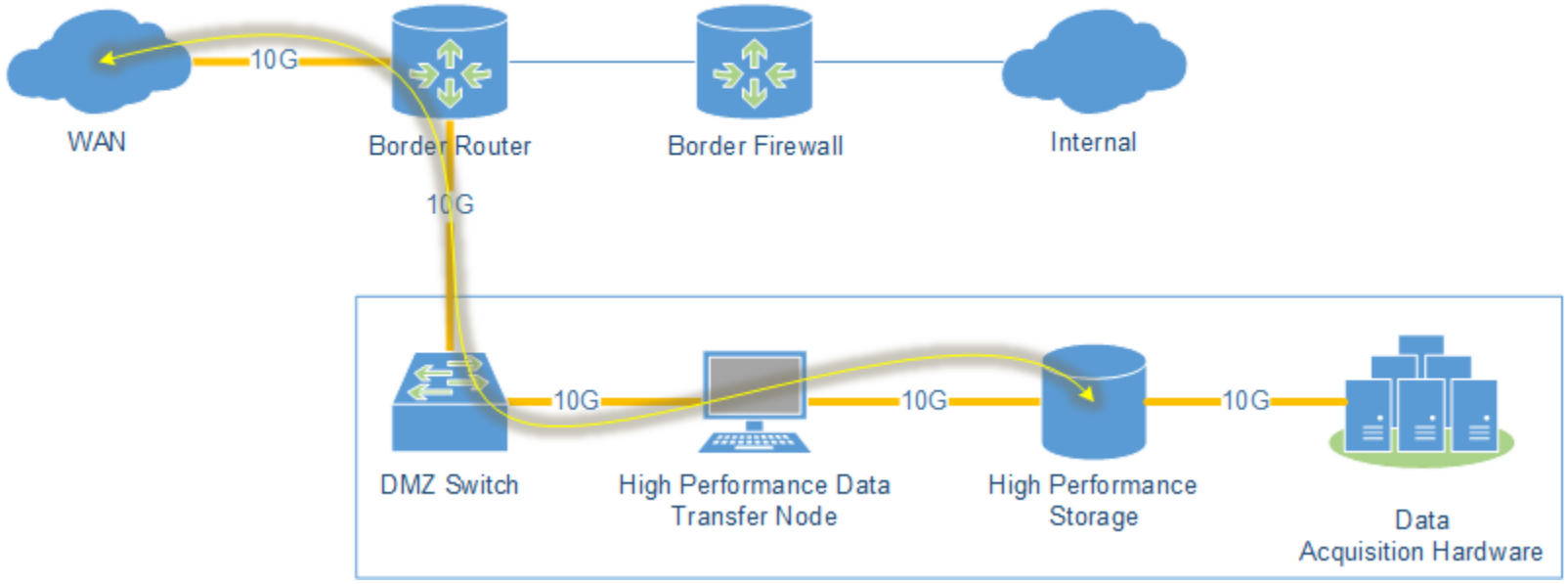


Parts of the puzzle…

- 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)

Data Transfer Nodes (DTN)

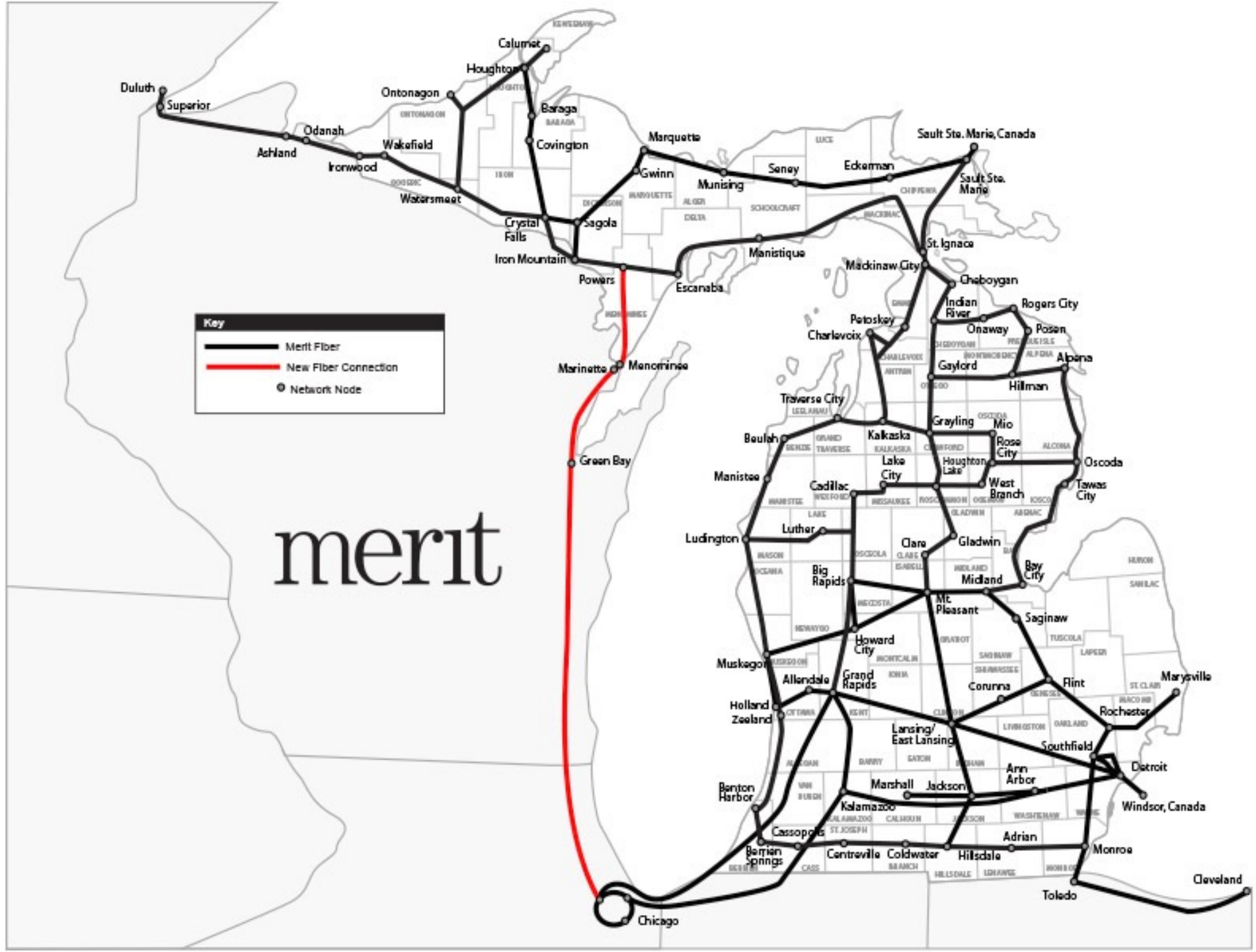
- Simply put, a DTN is a server that is specially designed to move data from disk to a network at speed.



State/regional networks

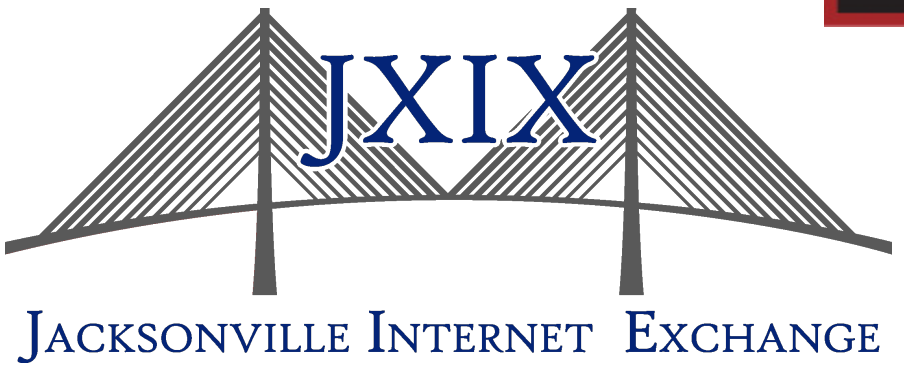
aka “your ISP”

Relationships make the packets flow…


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

Exchanges and PoPs

REANNZ



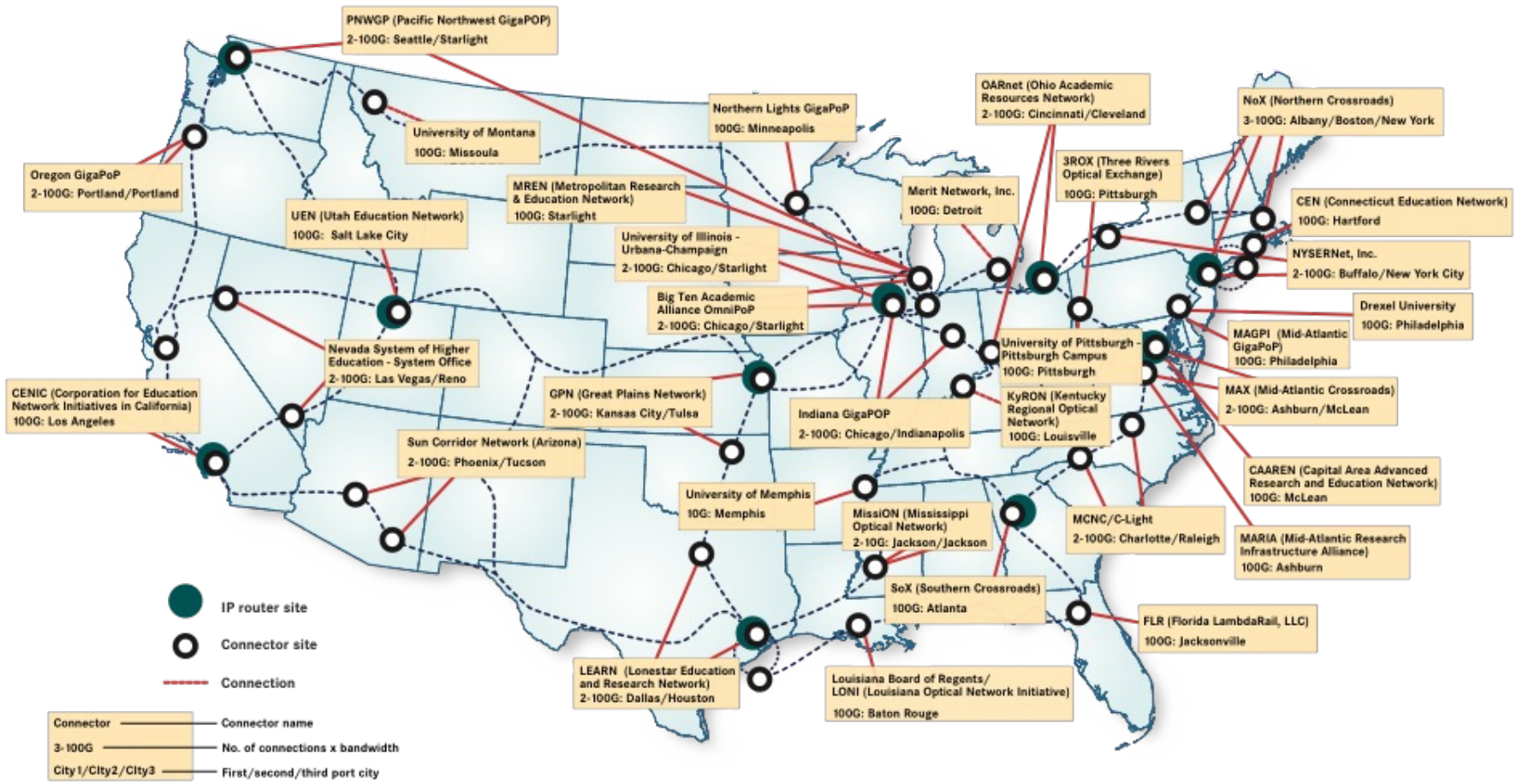
NNENIX
NORTHERN NEW ENGLAND
NEUTRAL INTERNET EXCHANGE

National Networks (US)

ESnet
ENERGY SCIENCES NETWORK

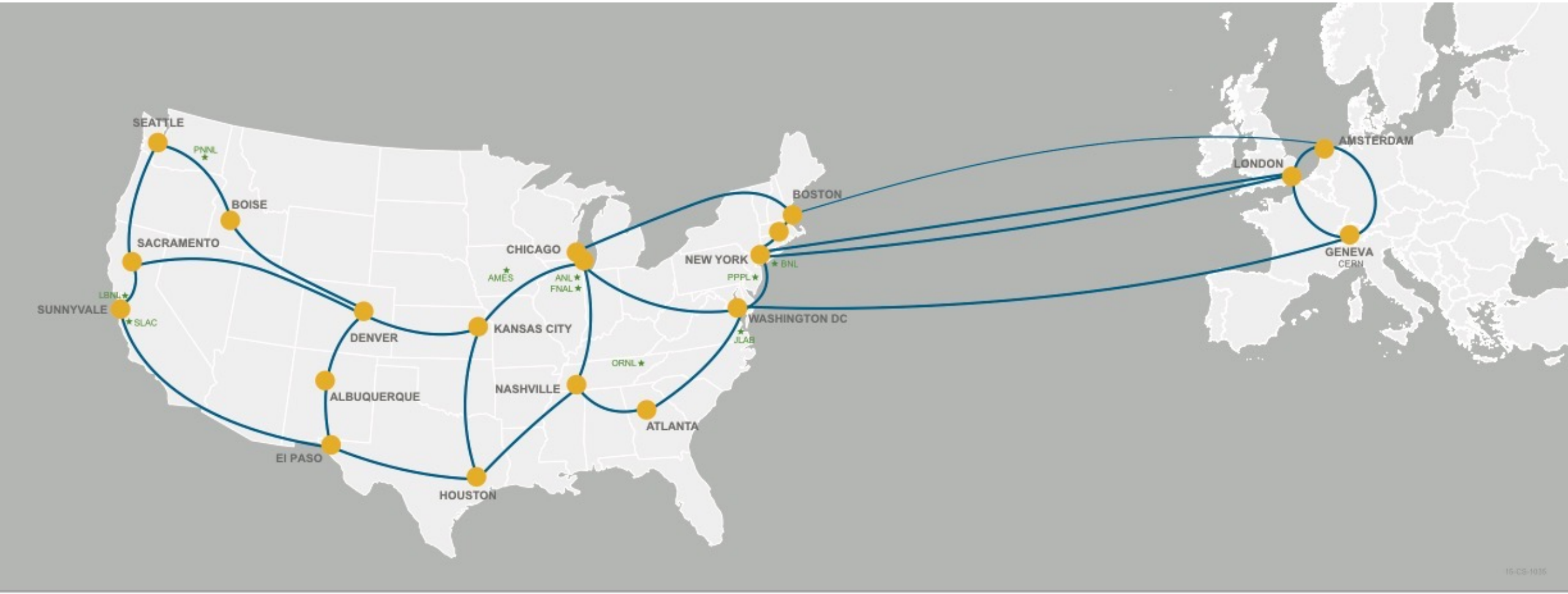
INTERNET2 NETWORK CONNECTIONS

WWW.INTERNET2.EDU/CONNECTORS – MARCH OF 2017



NETWORK PARTNERS

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

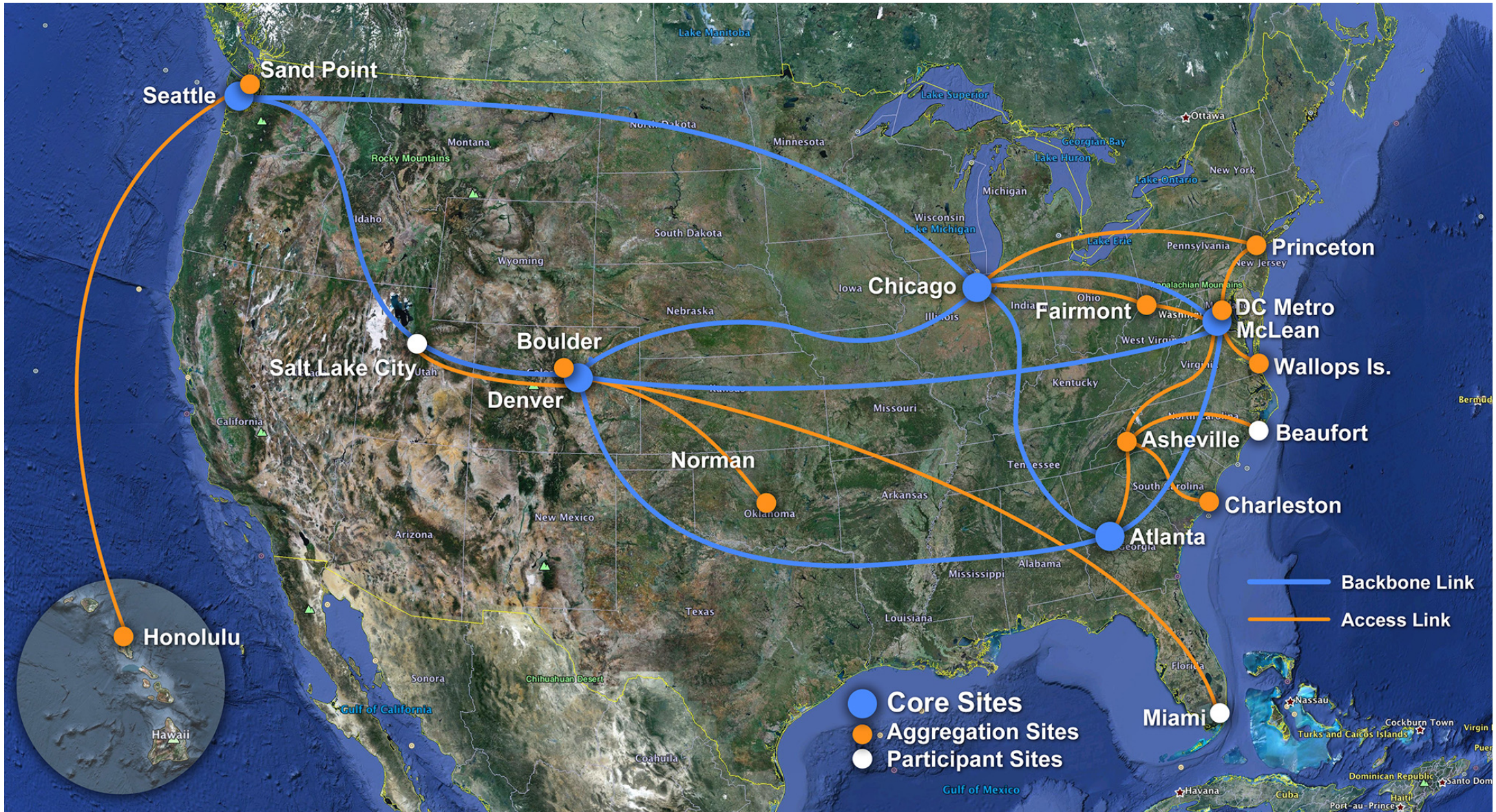


ESnet

ENERGY SCIENCES NETWORK

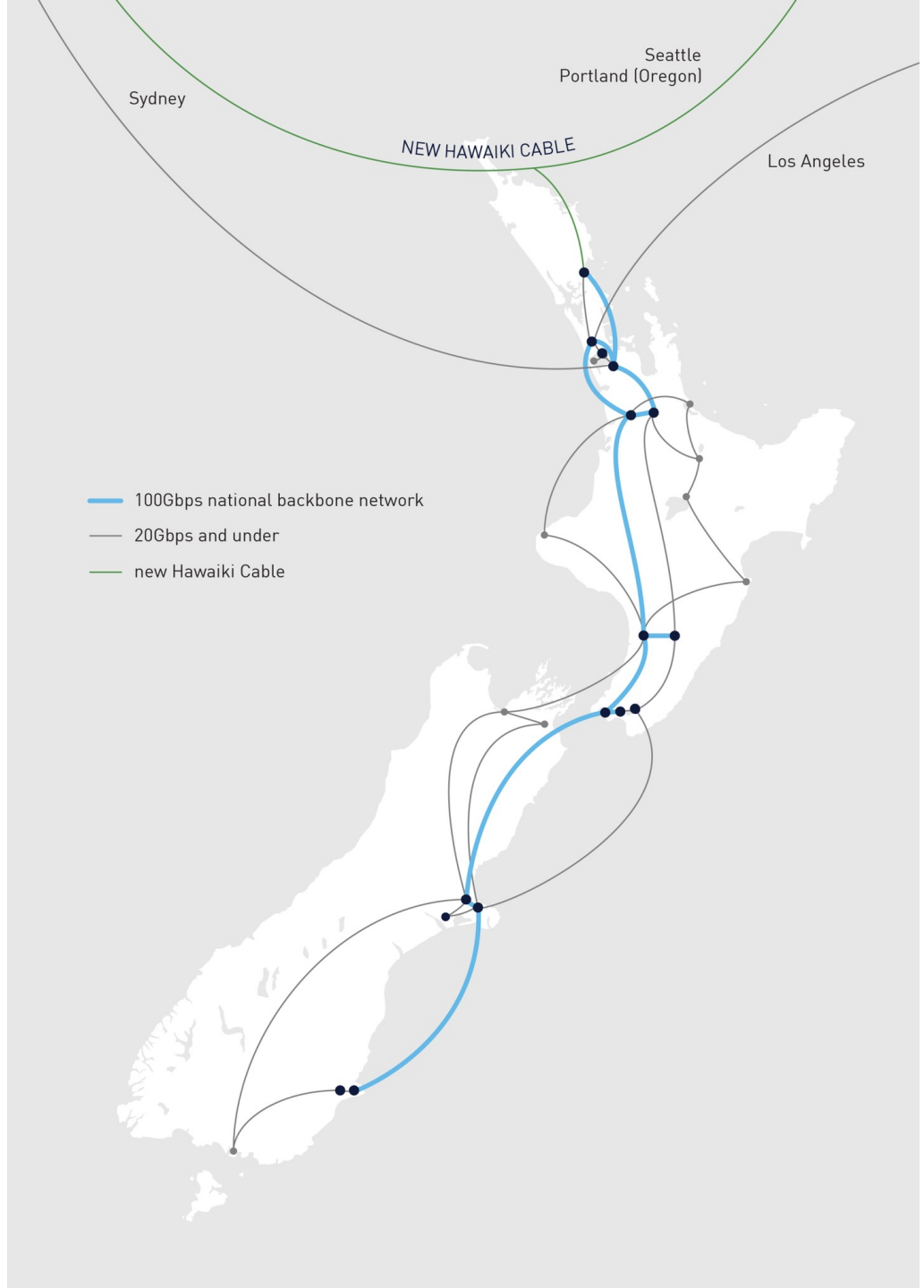
★ Department of Energy Office of Science National Labs

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)



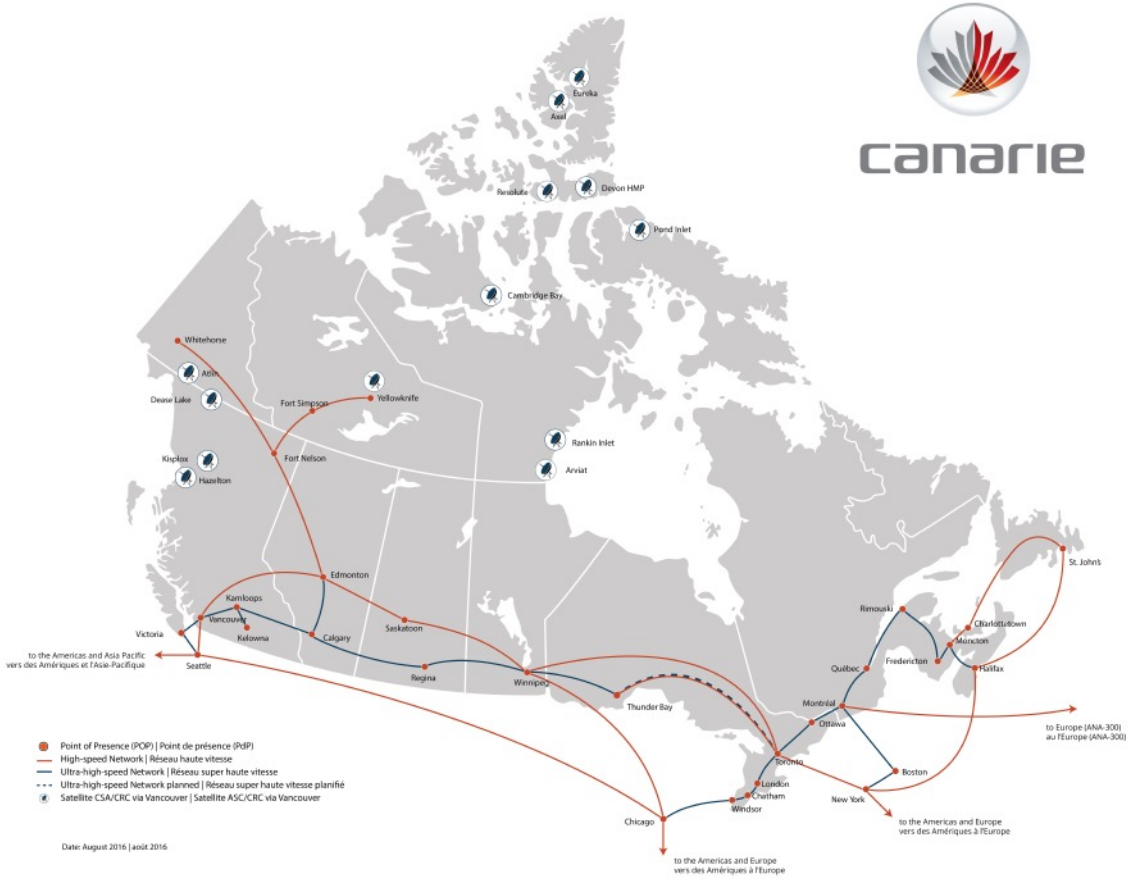
n-wave

NOAA ENTERPRISE NETWORK

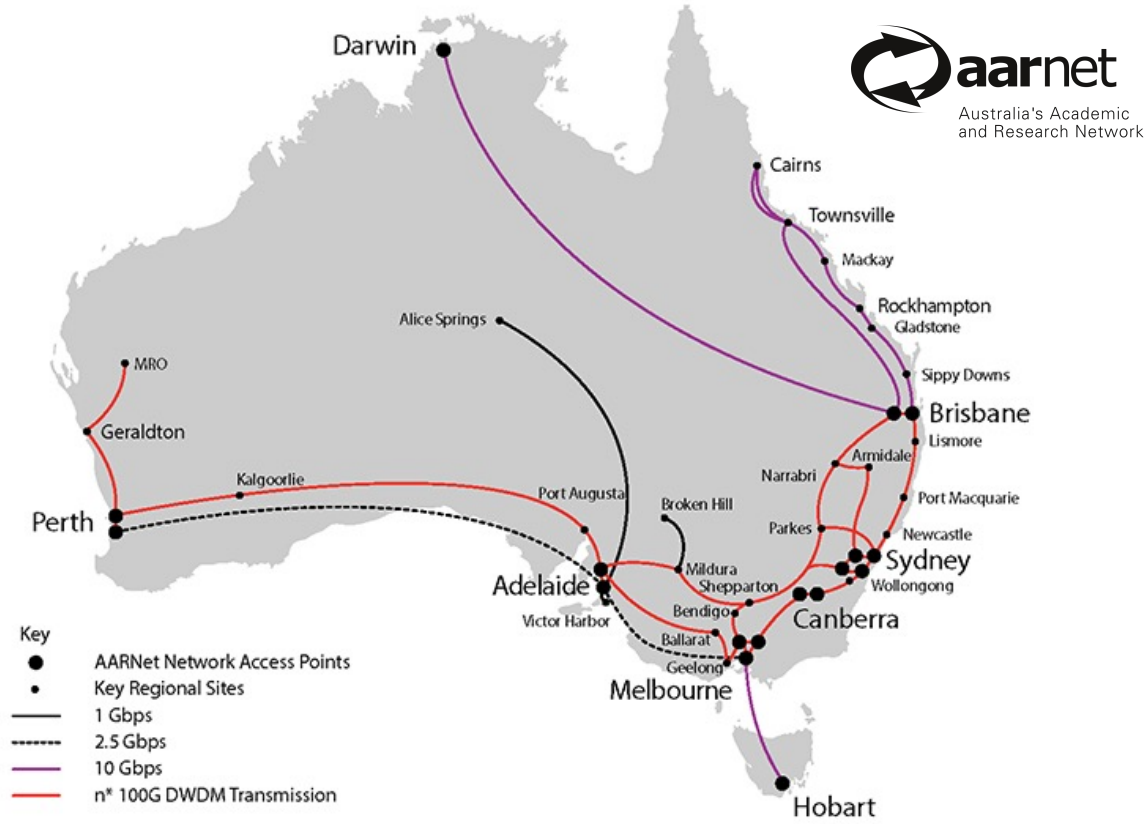

Seattle
Portland (Oregon)
Sydney
NEW HAWAIKI CABLE
Los Angeles
100Gbps national backbone network
20Gbps and under
new Hawaiki Cable

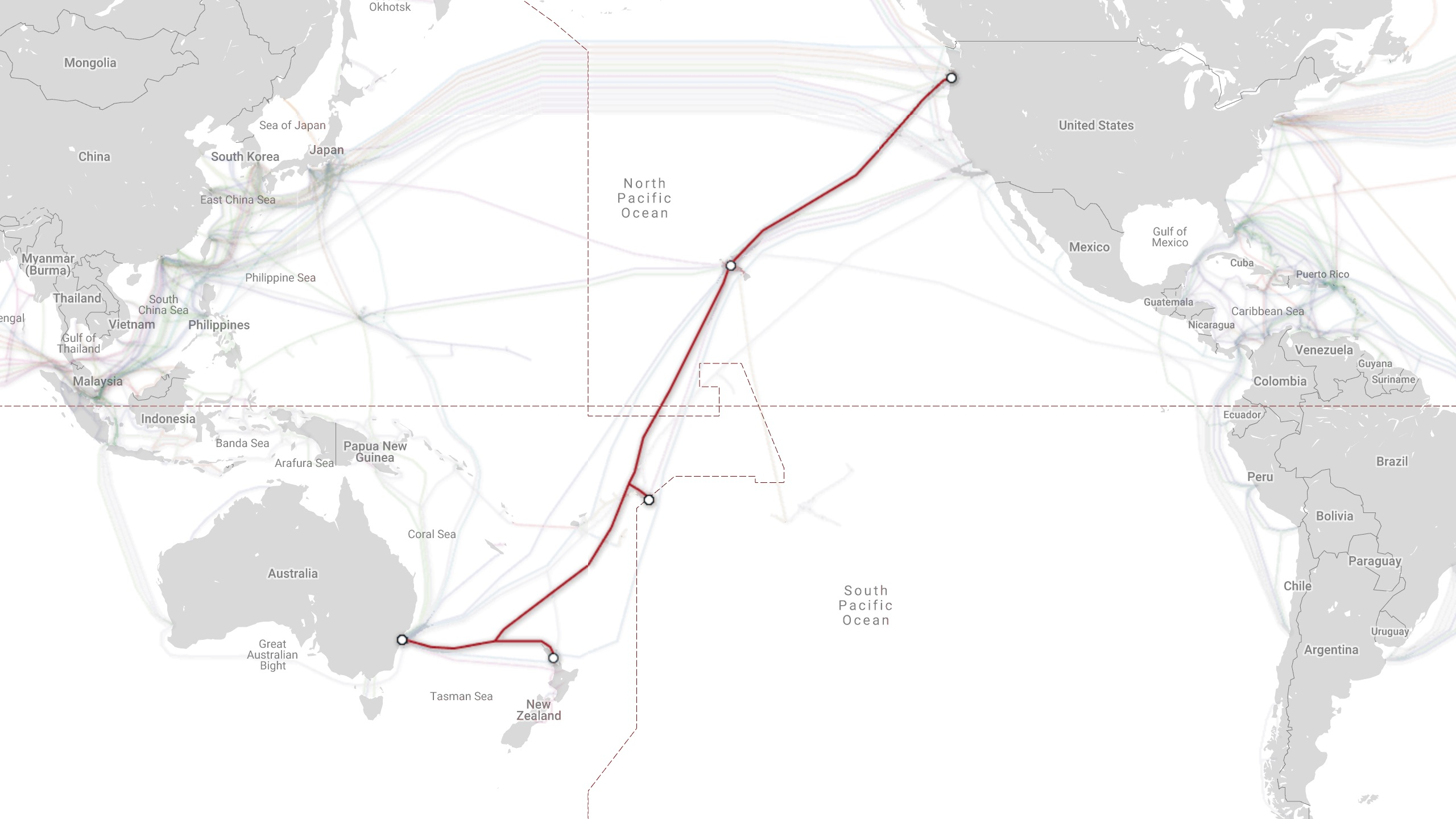
National Networks

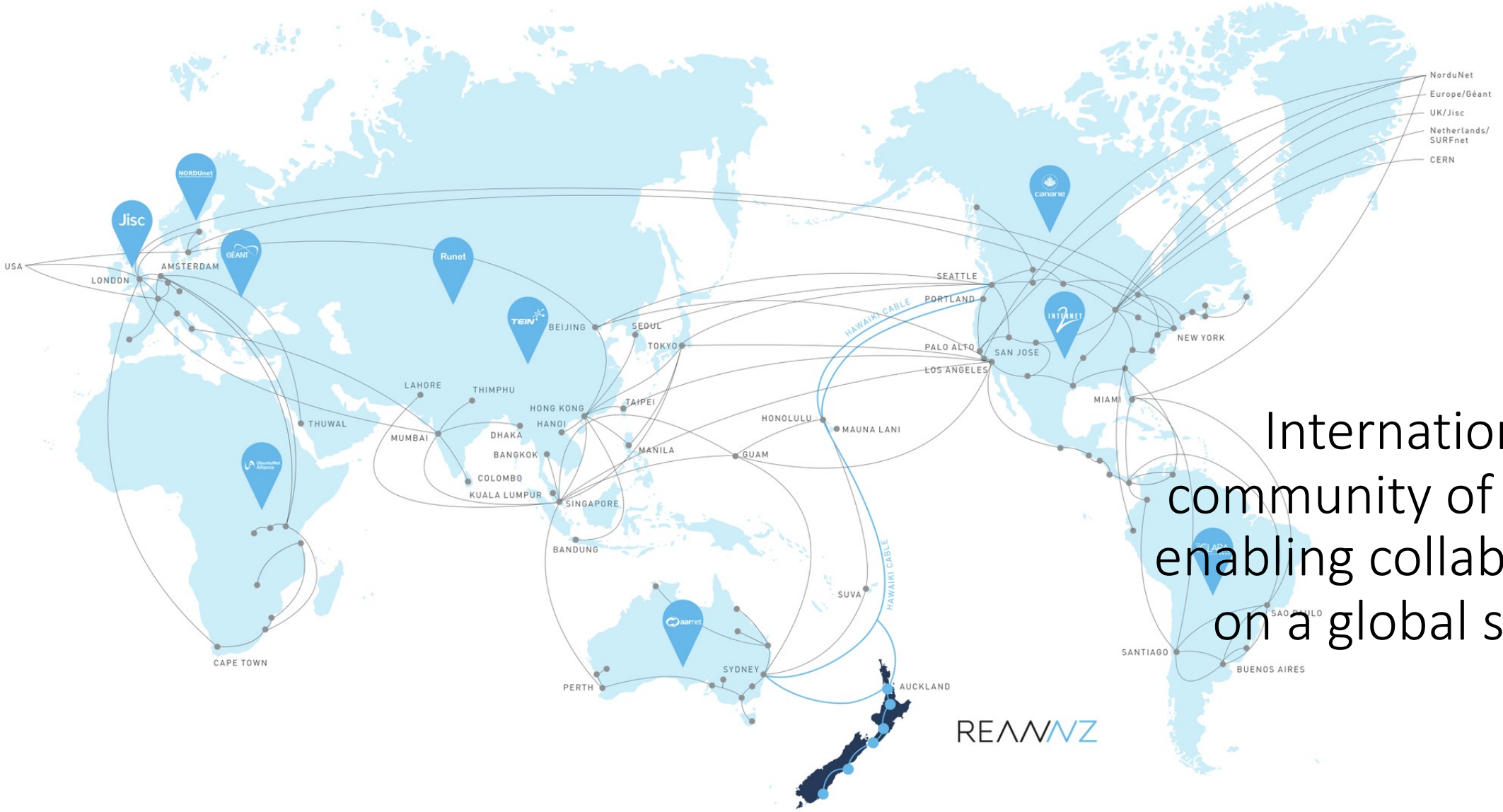
canarie



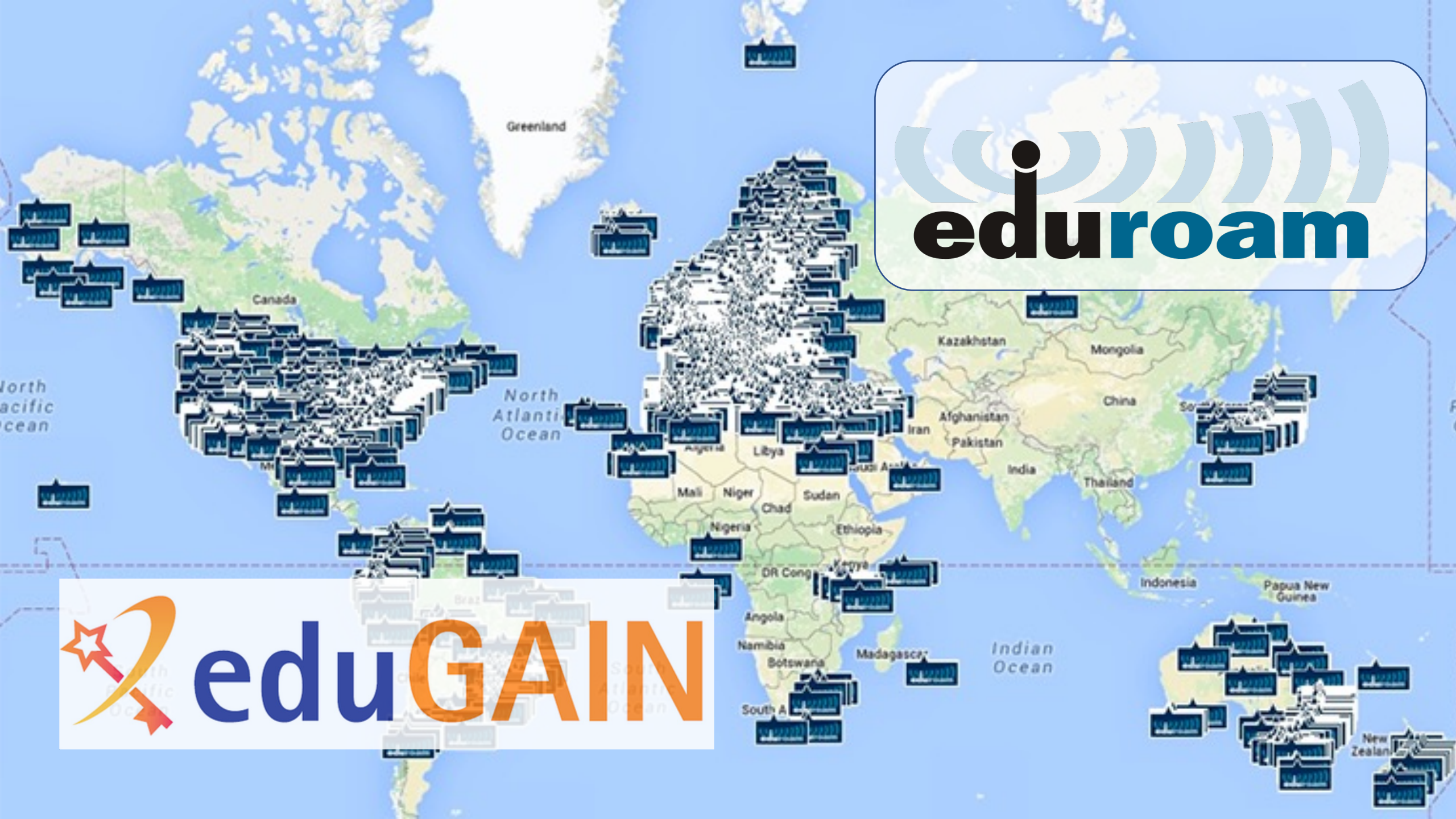
aarnet
Australia's Academic and Research Network

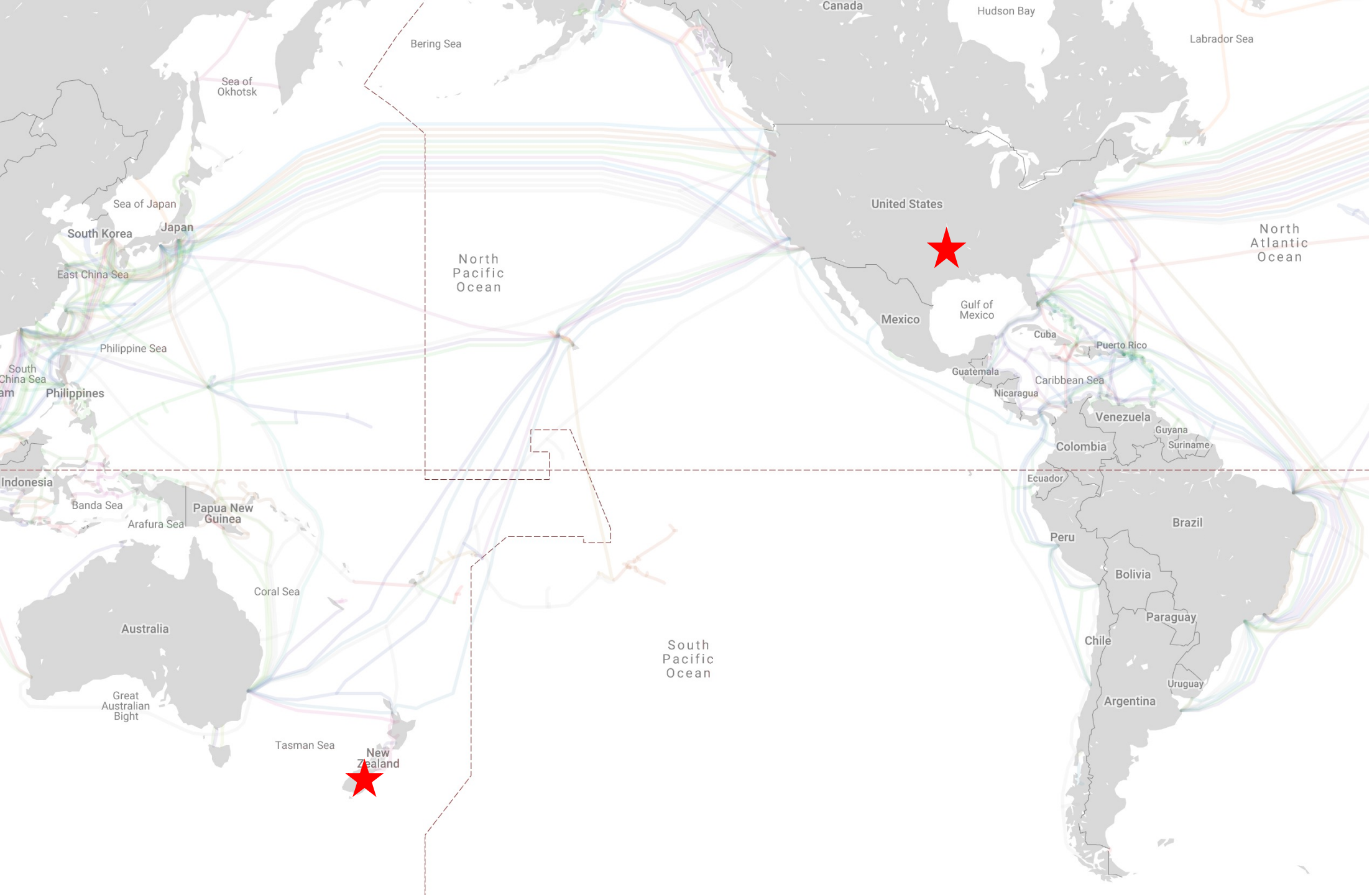


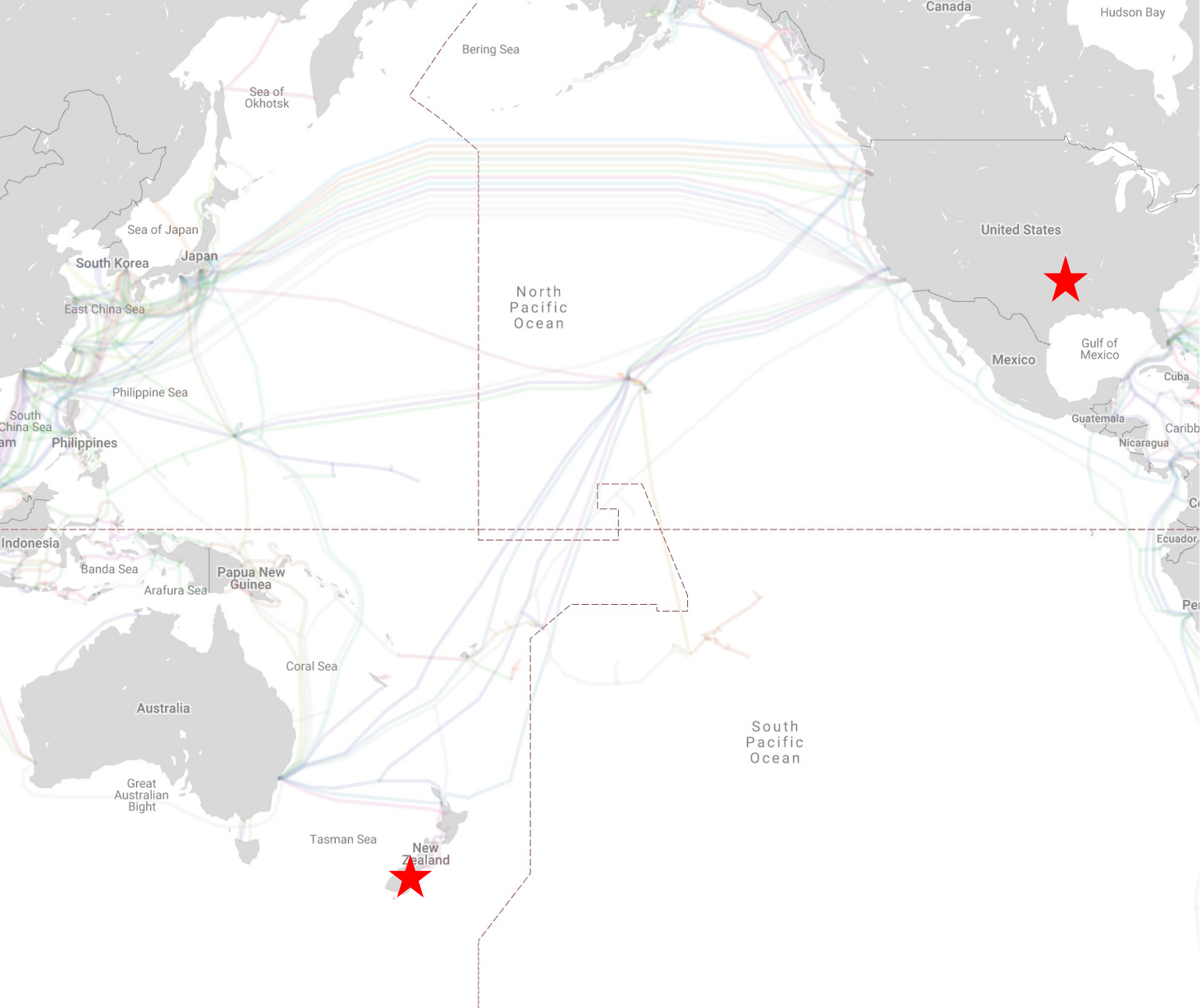

Okhotsk
Mongolia
Sea of Japan
China
South Korea
Japan
East China Sea
North Pacific Ocean
United States
Gulf of Mexico
Mexico
Cuba
Puerto Rico
Guatemala
Caribbean Sea
Nicaragua
Myanmar (Burma)
Philippine Sea
Thailand
South China Sea
Vietnam
Philippines
Gulf of Thailand
Malaysia
Venezuela
Guyana
Suriname
Colombia
Ecuador
Indonesia
Banda Sea
Papua New Guinea
Arafura Sea
Brazil
Peru
Bolivia
Coral Sea
Paraguay
Australia
Chile
South Pacific Ocean
Uruguay
Great Australian Bight
Argentina
Tasman Sea
New Zealand



International community of NRENs enabling collaboration on a global scale!


eduroam
eduGAIN
Greenland
Canada
North Atlantic Ocean
Kazakhstan
Mongolia
China
Afghanistan
Iran
Pakistan
India
Thailand
Libya
Mali
Niger
Chad
Sudan
Nigeria
Ethiopia
Kenya
DR Congo
Angola
Namibia
Botswana
Madagascar
Indian Ocean
Indonesia
Papua New Guinea


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

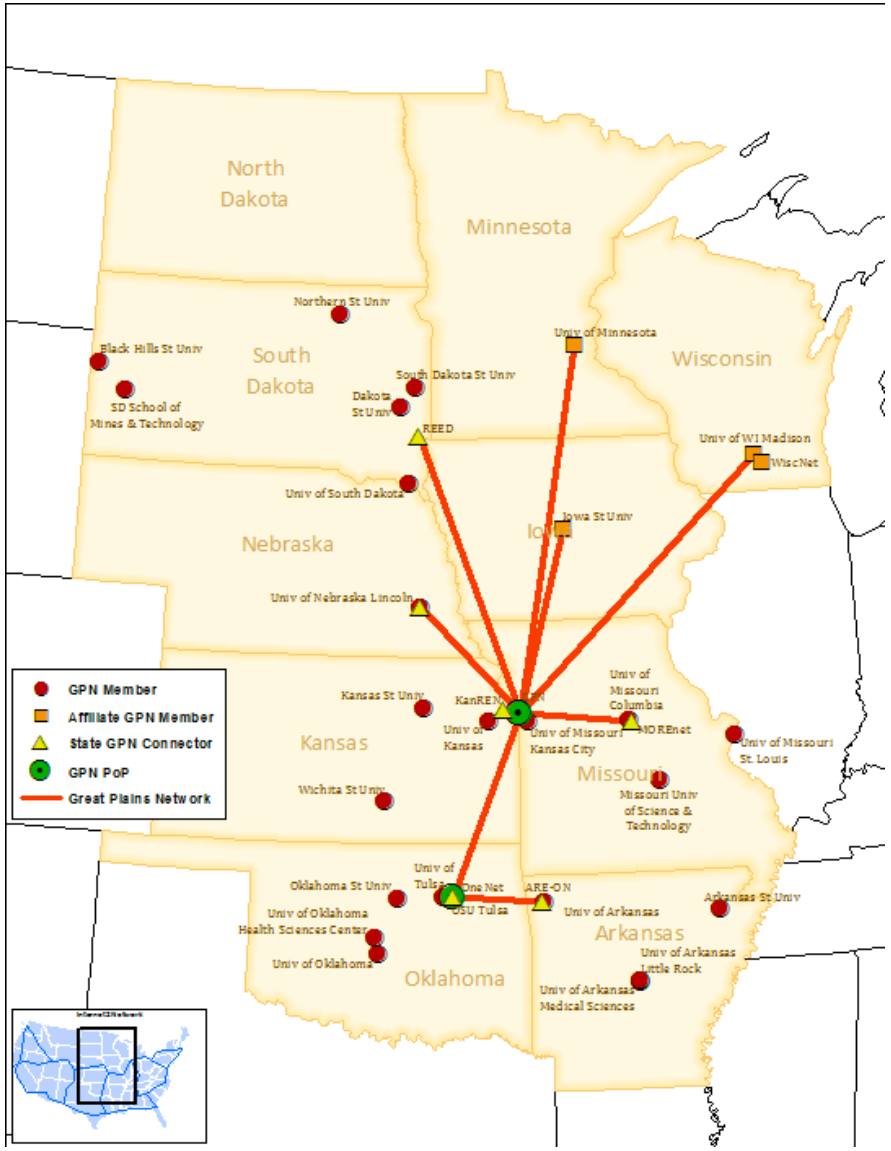
OU IT INFORMATION TECHNOLOGY
THE UNIVERSITY OF OKLAHOMA

OneNet

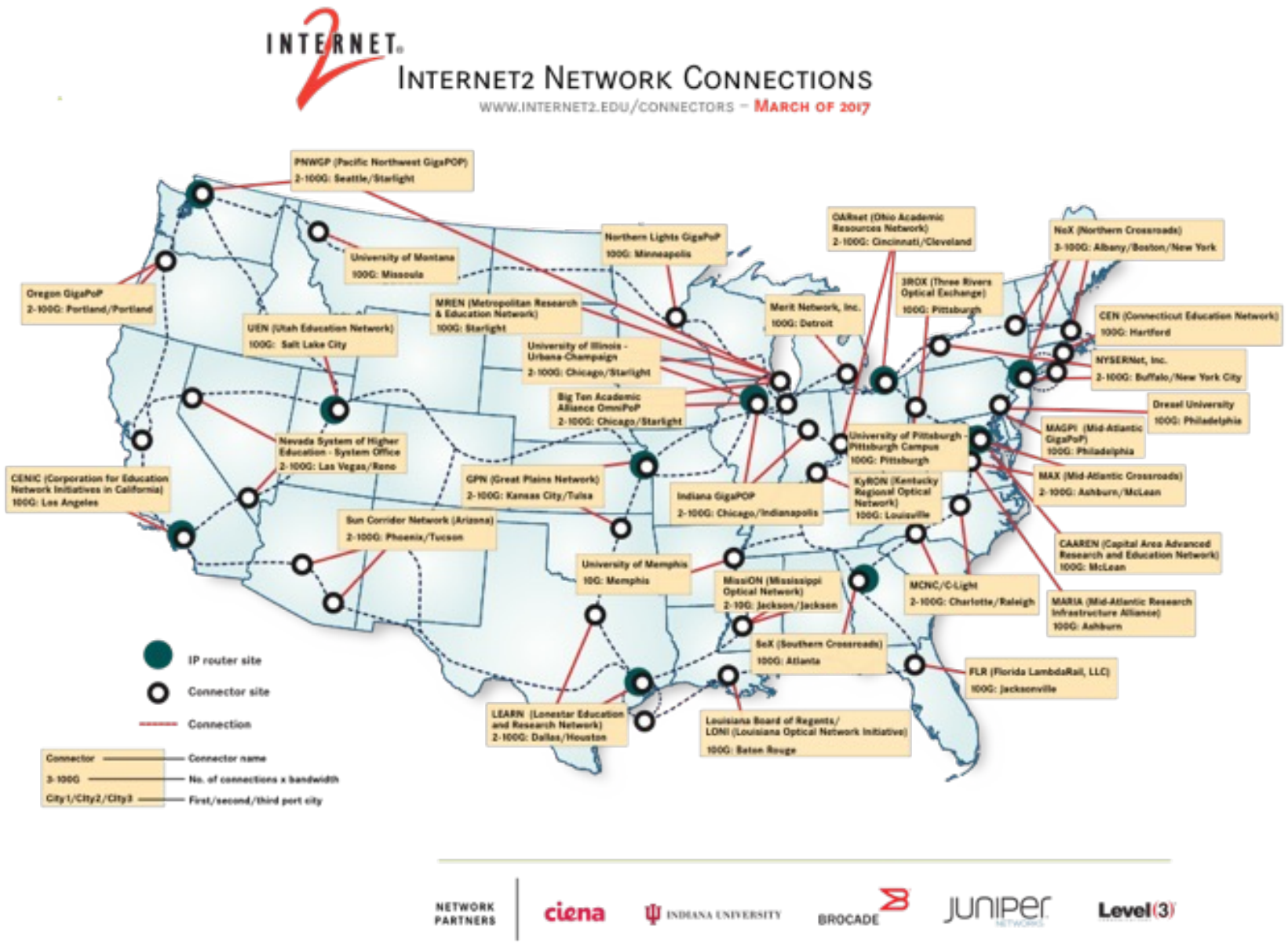
Advancing Technology Across Oklahoma

OneNet Points of Presence

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



GREAT PLAINS NETWORK



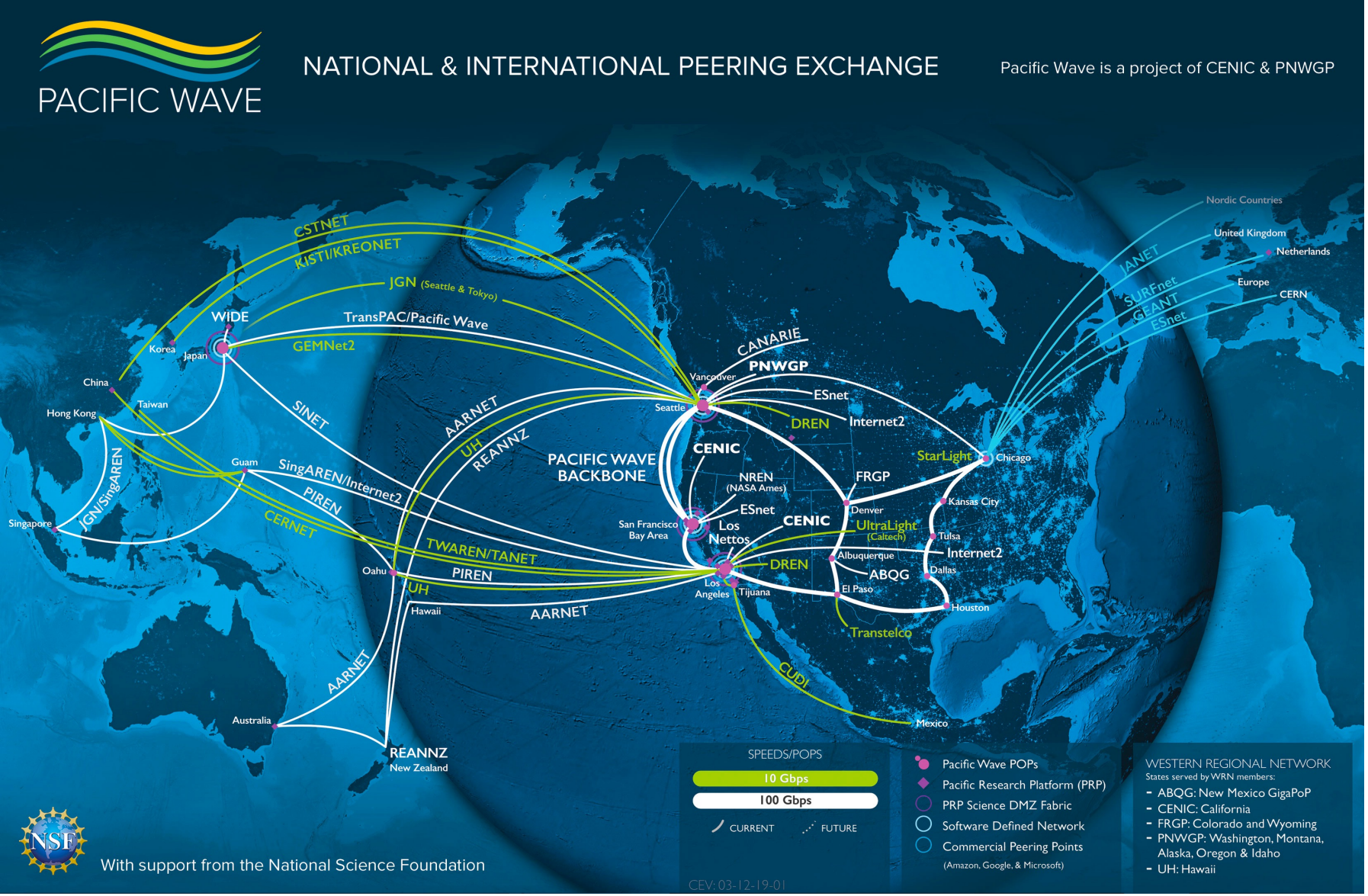
NETWORK PARTNERS ciena INDIANA UNIVERSITY BROCADE JUNIPER NETWORKS Level(3)

INFORMATION TECHNOLOGY THE UNIVERSITY OF OKLAHOMA

OneNet Advancing Technology Across Oklahoma

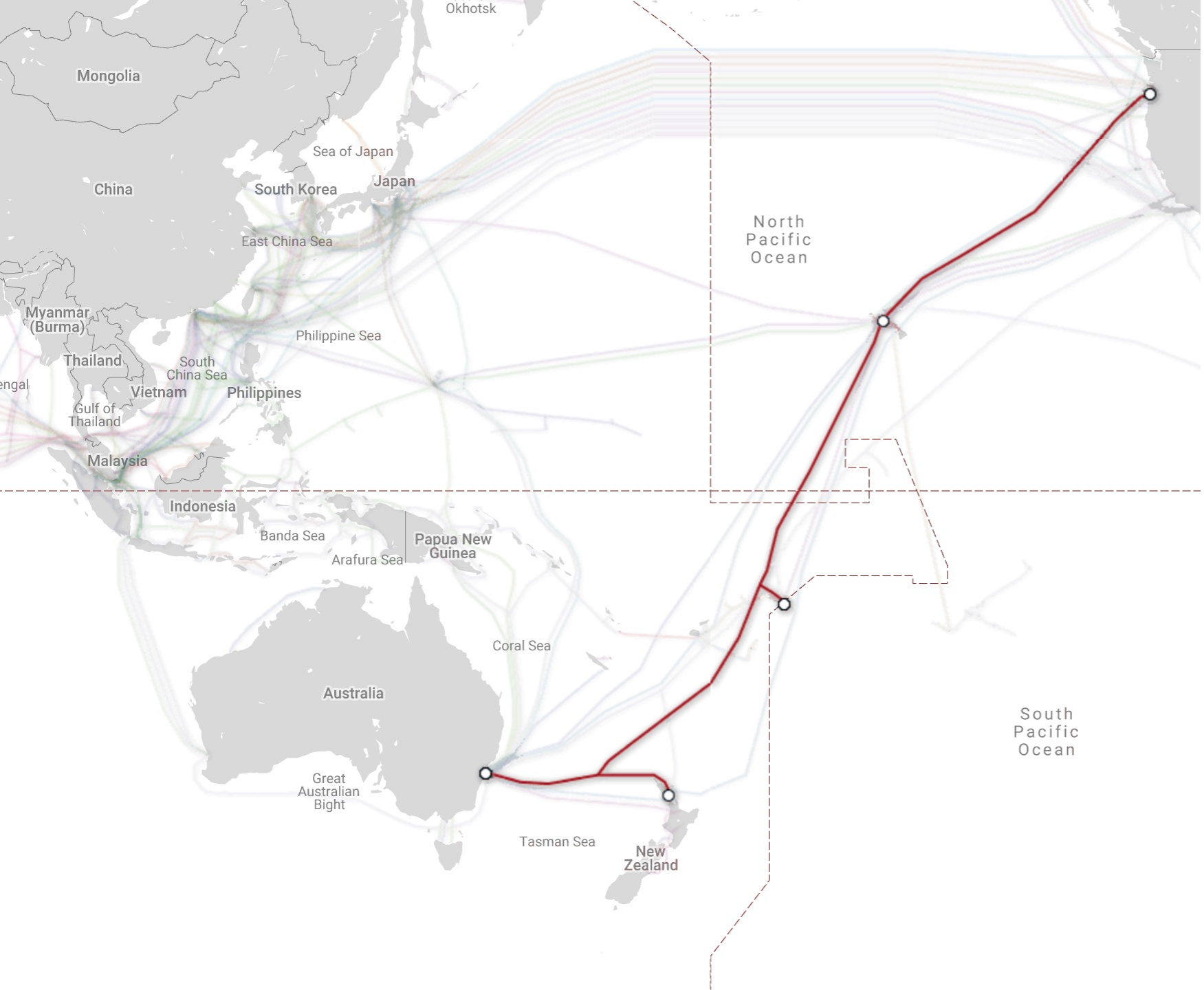
GPN GREAT PLAINS NETWORK

INTERNET®



PACIFIC WAVE

CENIC



OU IT Information Technology, The University of Oklahoma

OneNet — Advancing Technology Across Oklahoma

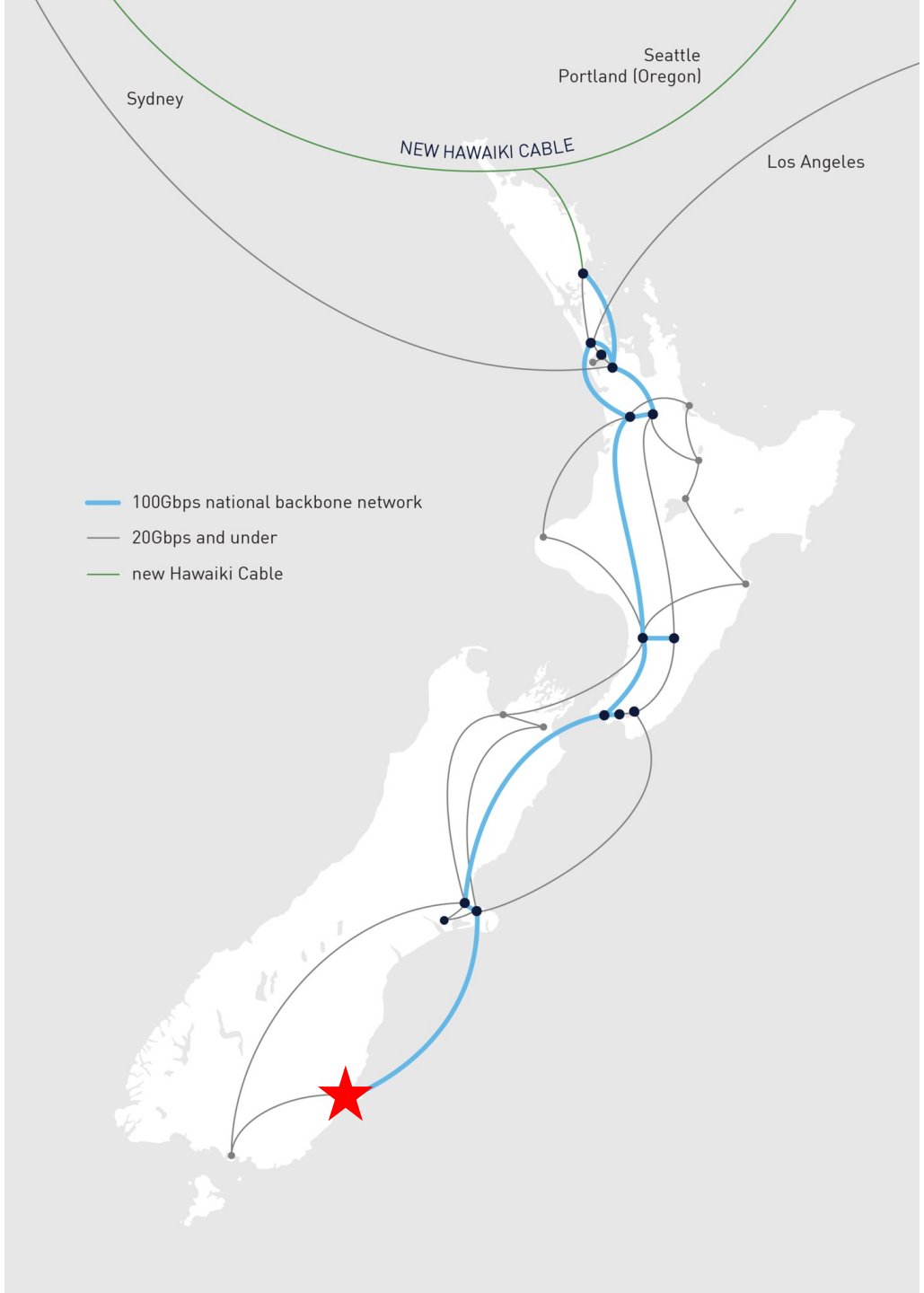
GPN — Great Plains Network

Internet2

Pacific Northwest GigaPop + CENIC

Pacific Wave

REANNZ



INFORMATION TECHNOLOGY
THE UNIVERSITY OF OKLAHOMA

OneNet
Advancing Technology Across Oklahoma

GPN
GREAT PLAINS NETWORK

INTERNET2

PACIFIC NORTHWEST GIGAPOP + CENIC

PACIFIC WAVE

REANNZ

OU IT Information Technology, The University of Oklahoma

OneNet
Advancing Technology Across Oklahoma

GPN
Great Plains Network

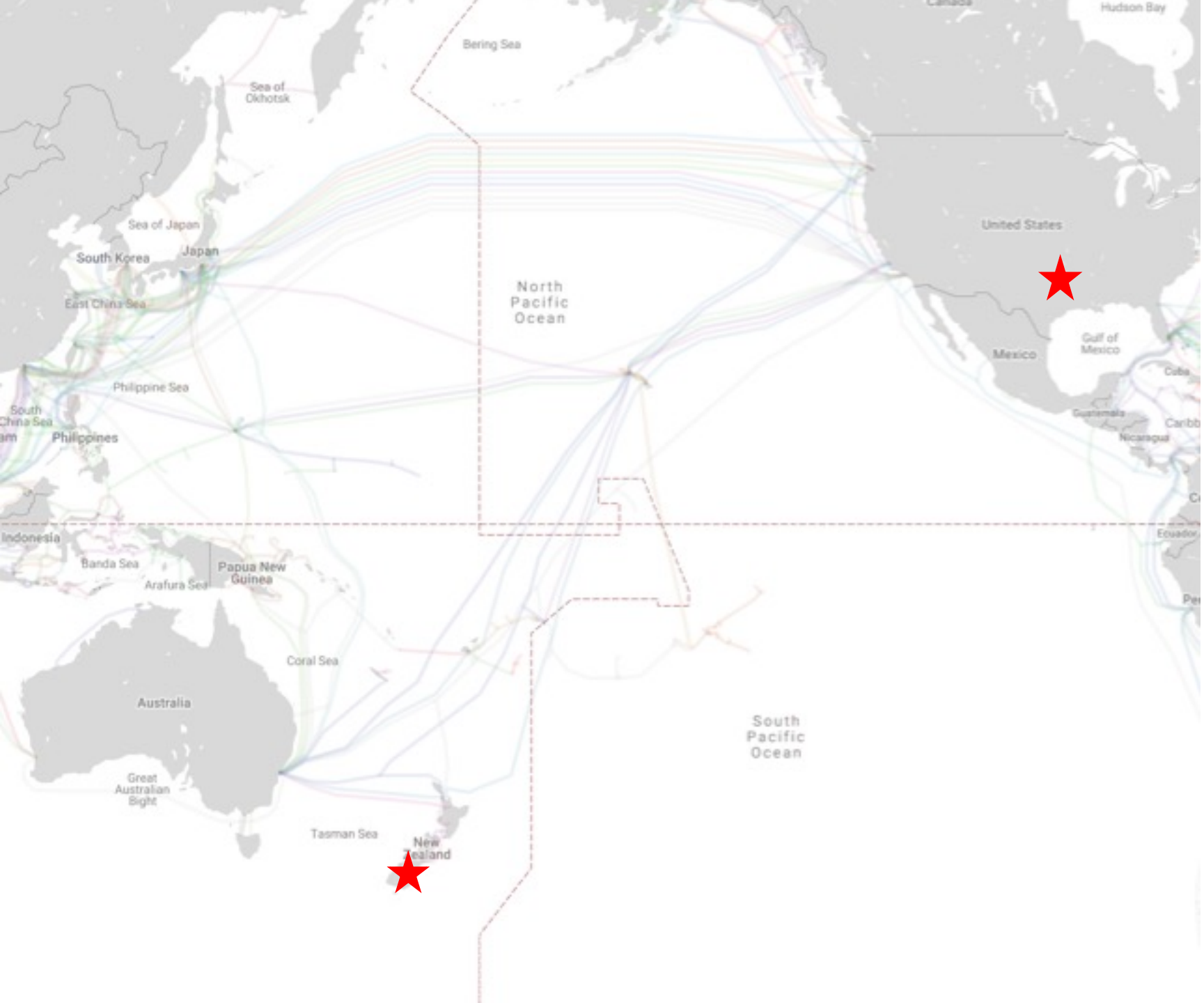
Internet2

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 — Advancing Technology Across Oklahoma

GPN — Great Plains Network

Internet2

Pacific Northwest GigaPop + CENIC

Pacific Wave

REANNZ

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

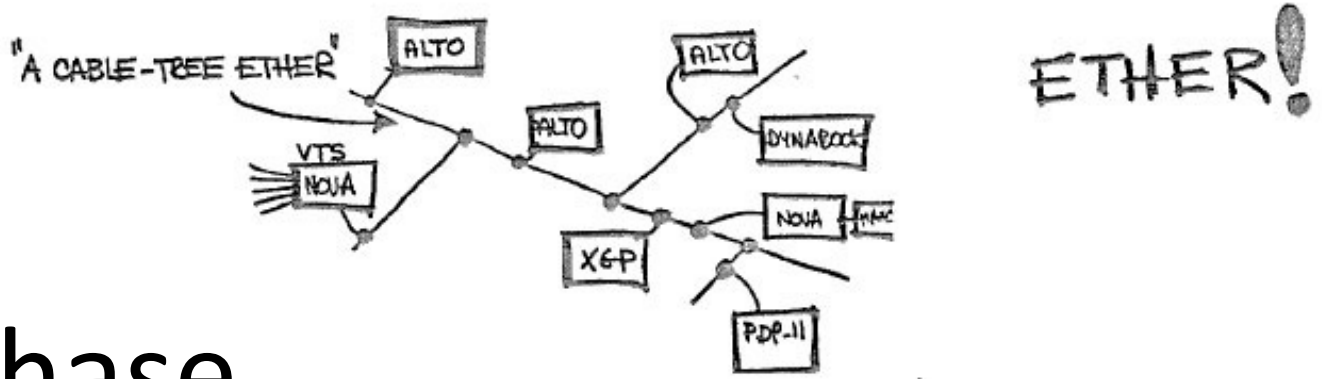
So… what does all this mean for me?

- 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 its not working, ask for help!

If your data must transit it - its “your” network!

Our goal.

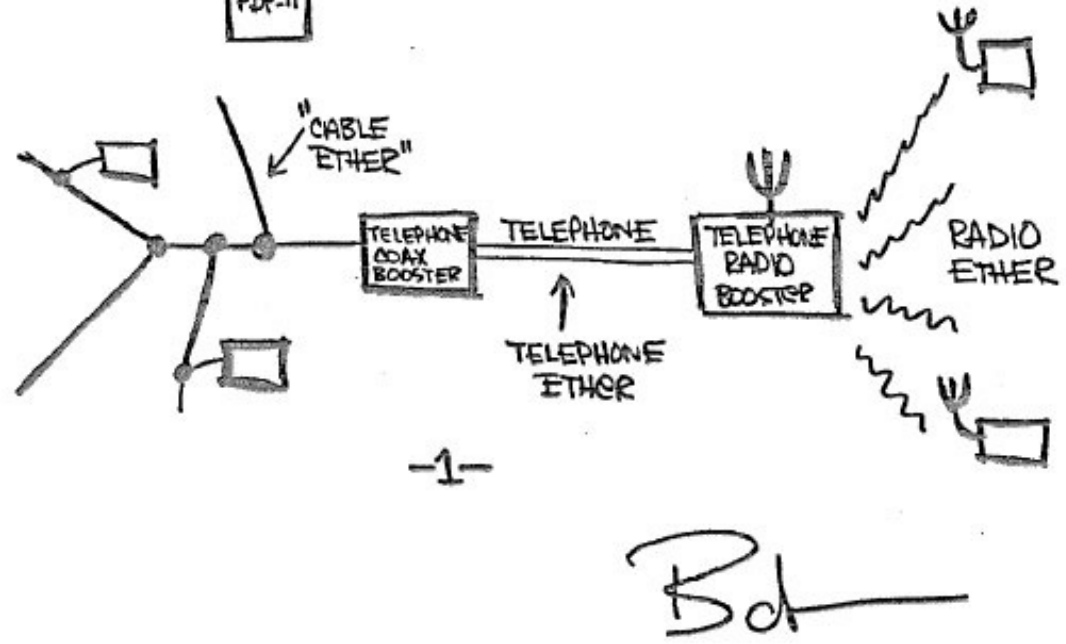


Wallace A. Chase

Head of Department, ITS

wallace.chase@otago.ac.nz

@bmtfr



UNIVERSITY of OTAGO

Te Whare Wānanga o Otāgo

NEW ZEALAND

A very special thanks to Matt Younkins at OU, as the raptors are on loan from him!