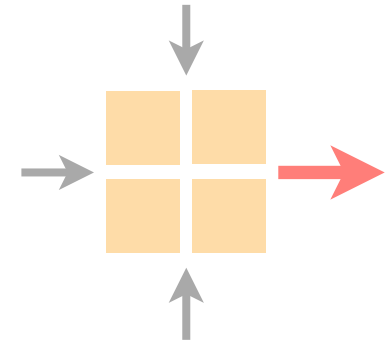


Communication Networks

Spring 2020



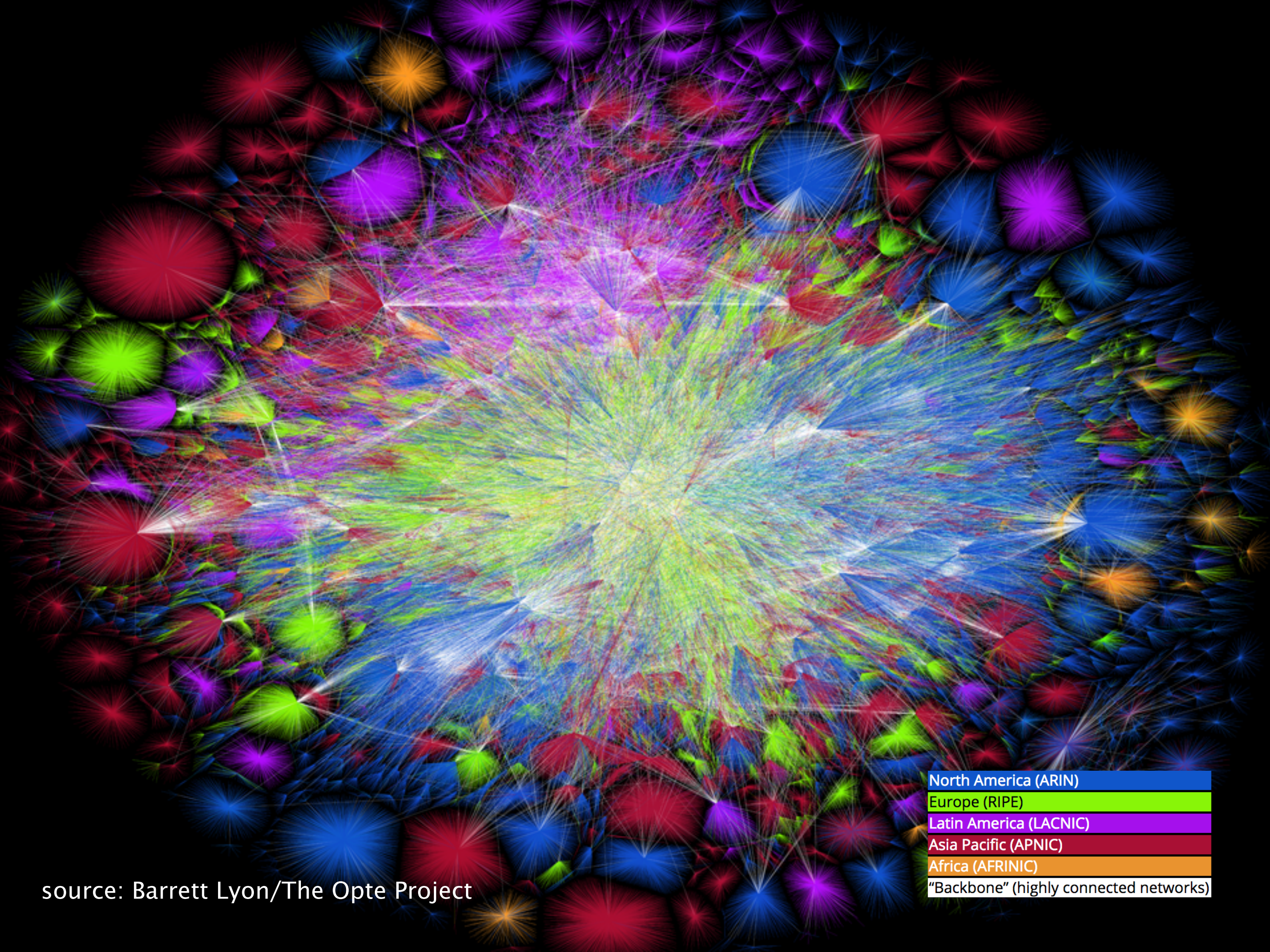
Laurent Vanbever

nsg.ee.ethz.ch

ETH Zürich

Feb 17 2020

Materials inspired from Scott Shenker & Jennifer Rexford



North America (ARIN)
Europe (RIPE)
Latin America (LACNIC)
Asia Pacific (APNIC)
Africa (AFRINIC)
"Backbone" (highly connected networks)

source: Barrett Lyon/The Opte Project

The Internet

An exciting place

18 billion

18 billion

estimated* # of Internet connected devices
in 2017

* Cisco Visual Networking Index 2017—2022

28.5 billion

estimated* # of Internet connected devices
in 2022

* Cisco Visual Networking Index 2017—2022

~4 exabytes

estimated* **daily** global IP traffic
in 2017

* Cisco Visual Networking Index 2017—2022

If



= 1 Gigabyte



volume(Great Wall of China) = 1 exabyte

~4 exabytes

estimated* **daily** global IP traffic
in 2017

* Cisco Visual Networking Index 2017—2022

~13 exabytes

estimated* daily global IP traffic
in 2022

* Cisco Visual Networking Index 2017—2022

~75% of all IP traffic

estimated* percentage of **video traffic**
in 2017

* Cisco Visual Networking Index 2017—2022

Upstream		Downstream		Aggregate	
BitTorrent	18.37%	Netflix	35.15%	Netflix	32.72%
YouTube	13.13%	YouTube	17.53%	YouTube	17.31%
Netflix	10.33%	Amazon Video	4.26%	HTTP - OTHER	4.14%
SSL - OTHER	8.55%	HTTP - OTHER	4.19%	Amazon Video	3.96%
Google Cloud	6.98%	iTunes	2.91%	SSL - OTHER	3.12%
iCloud	5.98%	Hulu	2.68%	BitTorrent	2.85%
HTTP - OTHER	3.70%	SSL - OTHER	2.53%	iTunes	2.67%
Facebook	3.04%	Xbox One Games Download	2.18%	Hulu	2.47%
FaceTime	2.50%	Facebook	1.89%	Xbox One Games Download	2.15%
Skype	1.75%	BitTorrent	1.73%	Facebook	2.01%
	69.32%		74.33%		72.72%




Table 1 - Top 10 Peak Period Applications - North America, Fixed Access

<http://bit.ly/2Glwl8G>

~82% of all IP traffic

estimated* percentage of **video traffic**
in 2022

* Cisco Visual Networking Index 2017—2022

The Internet

A tense place

Countries get disconnected for political reasons

The screenshot shows a web browser window with the URL <https://www.newscientist.com/blogs/onepercent/2012/07/syria-disconnects-from-the-int.html>. The page is from the New Scientist website, featuring the 'One Per Cent' blog header with the tagline 'Taking the sweat out of technology' and an illustration of a person on a bicycle connected to a laptop and a red button. The main article is titled 'Syria follows Egypt and disconnects from the internet', dated 17:20 20 July 2012, by Paul Marks, chief technology correspondent. The article includes a photograph of armed men in a city street with a damaged car. The right sidebar contains sections for 'Our other blogs' (Short Sharp Science, One Per Cent, New Scientist TV, CultureLab, Big Wide World), 'Bookmark&share' (with social media icons), and 'Categories' (listing various technology topics like 3D printing, AI, and Augmented reality).

NewScientist

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One Per Cent
Taking the sweat out of technology


Syria follows Egypt and disconnects from the internet
17:20 20 July 2012
Internet
Paul Marks, chief technology correspondent



Our other blogs

- Short Sharp Science
- One Per Cent
- New Scientist TV
- CultureLab
- Big Wide World

Bookmark&share

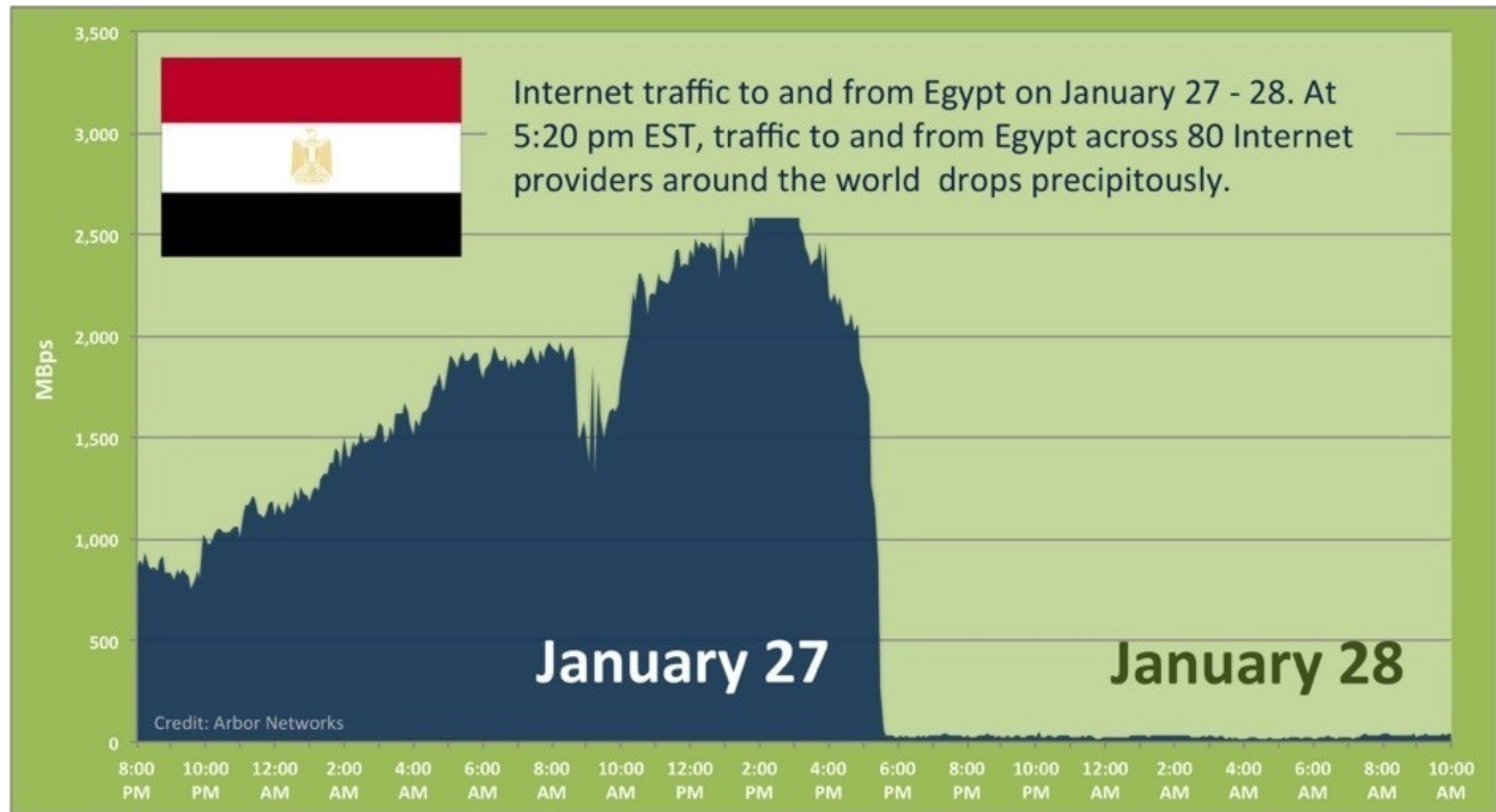


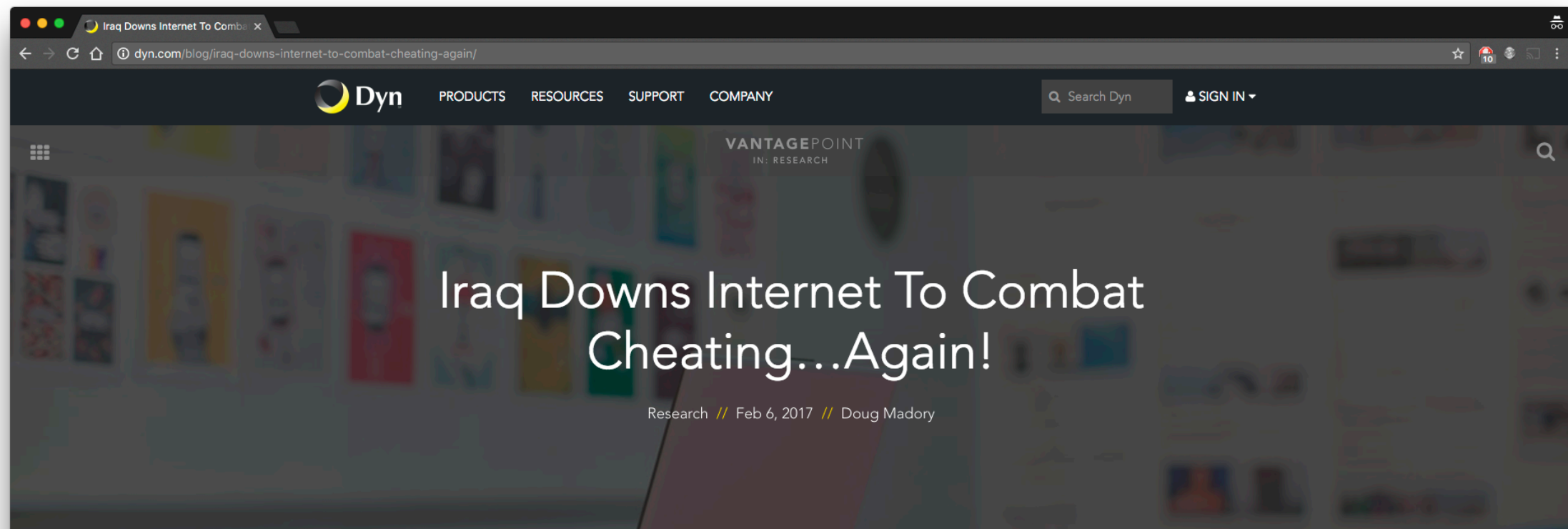
Categories

- 3D printing
- AI
- Aerospace
- Apple
- Apps
- Art
- Augmented reality

Also check: <http://research.dyn.com/2012/11/could-it-happen-in-your-countr/>

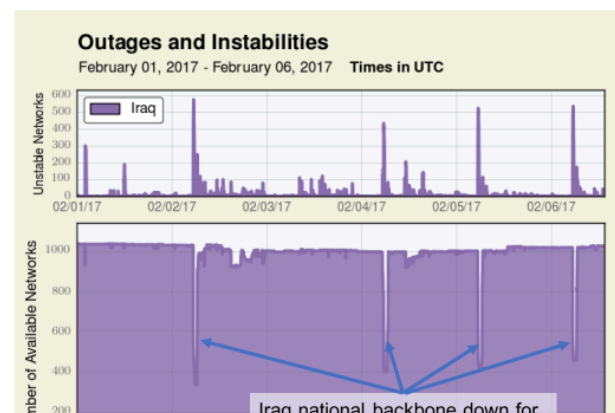
Internet traffic to/from Egypt in January 2011





Earlier this morning, the national fiber backbone of Iraq was taken offline in an effort to combat cheating on 6th grade placement exams. It was the fourth such outage in the past five days. 2017 marks the third year Iraq has used government-directed internet blackouts to combat cheating on student exams.

These recent outages are a continuation of a growing (and somewhat puzzling) trend by governments in many developing parts of the world to cut communications services in a desperate attempt to staunch rampant cheating on high-stakes student exams.

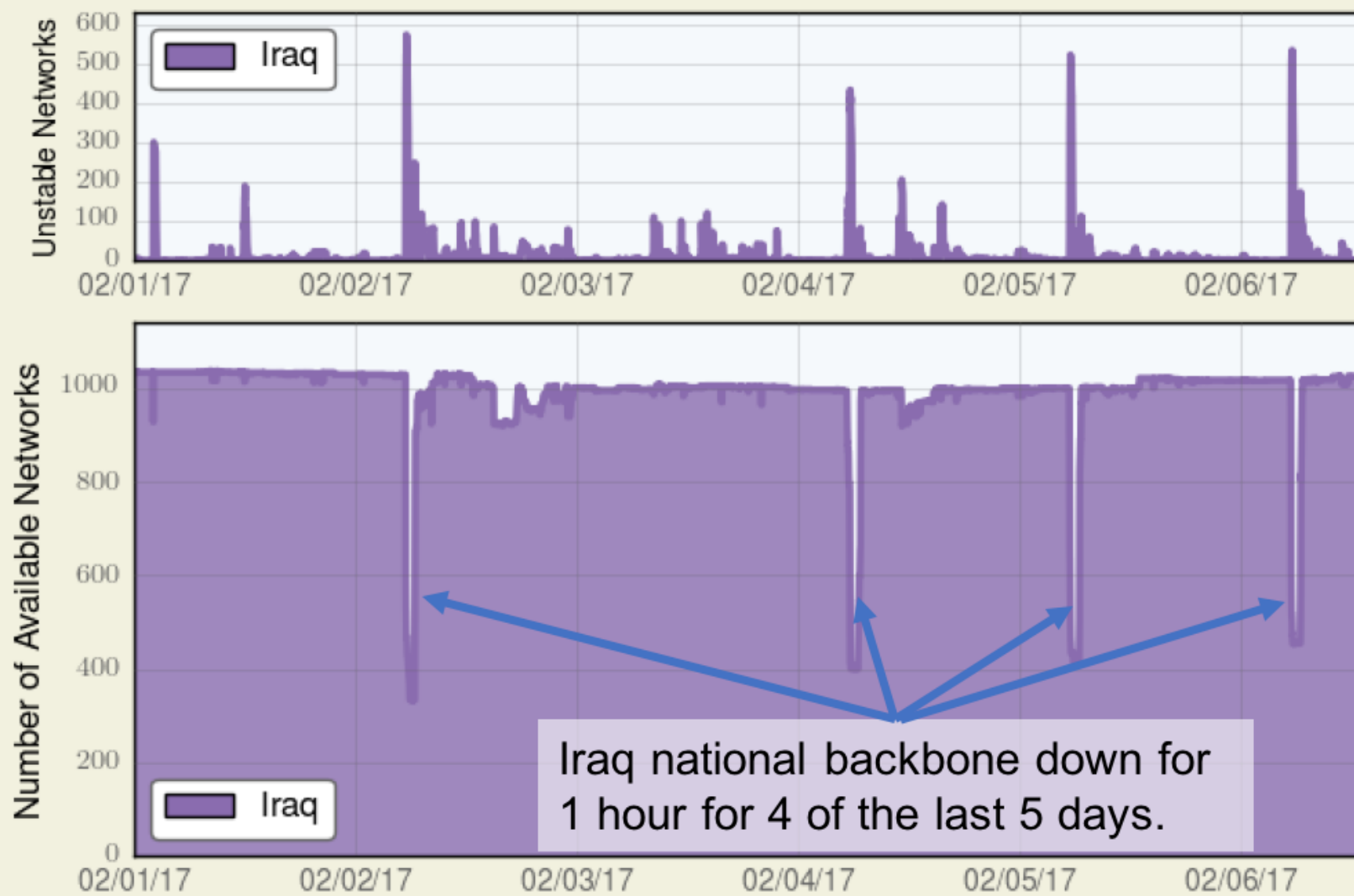


<http://dyn.com/blog/iraq-downs-internet-to-combat-cheating-again/>



Outages and Instabilities

February 01, 2017 - February 06, 2017 Times in UTC



Iraq national backbone down for 1 hour for 4 of the last 5 days.

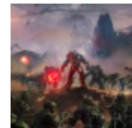
Source: BGP Data





Nintendo Switch isn't just a console, it's a 127-year saga that began with a deck of cards

— Nintendo | 1 hour ago



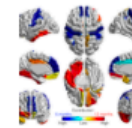
Halo Wars 2 review: a solidly Spartan sequel to the real-time strategy classic

8/10
— Halo | 56 minutes ago



Apple's WWDC 2017 will return to San Jose in June

— WWDC | 1 hour ago



This algorithm can spot signs of autism in children a year before they're diagnosed

— Autism | 2 hours ago

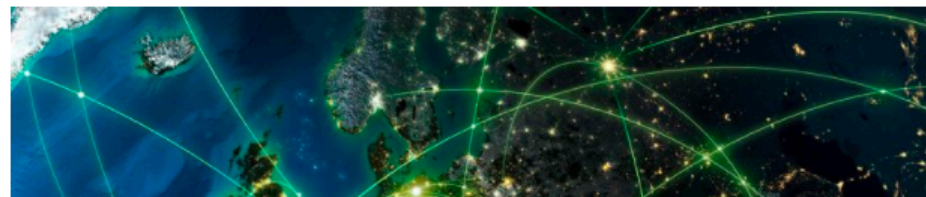


Humble collection migration
— Humble

Internet Freedom

Governments shut down the internet more than 50 times in 2016

Economic impact alone was £1.9bn, with greater fears over human rights and freedom of speech



<http://www.wired.co.uk/article/over-50-internet-shutdowns-2016>

By MATT KAMEN

Tuesday 3 January 2017



Algeria and Iraq shut down inte

https://www.independent.co.uk/news/world/africa/algeria-iraq-shut-down-internet-students-cheating-exams-facebook-a8410341.html

 INDEPENDENT

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Q

News > World > Africa

Algeria and Iraq shut down internet nationwide to stop students cheating in exams

'Shutting down digital communication often disproportionately harms marginalised and vulnerable groups, cripples the local economy, and creates cascades of chaos'

Chris Baynes | Thursday 21 June 2018 22:25 | 180 shares |

f

Like Click to follow The Independent




<https://www.independent.co.uk/news/world/africa/algeria-iraq-shut-down-internet-students-cheating-exams-facebook-a8410341.html>

Russia to disconnect from the internet as part of a planned test

← → ↺ 🏠 🔒 https://www.zdnet.com/article/russia-to-disconnect-from-the-internet-as-part-of-a-planned-test/ 🔍 ☆ ⚙️

Russia to disconnect from the internet as part of a planned test

Russia's internet contingency plan gets closer to reality.

 By [Catalin Cimpanu](#) for [Zero Day](#) | February 11, 2019 -- 00:33 GMT (00:33 GMT) | Topic: [Government](#)

Recommended Content:

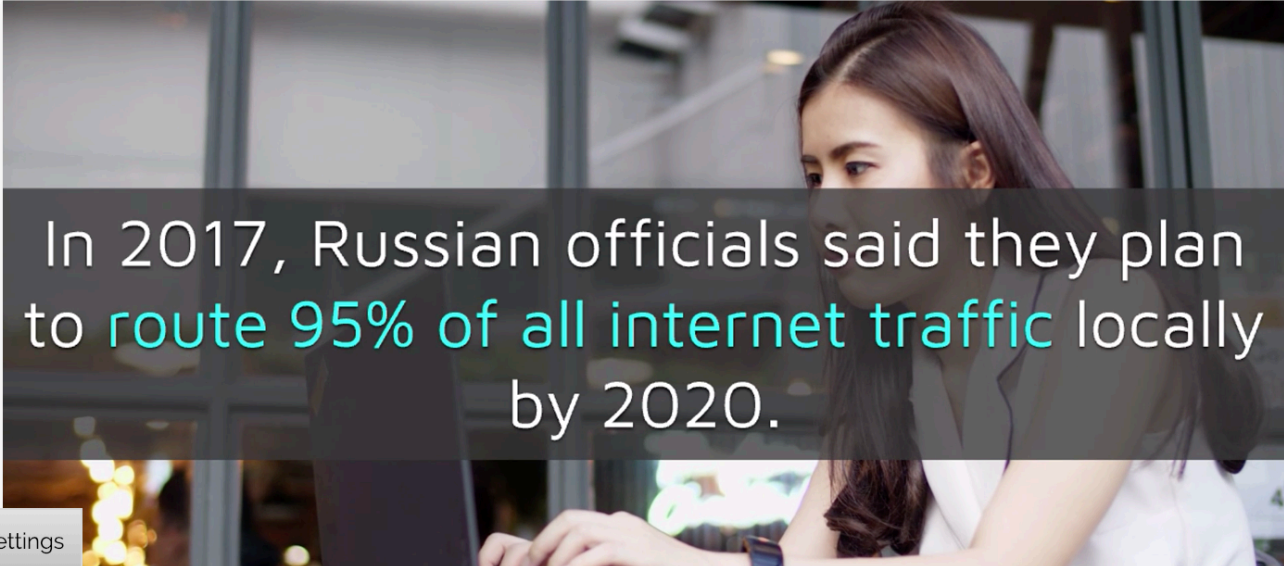
Resource Center: Create your personalised cloud learning experience
Curious about how cloud can help your business? Join the Google Cloud resource hub and unlock the possibilities of the cloud with access to specially curated content just for you. Start now and get ahead on the cloud.

Get Started

33

f

in



In 2017, Russian officials said they plan to route 95% of all internet traffic locally by 2020.

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Security
Google working on new Chrome security feature to 'obliterate DOM XSS'



Government : US
GAO gives Congress go-ahead for a GDPR-like privacy legislation

https://www.zdnet.com/article/russia-to-disconnect-from-the-internet-as-part-of-a-planned-test/

Browser tabs: BBC Russia 'successfully tests' its unplugged internet x +

Address bar: [bbc.com/news/technology-50902496](https://www.bbc.com/news/technology-50902496)

Navigation: Sign in | News | Sport | Reel | Worklife | Travel | Future | More | Search

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Technology

Russia 'successfully tests' its unplugged internet

By Jane Wakefield
Technology reporter

24 December 2019

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REUTERS

The net independence plan is seen as a way for Russia's government to get more control over online life

Russia has successfully tested a country-wide alternative to the global internet, its government has announced.

Details of what the test involved were vague but, according to the Ministry of Communications, ordinary users did not notice any changes.


The results will now be presented to President Putin.

Experts remain concerned about the trend for some countries to dismantle the internet.

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11 February 2020

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Features



The virus that threatens everything in China

<https://www.bbc.com/news/technology-50902496>

Some Internet communications
are interfered against or heavily congested





Can ISPs selectively slow down traffic?

The U.S. Federal Communications Commission (FCC) set network neutrality rules in 2015

A screenshot of a web browser displaying the New York Times article titled "F.C.C. Sets Net Neutrality Rules". The browser's address bar shows the URL: <https://www.nytimes.com/2015/03/13/technology/fcc-releases-net-neutrality-rules.html>. The page features a navigation bar with "SECTIONS", "HOME", and "SEARCH" options, along with "SUBSCRIBE NOW" and "LOG IN" buttons. Below the navigation bar, there are several featured articles, including "Snap Aims for Valuation of More Than \$20 Billion in I.P.O.", "Facebook's Zuckerberg, Bucking Tide, Takes Public Stand Against Isolationism", "Tech We're Using: Why I Still Love TiVo and How a Sous Vide Gadget Rescued Me", "Airlines Phasing Out Screens Because You Are All on Your Devices", "Social Q's: Family Planning ... for Your Phones", and "Tech Tip: Adding Facebook's Birthday List to a Calendar Program".

The main article, "F.C.C. Sets Net Neutrality Rules", is by Rebecca R. Ruiz and dated March 12, 2015. It includes a video player showing a hand clicking a computer mouse, with a title "The New Net Neutrality Rules" and byline "By NATALIA V. OSIPOVA and CAITLIN PRENTKE". Below the video, the text reads: "The Federal Communications Commission is to take a more active role in regulating the Internet as a public utility, which is expected to provoke court cases from major broadband providers. By NATALIA V. OSIPOVA and CAITLIN PRENTKE on March 12, 2015. Photo by The New York Times. Watch in Times Video".

Related coverage includes "F.C.C. Approves Net Neutrality Rules, Classifying Broadband Internet Service as a Utility" (Feb. 26, 2015) and "News Analysis: The Push for Net Neutrality Arose From Lack of Choice" (Feb. 25, 2015).

WASHINGTON — The [Federal Communications Commission](#) on Thursday released extensive details of how it would regulate broadband Internet providers as a public utility, producing official wording that almost certainly sets the stage for extended legal fights.

The release of the rules had been eagerly anticipated by advocates and lawmakers, as well as broadband and technology companies, since the agency approved new rules for Internet service [two weeks ago](#). The details came in a [313-page document](#) that included the new rules and the legal justifications for them.

The rules revealed how the strict laws would be modified for Internet providers, exempting the companies from the sort of price controls typically

<http://nyti.ms/2kZUnDA>

... which it then repealed in 2017

F.C.C. Repeals Net Neutrality R x

Secure | https://www.nytimes.com/2017/12/14/technology/net-neutrality-repeal-vote.html


SECTIONS HOME SEARCH The New York Times SUBSCRIBE NOW LOG IN

TECHNOLOGY

F.C.C. Repeals Net Neutrality Rules

By CECILIA KANG DEC. 14, 2017

1950



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- Opinion | Op-Ed Contributor Why Concerns About Net Neutrality Are Overblown DEC. 4, 2017
- Opinion | Contributing Op-Ed Writer Tim Wu: Why the Courts Will Have to Save Net Neutrality NOV. 22, 2017

Connecting... Ajit Pai, the F.C.C. chairman, said the rollback of the net neutrality rules would eventually help consumers.

<http://nyti.ms/2CkTbRR>




Netflix US 

@netflix

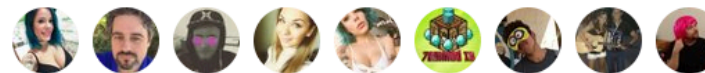
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We're disappointed in the decision to gut **#NetNeutrality**  protections that ushered in an unprecedented era of innovation, creativity & civic engagement. This is the beginning of a longer legal battle. Netflix stands w/ innovators, large & small, to oppose this misguided FCC order.

10:26 AM - 14 Dec 2017

335,726 Retweets 831,986 Likes



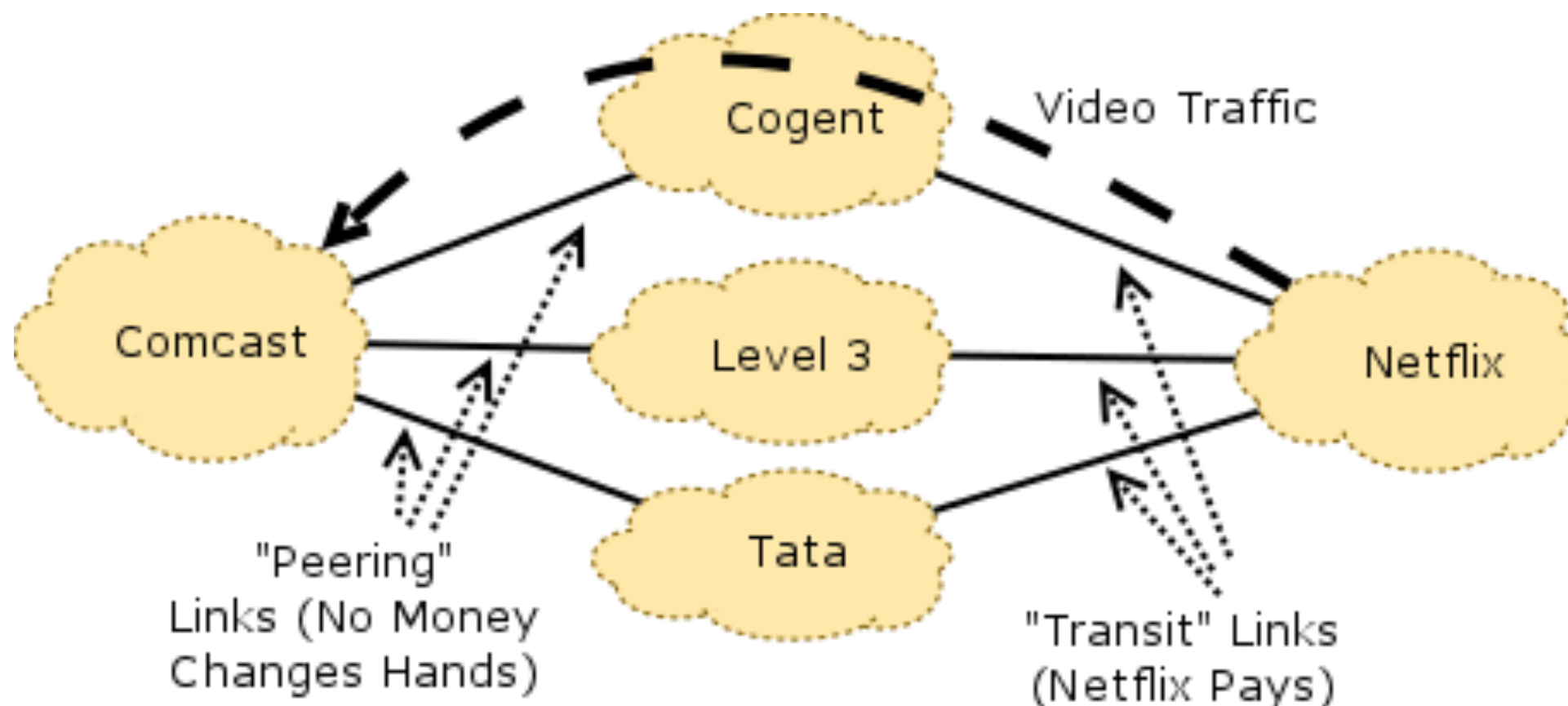
 7.1K  336K  832K

Some Internet communications
are interfered against or heavily congested



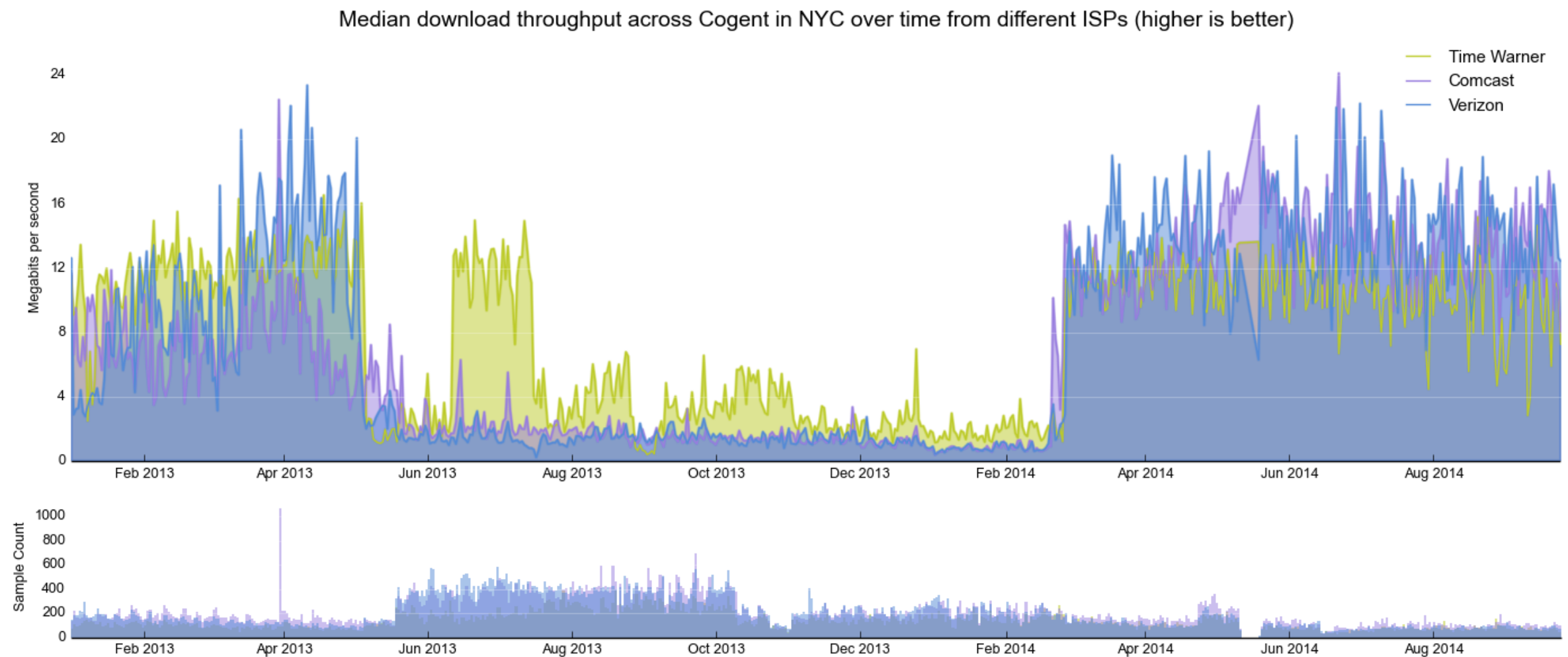
Who should pay the other for Internet connectivity?

A primer on the conflict between Netflix and Comcast



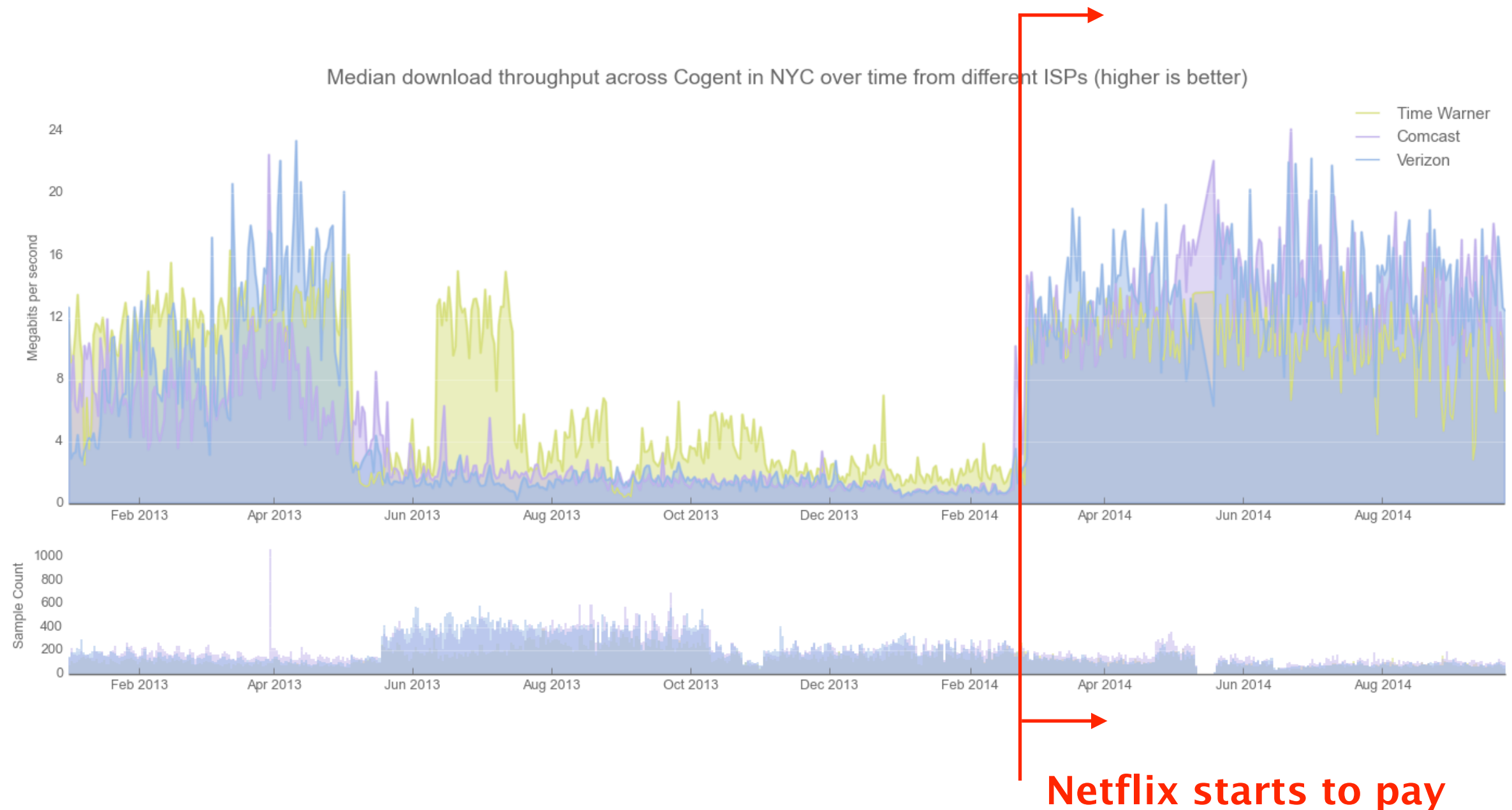
<https://freedom-to-tinker.com/blog/feamster/why-your-netflix-traffic-is-slow-and-why-the-open-internet-order-wont-necessarily-make-it-faster/>

Due to congestion, throughput across Cogent to Comcast, Time Warner and Verizon were miserable



<http://bit.ly/1thPzro>

Situation massively improved after Netflix agreed to paid direct connection to the providers

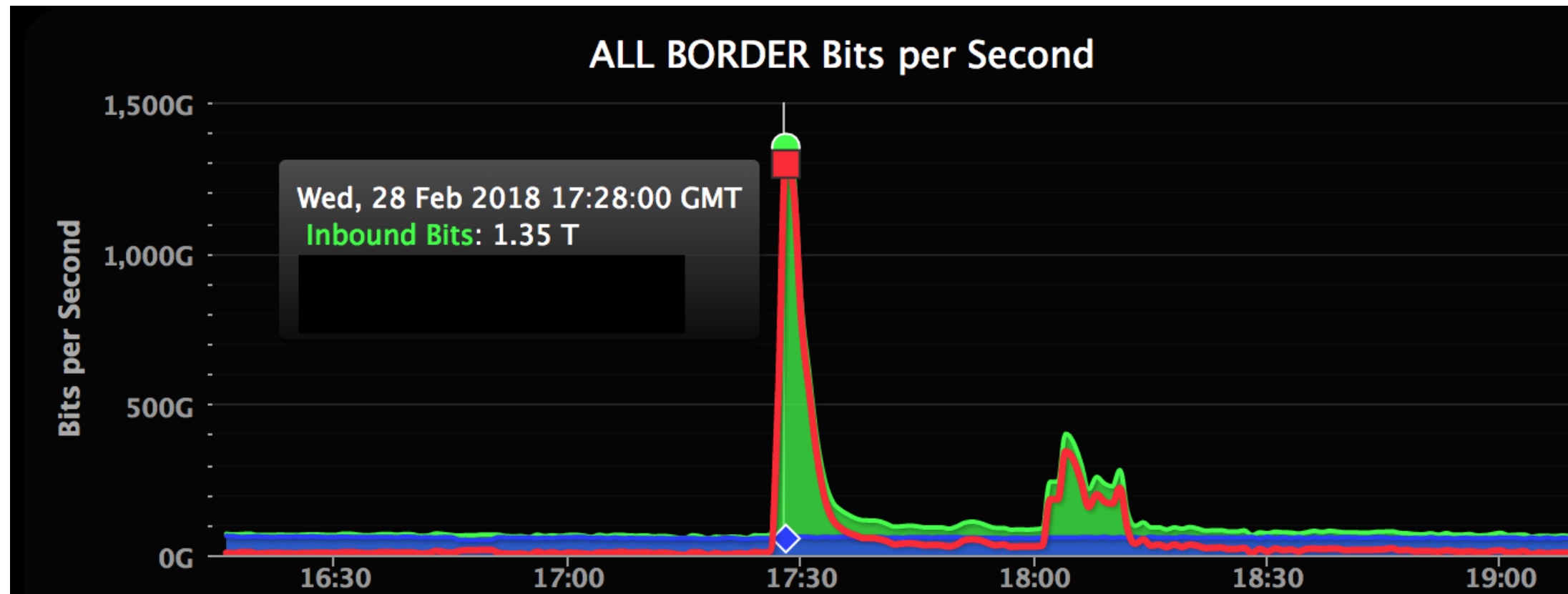


Closer to us...



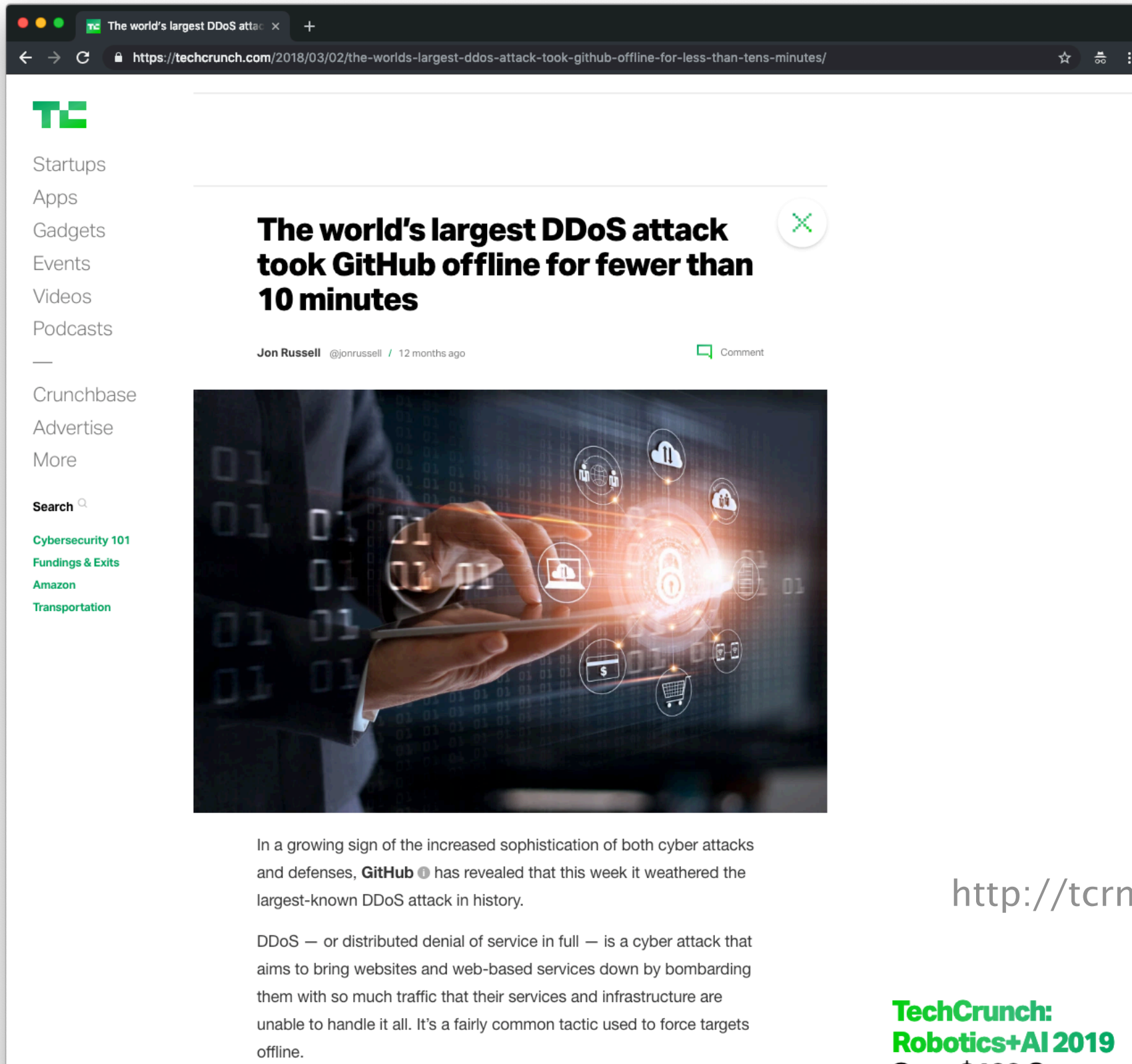
<https://www.nzz.ch/digital/streaming-warum-swisscom-kunden-probleme-mit-netflix-haben-ld.9174>

In February 2018, GitHub was targeted by the (so far) largest DDoS attack...



from a normal ~ 0.1 Tbps to **1.35 Tbps**

At the same time, countermeasures improve...



The screenshot shows a web browser window with the URL <https://techcrunch.com/2018/03/02/the-worlds-largest-ddos-attack-took-github-offline-for-less-than-tens-minutes/>. The article is titled "The world's largest DDoS attack took GitHub offline for fewer than 10 minutes" by Jon Russell, published 12 months ago. The article text begins with: "In a growing sign of the increased sophistication of both cyber attacks and defenses, GitHub has revealed that this week it weathered the largest-known DDoS attack in history. DDoS — or distributed denial of service in full — is a cyber attack that aims to bring websites and web-based services down by bombarding them with so much traffic that their services and infrastructure are unable to handle it all. It's a fairly common tactic used to force targets offline."

TechCrunch:
Robotics+AI 2019

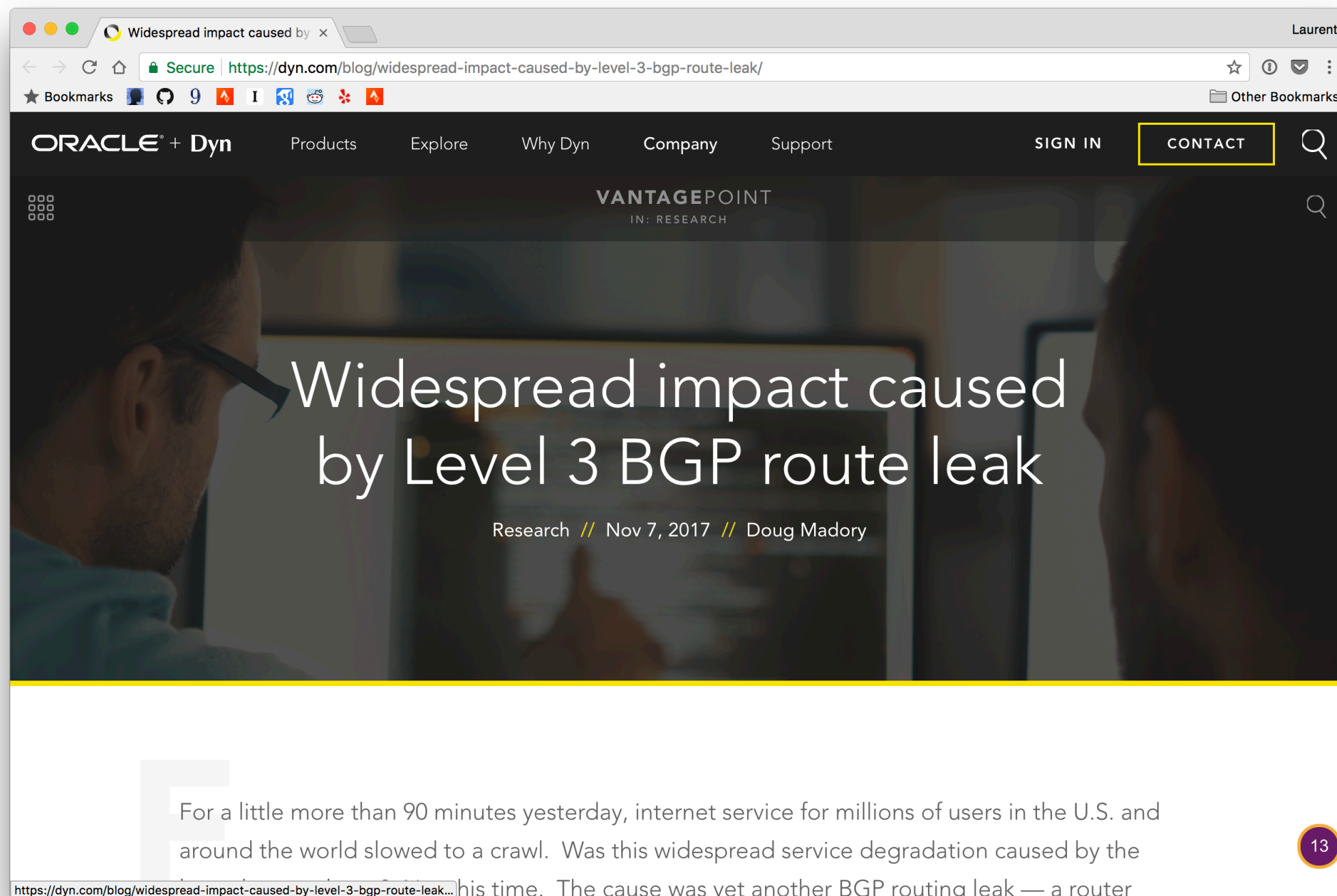
<http://tcn.ch/2tbJmFD>

The Internet

A fragile place

Despite being absolutely critical,
Internet communications are inherently fragile

November 2017



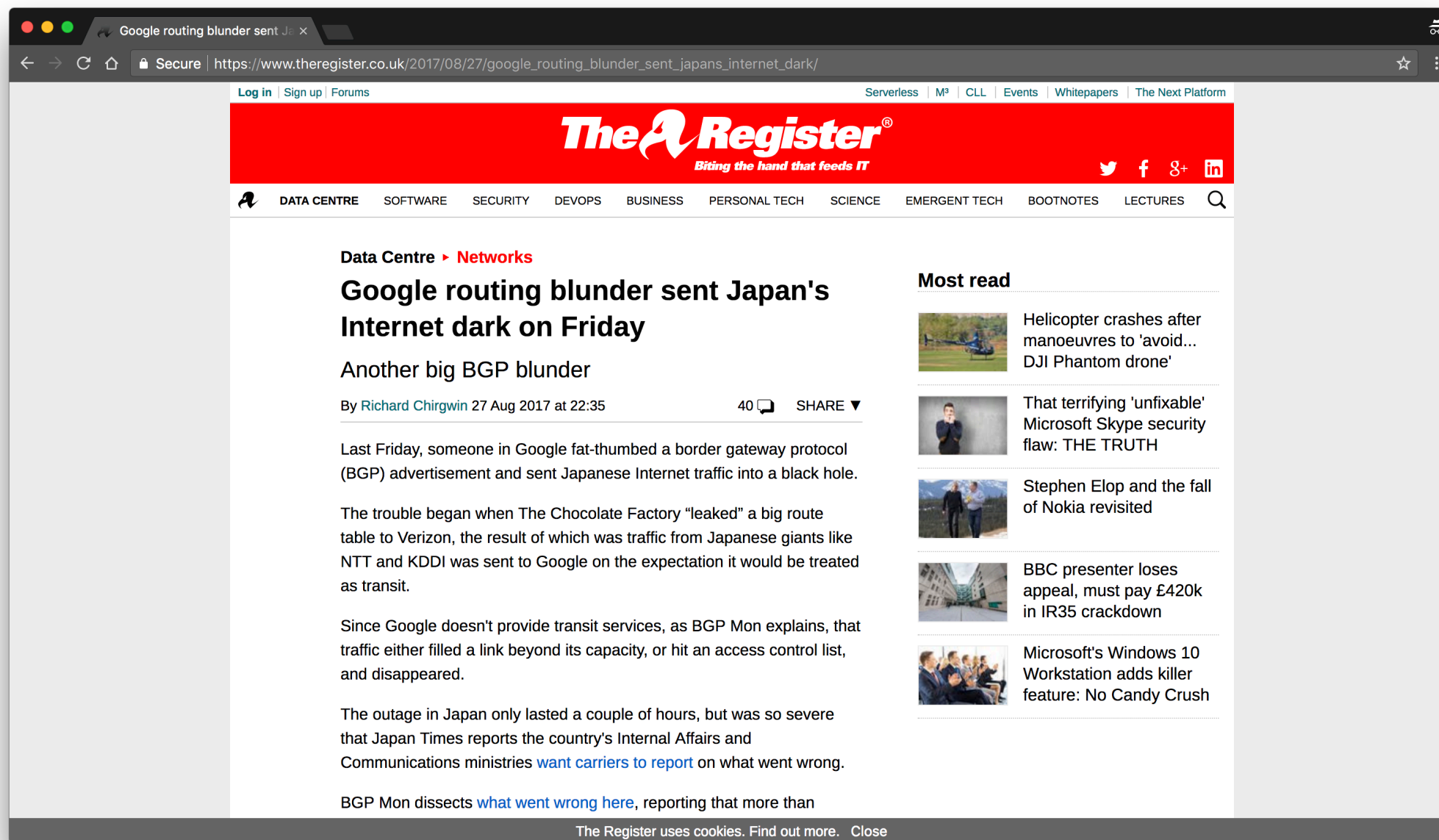
<https://dyn.com/blog/widespread-impact-caused-by-level-3-bgp-route-leak/>

For a little more than 90 minutes [...],

Internet service for millions of users in the U.S.
and around the world slowed to a crawl.

The cause was yet another BGP routing leak,
a **router misconfiguration** directing Internet traffic
from its intended path to somewhere else.

August 2017



https://www.theregister.co.uk/2017/08/27/google_routing_blunder_sent_japans_internet_dark/

Someone in Google fat-thumbbed a
Border Gateway Protocol (BGP) advertisement
and sent Japanese Internet traffic into a black hole.

[...] the result of which was traffic from Japanese giants
like NTT and KDDI was sent to Google
on the expectation it would be treated as transit.

The outage in Japan **only lasted a couple of hours**,
but was so severe that [...] the country's
Internal Affairs and Communications ministries
want carriers to report on what went wrong.

People also often mistakenly destroy
their own infrastructure



Traders work on the floor of the New York Stock Exchange (NYSE) in July 2015.
(Photo by Spencer Platt/Getty Images)

DOWNTIME

UPDATED: "Configuration Issue" Halts Trading on NYSE

The article has been updated with the time trading resumed.

A second update identified the cause of the outage as a "configuration issue."

A third update added information about a software update that created the configuration issue.

NYSE network operators identified the culprit of the 3.5 hour outage, blaming the incident on a “network configuration issue”

JUL 8, 2015 @ 03:36 PM 11,261 VIEWS

United Airlines Blames Router for Grounded Flights

**Alexandra Talty**, CONTRIBUTOR*I cover personal finance and travel.*[FOLLOW ON FORBES \(110\)](#)

Opinions expressed by Forbes Contributors are their own.

FULL BIO ▾

After a computer problem caused nearly two hours of grounded flights for United Airlines this morning and ongoing delays throughout the day, the airline announced the culprit: a [faulty router](#).

Spokeswoman Jennifer Dohm said that the router problem caused “degraded network connectivity,” which affected various applications.

A computer glitch in the airline’s reservations system caused the Federal Aviation Administration to impose a groundstop at 8:26 a.m. E.T. Planes that were in the air continued to operate, but all planes on the ground were held. There were reports of agents writing tickets by hand. The ground stop was lifted around 9:47 a.m. ET.

<http://bit.ly/2sBJ2jf>

The Internet Under Crisis Conditions

Learning from September 11

Committee on the Internet Under Crisis Conditions:
Learning from September 11

Computer Science and Telecommunications Board
Division on Engineering and Physical Sciences

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The Internet Under Crisis Conditions

Learning from September 11

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Internet advertisements rates
suggest that

The Internet was **more stable
than normal on Sept 11**

The Internet Under Crisis Conditions

Learning from September 11

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Learning from September 11

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Division on Engineering and Physical Sciences

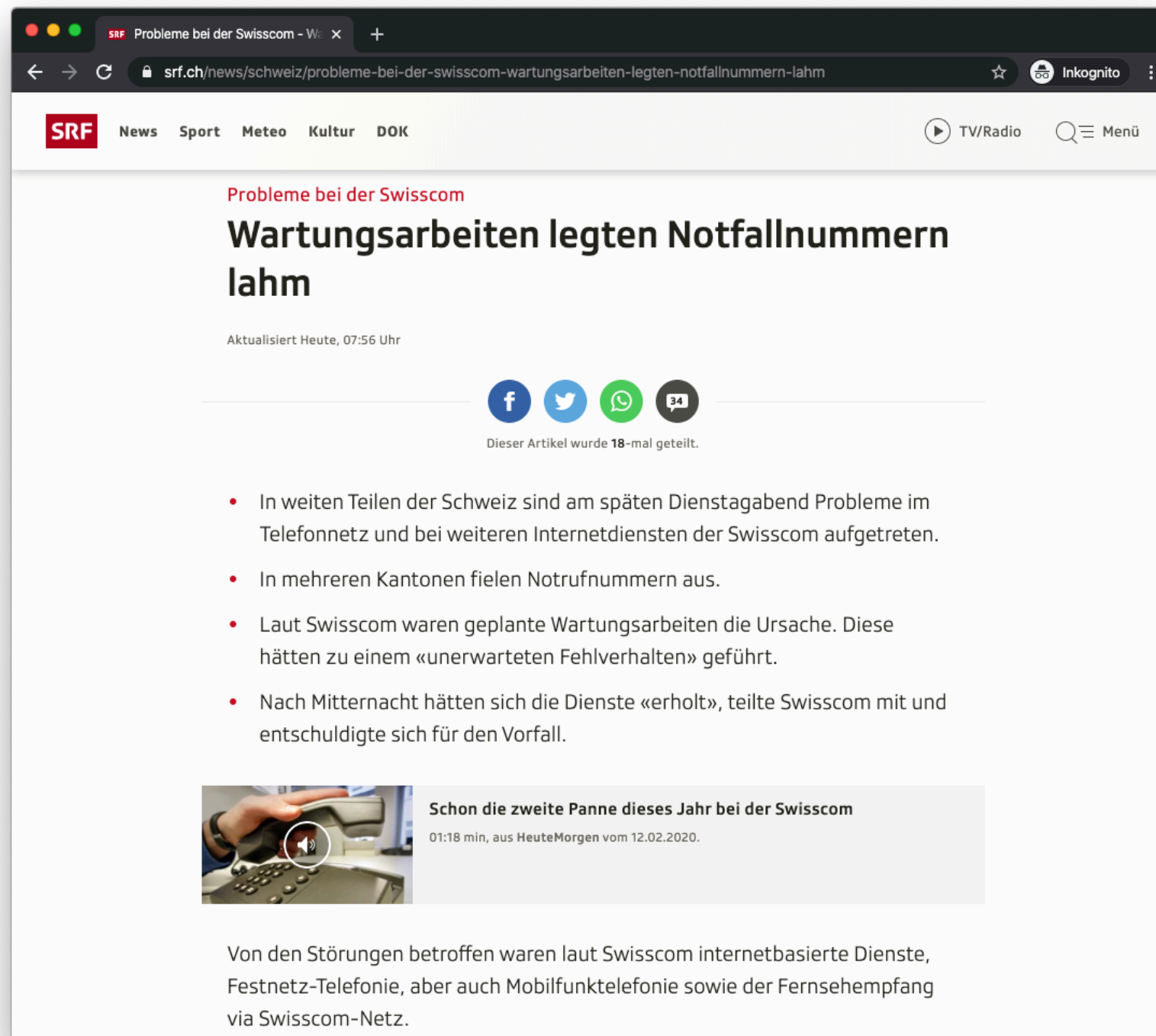
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Internet advertisements rates
suggest that

The Internet was **more stable**
than normal on Sept 11

Information suggests that
operators were **watching the news**
instead of making changes
to their infrastructure

Planned maintenance work in Swisscom's network shuts down emergency numbers (11.02.2020)



The screenshot shows a web browser window with the SRF logo and navigation links (News, Sport, Meteo, Kultur, DOK) at the top. The article title is "Probleme bei der Swisscom: Wartungsarbeiten legten Notfallnummern lahm". It is dated "Aktualisiert Heute, 07:56 Uhr". Below the title are social media sharing icons for Facebook, Twitter, WhatsApp, and a comment icon showing 34 comments. A note states "Dieser Artikel wurde 18-mal geteilt." The main text consists of four bullet points describing the network issues. At the bottom, there is a video player with a thumbnail of a hand holding a telephone receiver, titled "Schon die zweite Panne dieses Jahr bei der Swisscom", and a paragraph summarizing the impact of the outages.

Probleme bei der Swisscom

Wartungsarbeiten legten Notfallnummern lahm

Aktualisiert Heute, 07:56 Uhr

Dieser Artikel wurde 18-mal geteilt.

- In weiten Teilen der Schweiz sind am späten Dienstagabend Probleme im Telefonnetz und bei weiteren Internetdiensten der Swisscom aufgetreten.
- In mehreren Kantonen fielen Notrufnummern aus.
- Laut Swisscom waren geplante Wartungsarbeiten die Ursache. Diese hätten zu einem «unerwarteten Fehlverhalten» geführt.
- Nach Mitternacht hätten sich die Dienste «erholt», teilte Swisscom mit und entschuldigte sich für den Vorfall.

Schon die zweite Panne dieses Jahr bei der Swisscom

01:18 min, aus HeuteMorgen vom 12.02.2020.

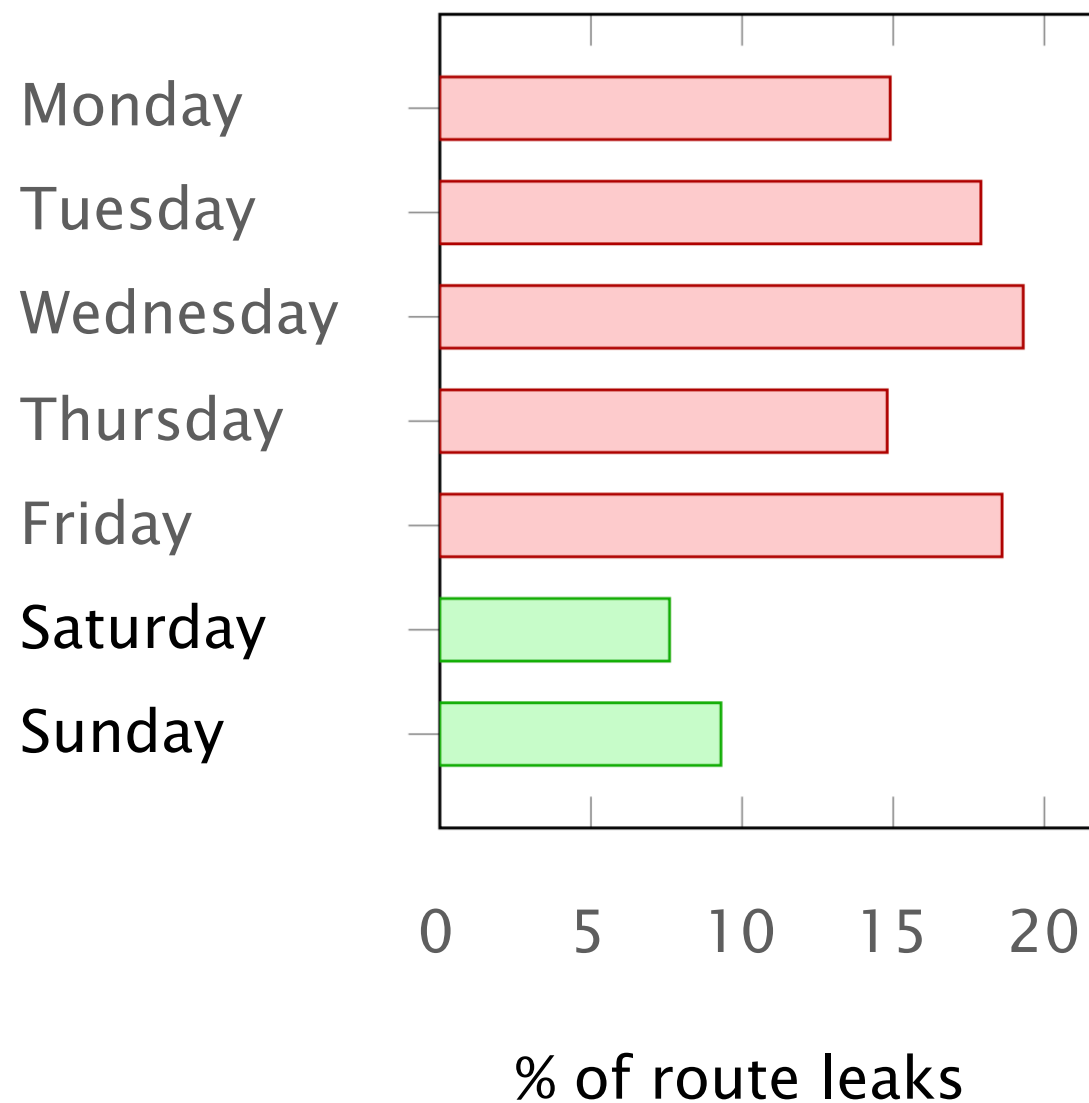
Von den Störungen betroffen waren laut Swisscom internetbasierte Dienste, Festnetz-Telefonie, aber auch Mobilfunktelefonie sowie der Fernsehempfang via Swisscom-Netz.

Internet, 4G, TV
and telephone
network affected
as well

“Human factors are responsible
for 50% to 80% of network outages”

Juniper Networks, *What's Behind Network Downtime?*, 2008

Ironically, this means that data networks work better during week-ends...



source: Job Snijders (NTT)

“Cost per network outage
can be as high as 750 000\$”

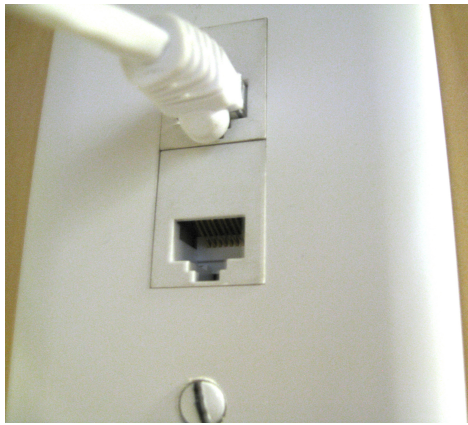
Smart Management for Robust Carrier Network Health
and Reduced TCO!, NANOG54, 2012

Communication Networks

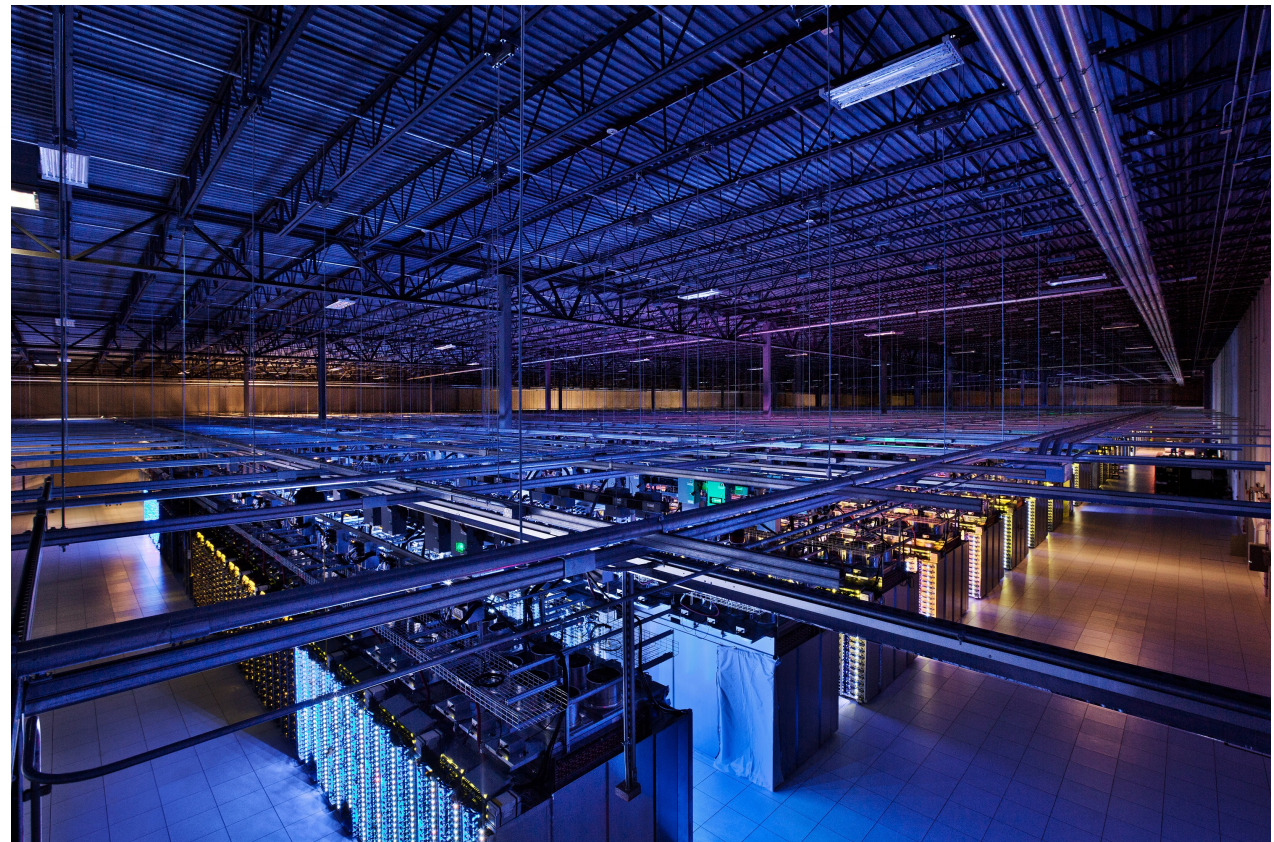
Course goals

Knowledge

Understand how the Internet works **and why**



from your
network plug...



...to Google's data-center

Insights

Key concepts and problems in Networking

Naming

Layering

Routing

Reliability

Sharing

Naming Layering Routing Reliability Sharing

How do you address computers, services, protocols?

Naming **Layering** Routing Reliability Sharing

How do you **manage complexity**?

Naming Layering **Routing** Reliability Sharing

How do you **go from A to B?**

Naming Layering Routing **Reliability** Sharing

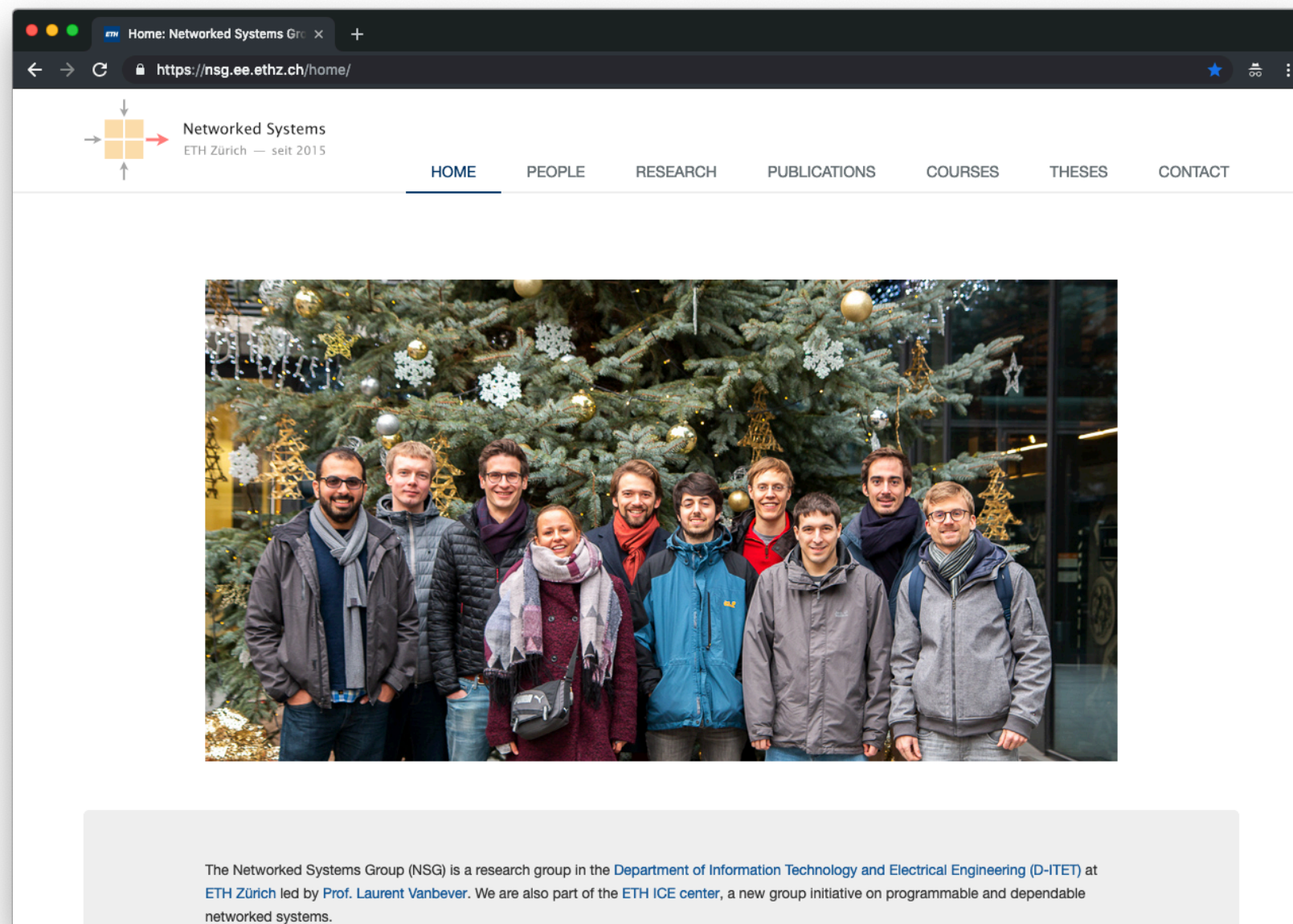
How do you **communicate reliably using unreliable mediums?**

Naming Layering Routing Reliability **Sharing**

How do you **divide scarce resources among competing parties?**

Insights

Current research developments

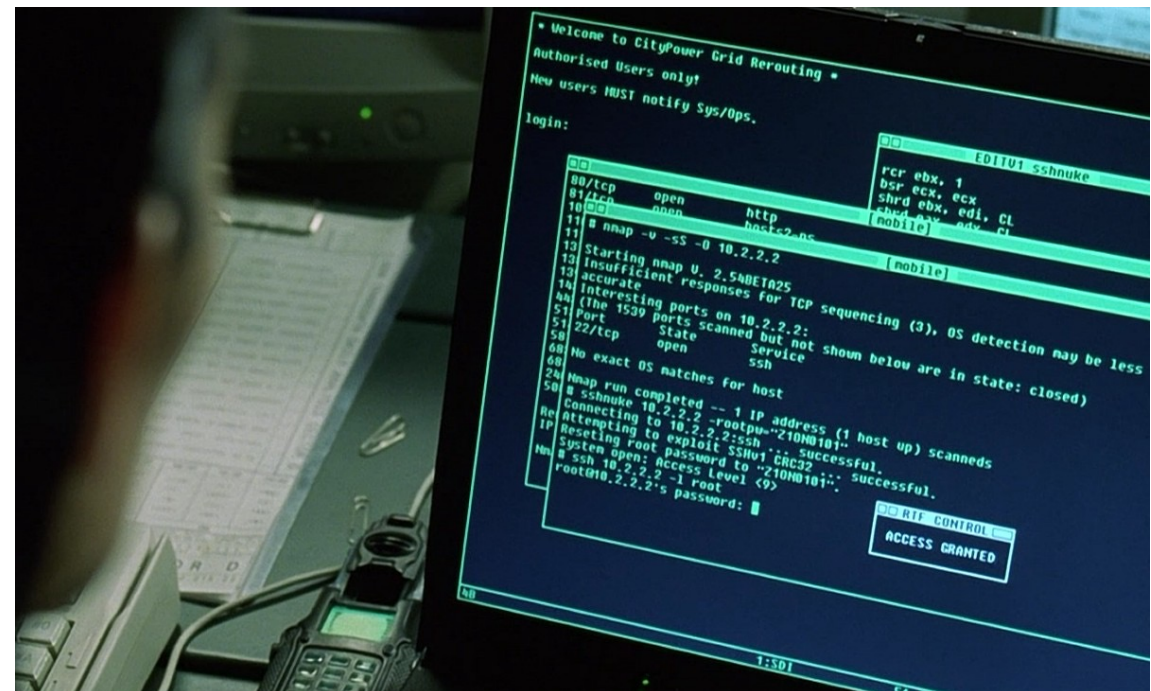


Networked Systems Group

nsg.ee.ethz.ch

Skills

Build, operate and configure networks



Trinity using a port scanner (nmap) in Matrix Reloaded™

Communication Networks

Course organization

Your dream team for the semester



Tobias [head]



Alexander



Rüdiger



Coralie



Thomas



Roland



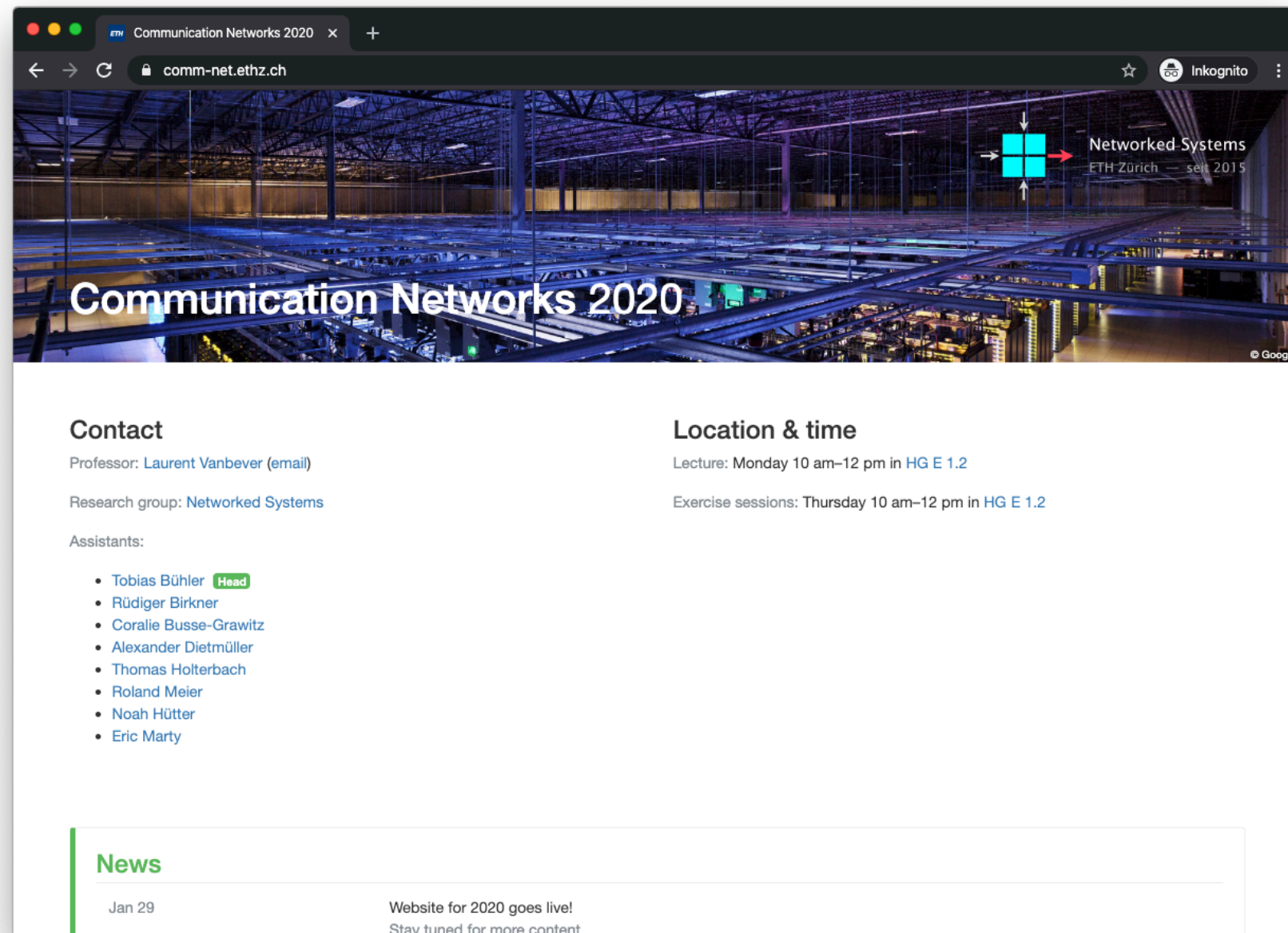
Noah



Eric

followed the lecture
in previous years

Our website: <https://comm-net.ethz.ch>
check it out regularly!



Slides, exercises, projects, extra readings, previous exams, ...

The course will be split in three parts

Part 1

Overview

~1.5 lectures

Part 2

Concepts

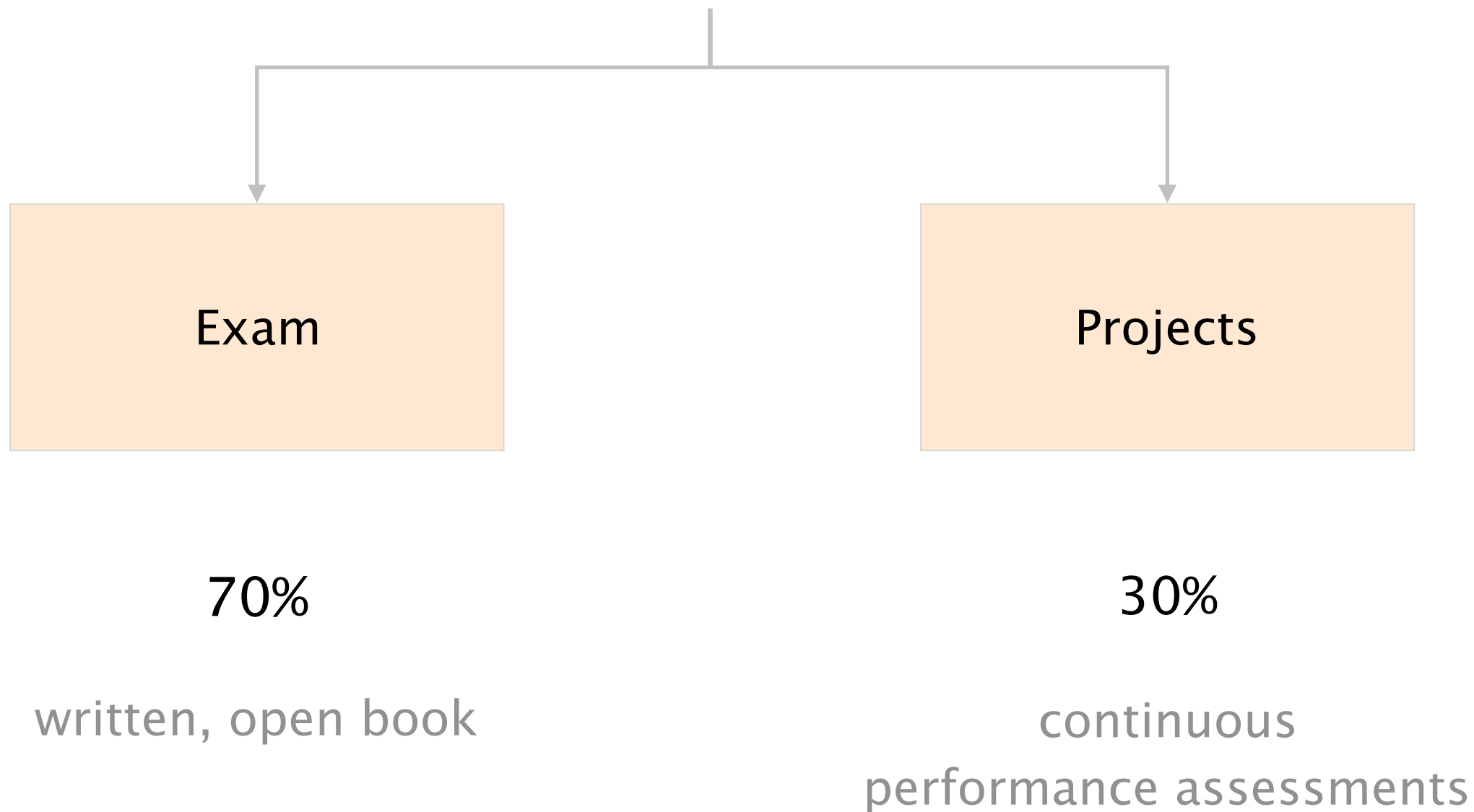
~1.5 lectures

Part 3

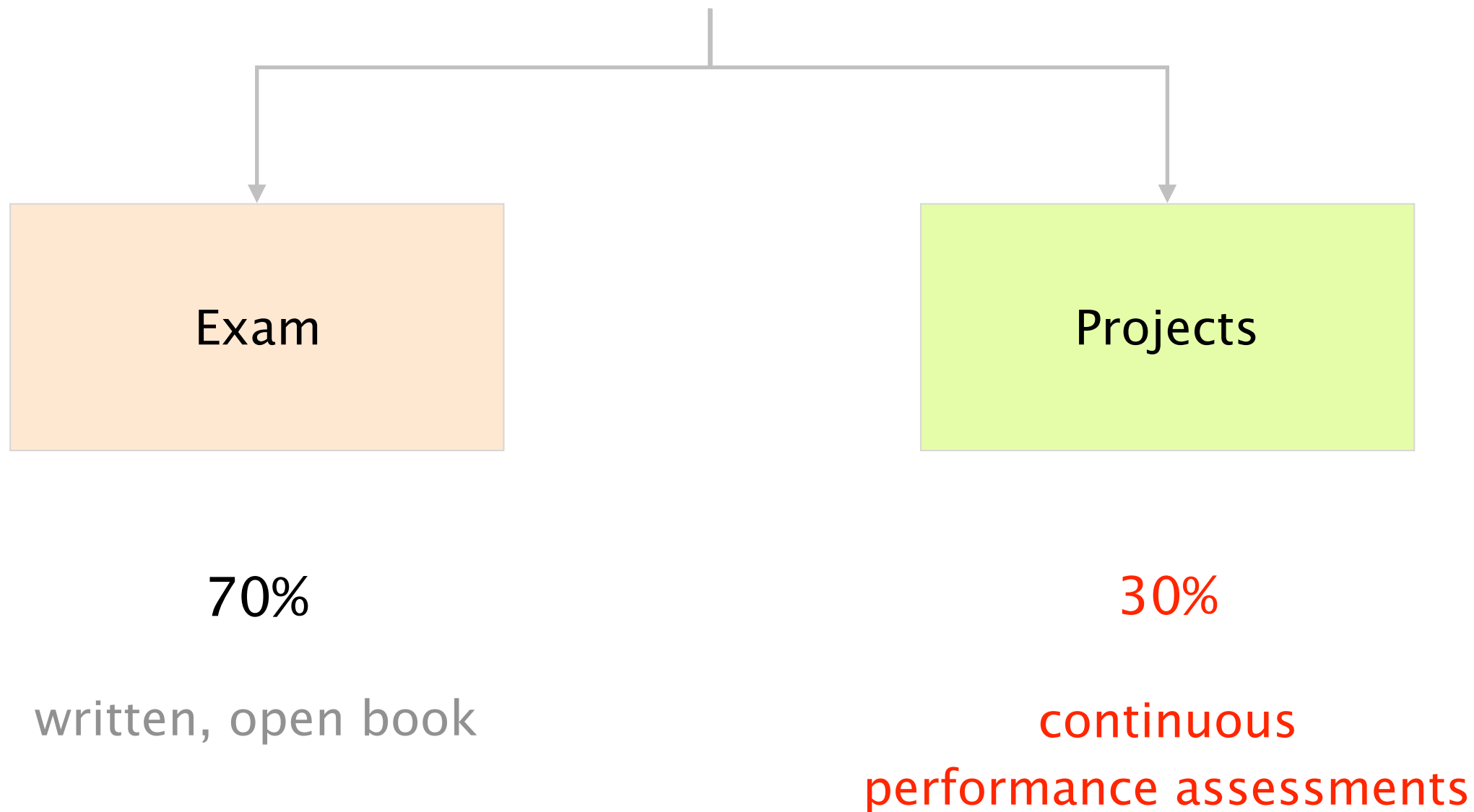
Today's Internet

~10 lectures

Your final grade



Your final grade



There will be two practical projects,
to be done in group of maximum three students

- #1 Build and operate a real, working “Internet” (20%)
- #2 Implement an interoperable reliable protocol (10%)

Detailed instructions will follow

If you are a repeating student,
let us know if you want to keep your grades!

“Internet Hackathon”

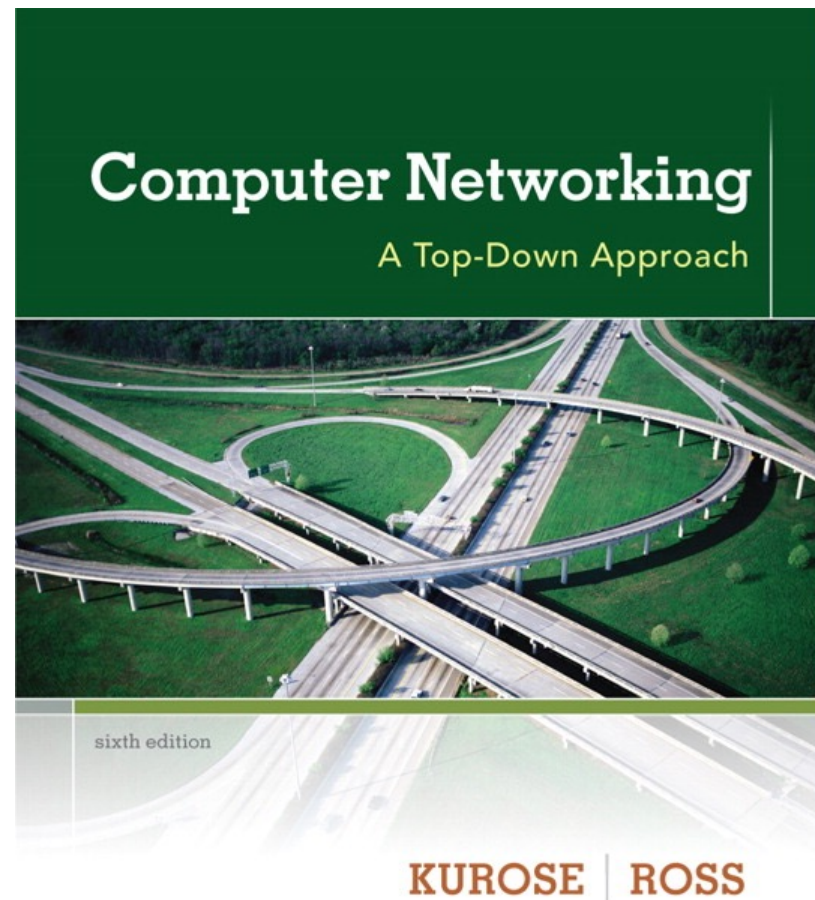
sometime around week 6-7

2016 edition



The course follows the textbook

Computer Networking: a Top-Down Approach

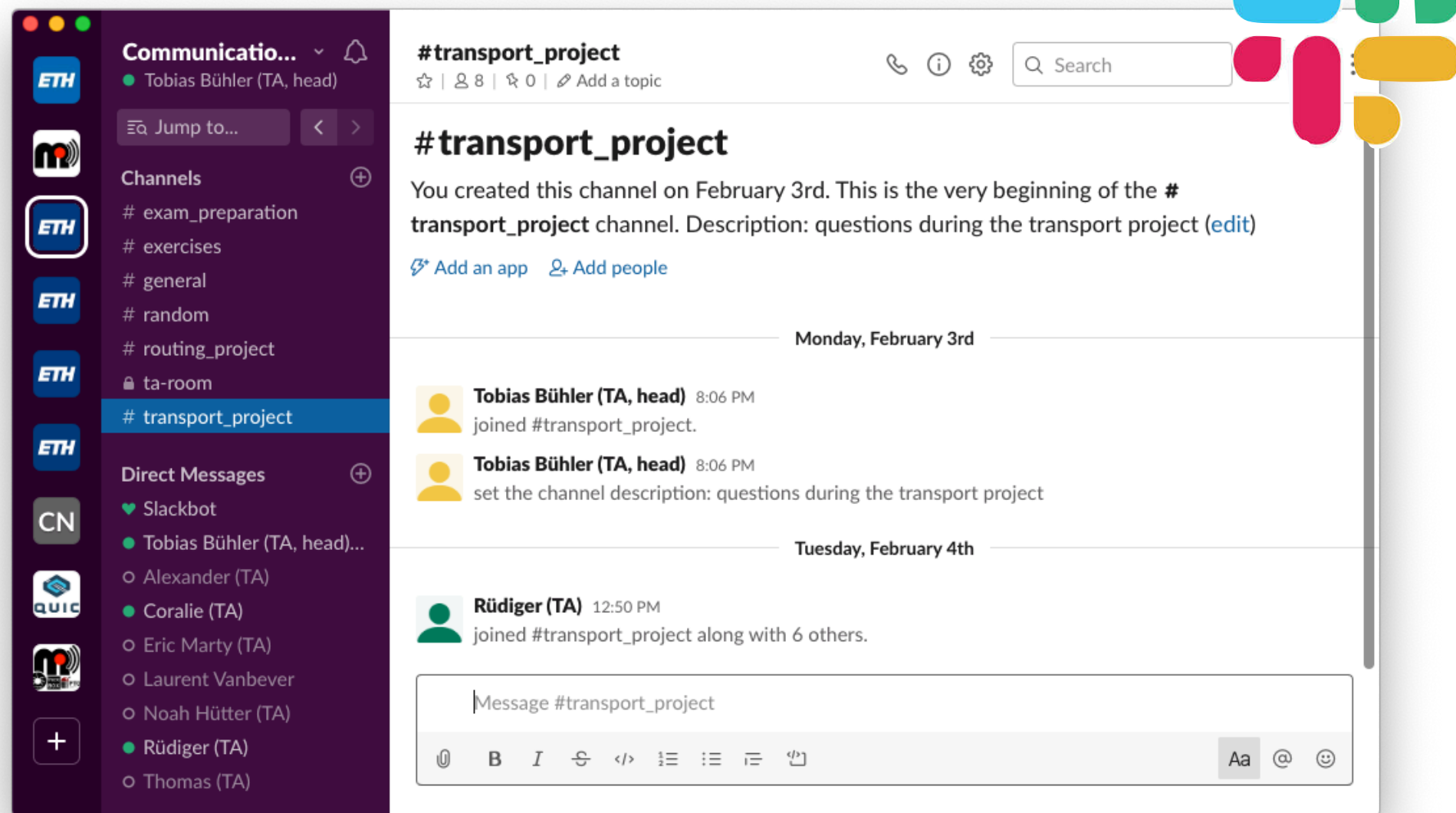


6th edition

ok to use the 5th or 7th

see sections indicated
on comm-net.ethz.ch

We'll use **Slack** (a chat client)
to discuss about the course and assignments



Web, smartphone and desktop clients available

Using Slack is facultative but highly recommended

Use Slack to

- ask questions
- chat with other students (e.g. your group)
- be informed about course announcements
(also on our website)

Register today

> <https://join.slack.com/t/comm-net20/signup>

Register with your @ethz.ch email

Ping us if you prefer using another one

Use your real name

It greatly facilitates our organization...

We will never use Slack to distribute sensitive data

e.g. your project grades

Communication Networks

Communication Networks

Part 1: Overview



- #1 What is a network made of?
- #2 How is it shared?
- #3 How is it organized?
- #4 How does communication happen?
- #5 How do we characterize it?

Communication Networks

Part 1: Overview



#1

What is a network made of?

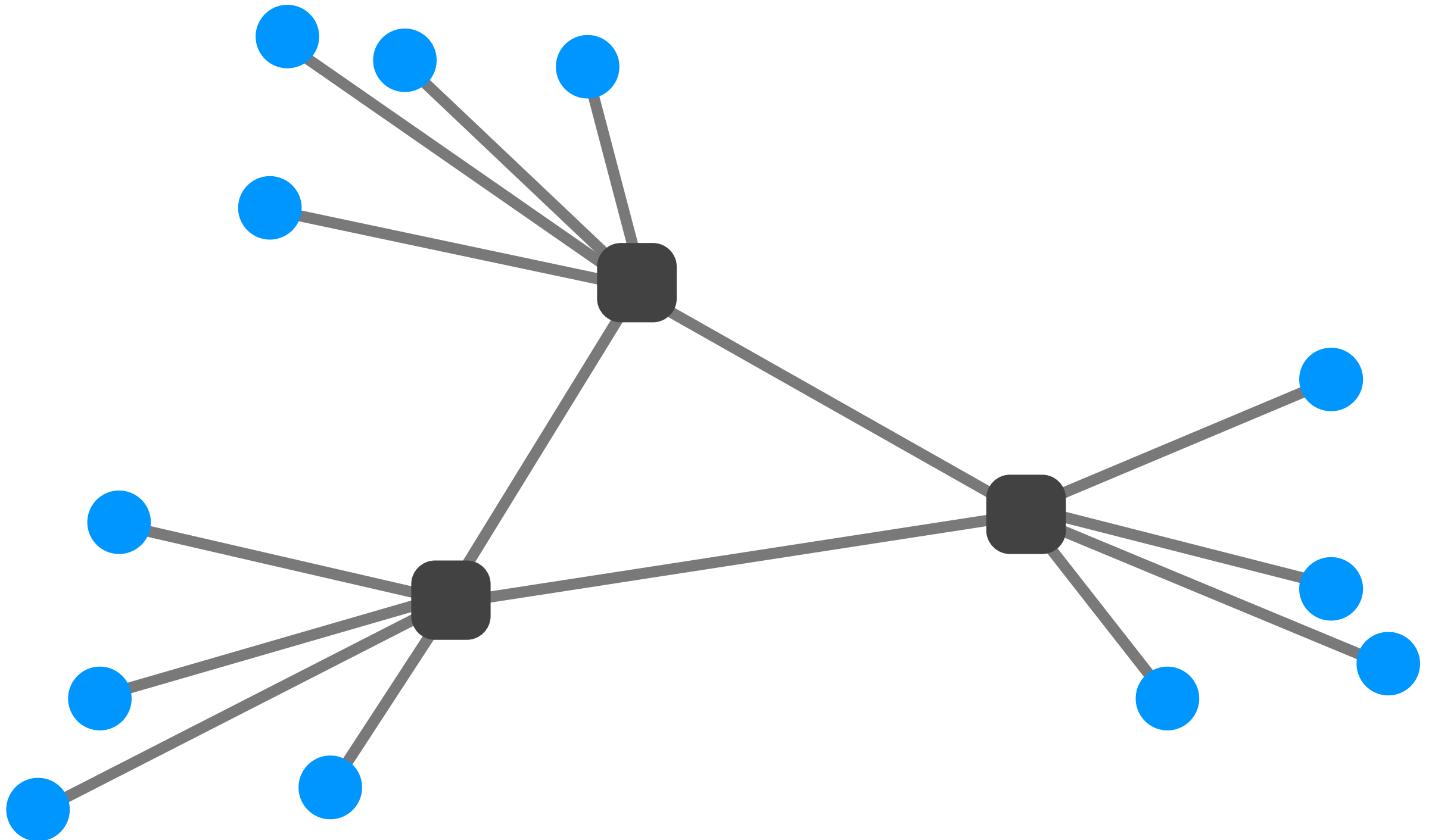
How is it shared?

How is it organized?

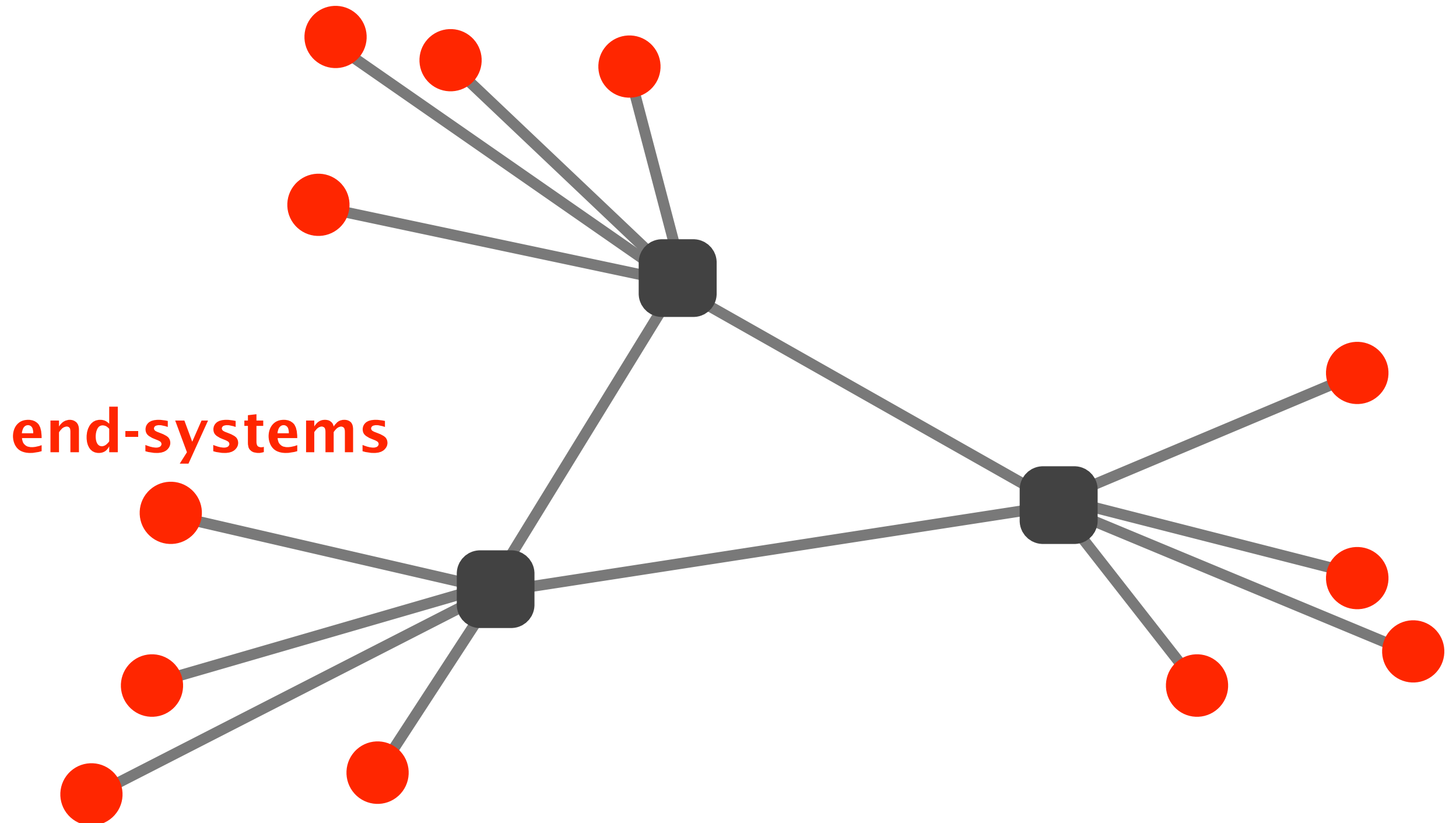
How does communication happen?

How do we characterize it?

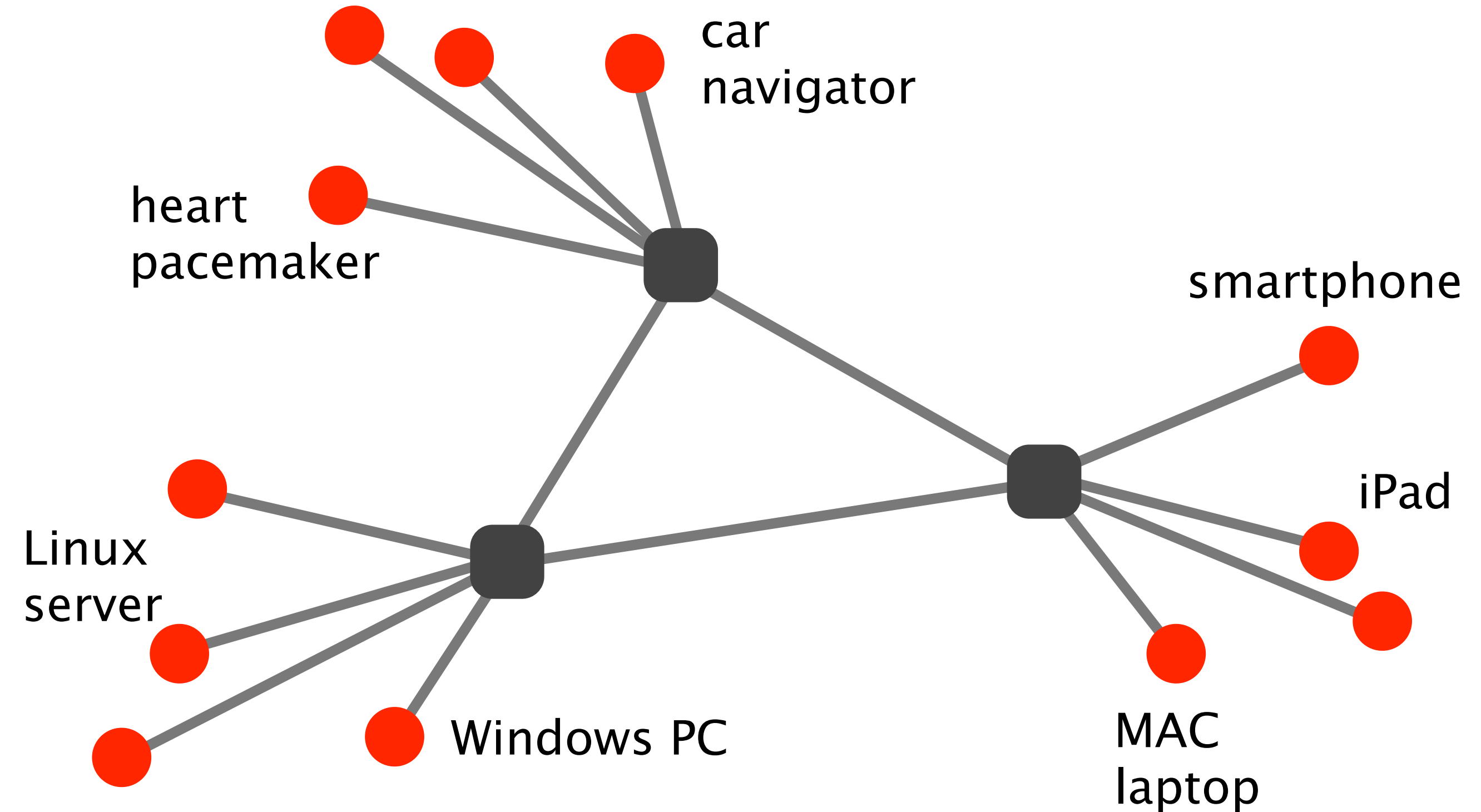
Networks are composed of three basic components



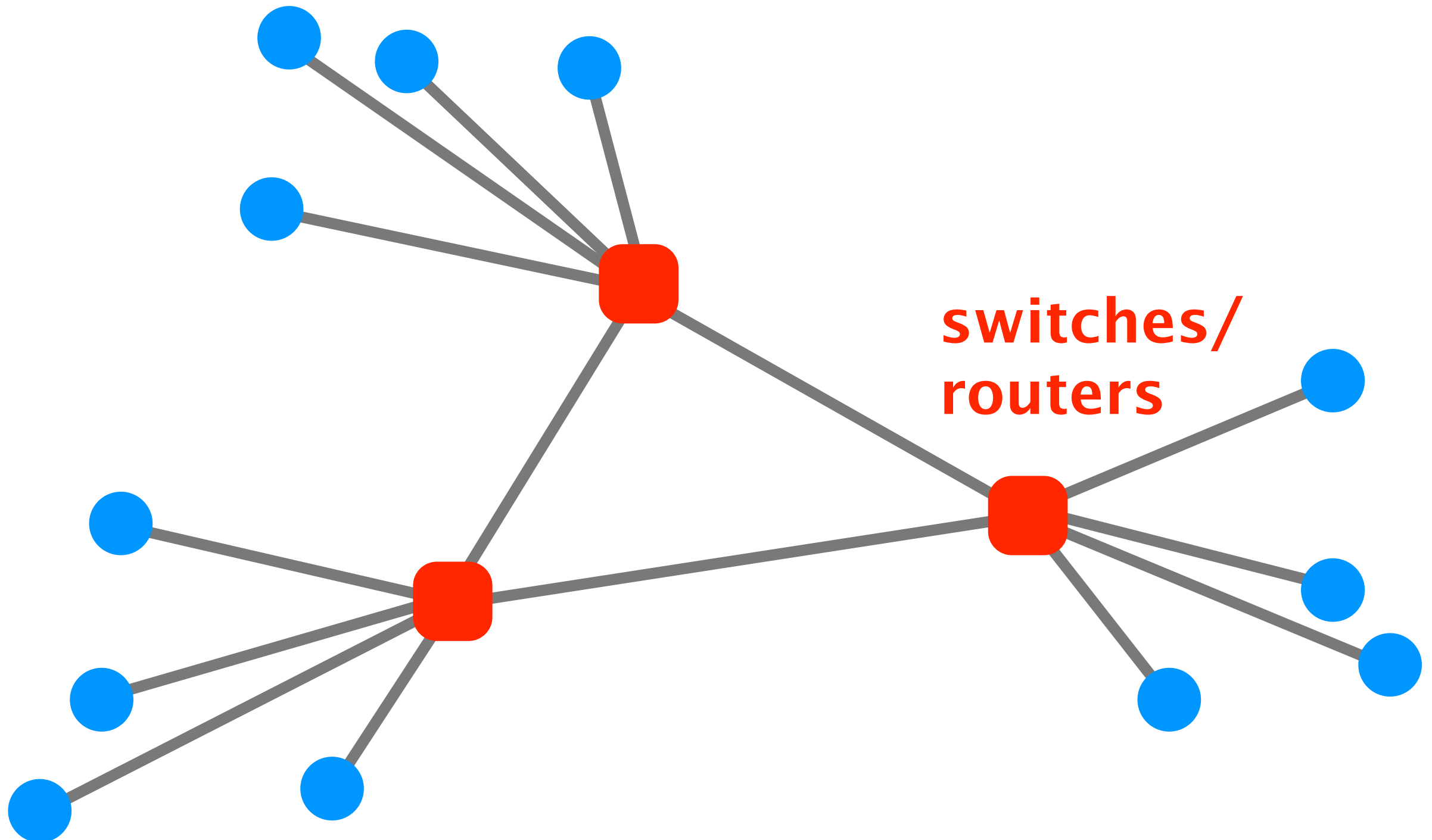
End-systems send & receive data



End-systems come in a wide-variety



Switches & routers forward data to the destination



Routers/switches vary in size and usage

Home
router



~20 cm

0,5 kg

1 Gbps

Internet core
router

>200cm

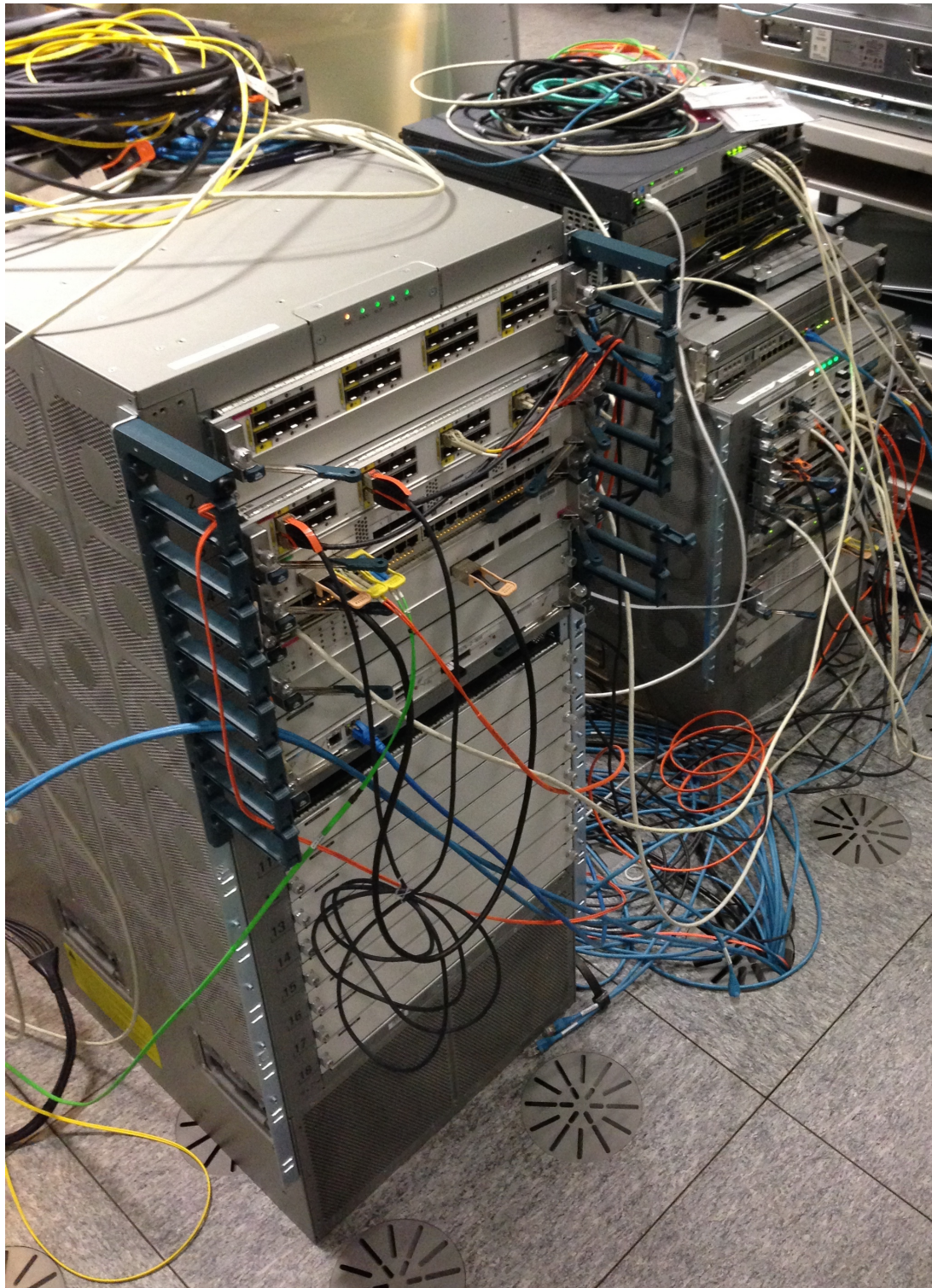
700kg

>12 Tbps

(>920 Tbps in
multi-chassis*)



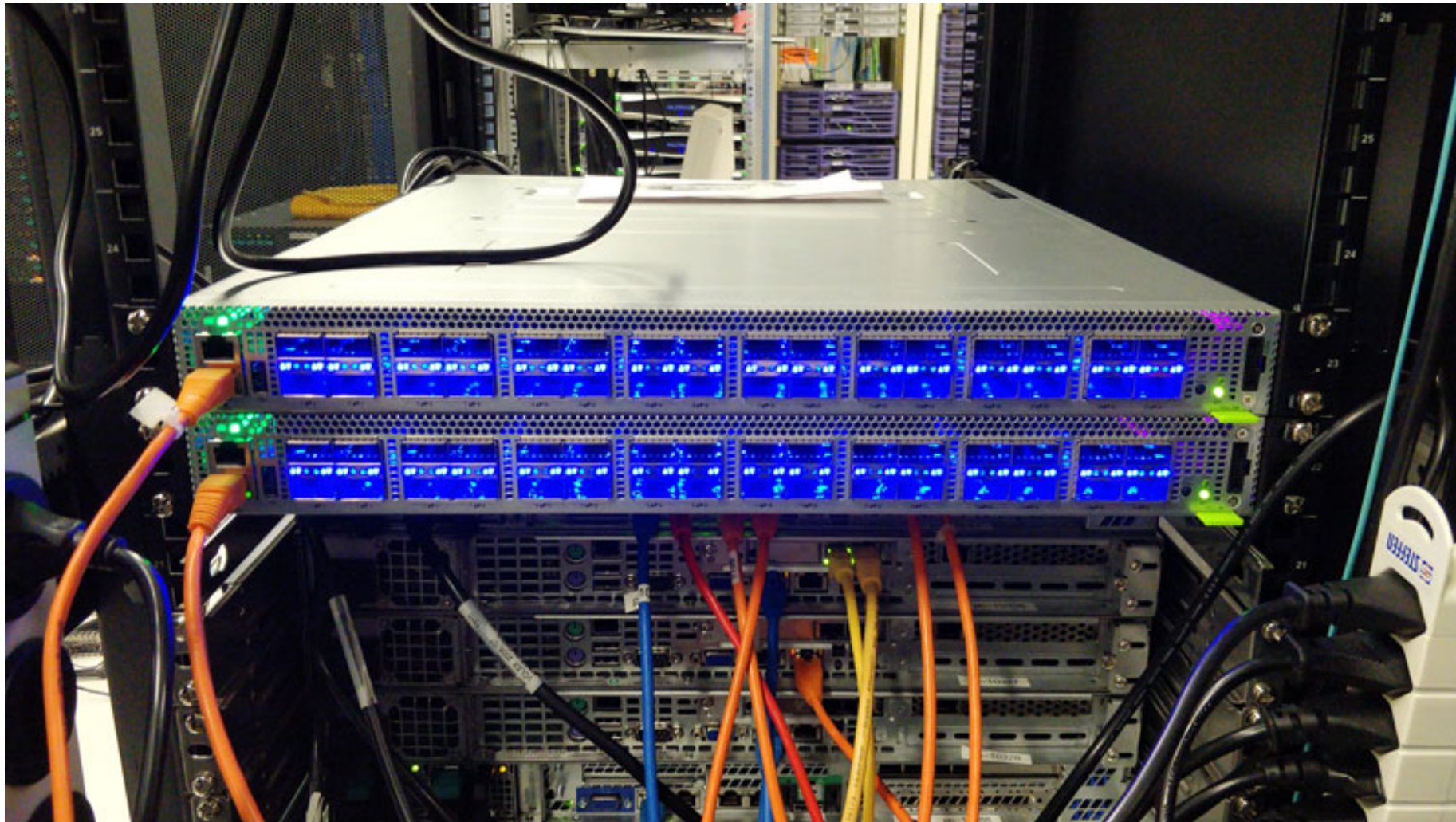
*https://www.cisco.com/c/en/us/products/collateral/routers/carrier-routing-system/data_sheet_c78-726136.html



Cisco Nexus 7k
Routers @ETHZ

~25 deployed

Next-generation programmable switches
up to 12.8 Tbps of backplane capacity*

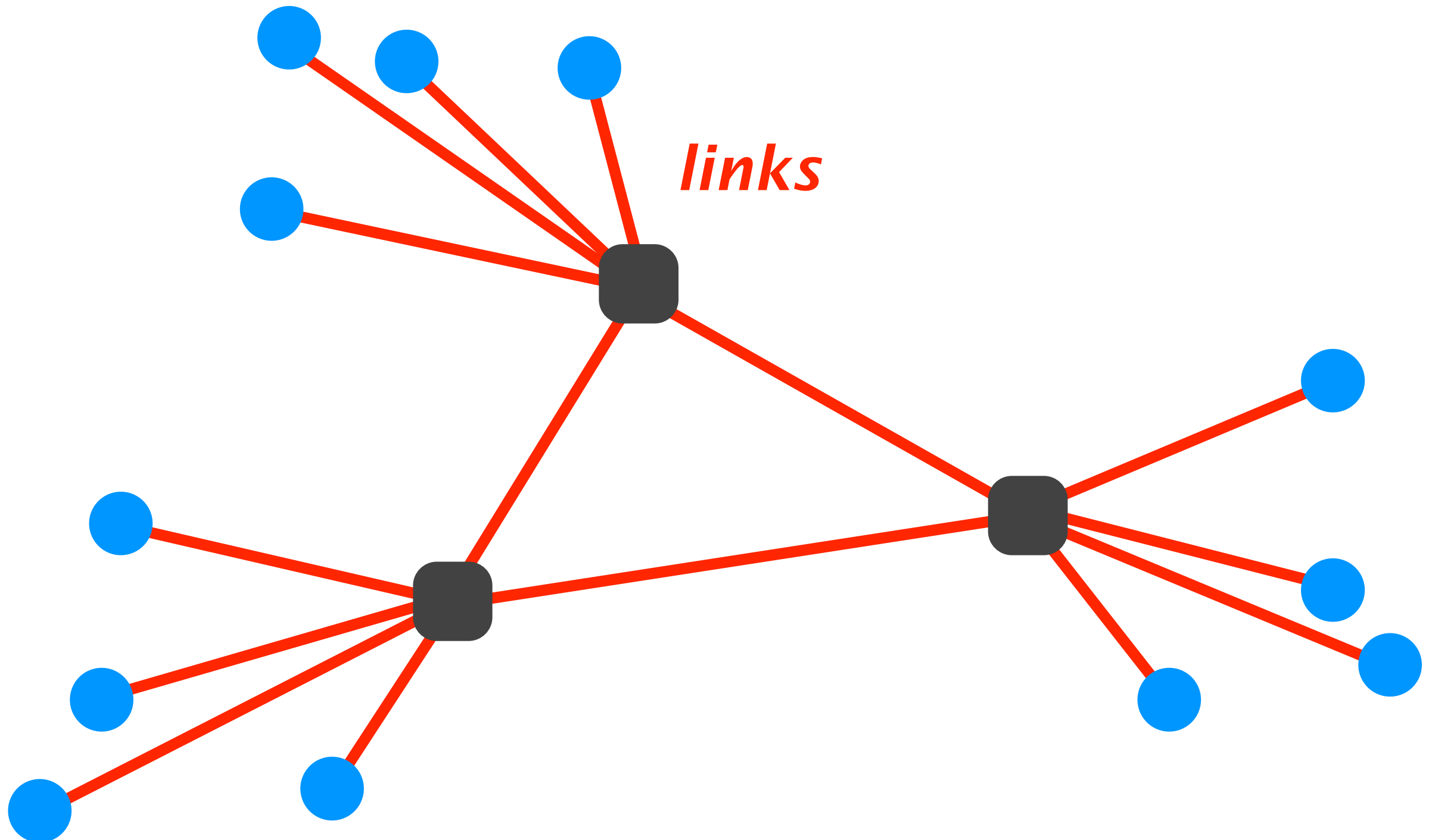


Barefoot Tofino Wedge 100BF-32X

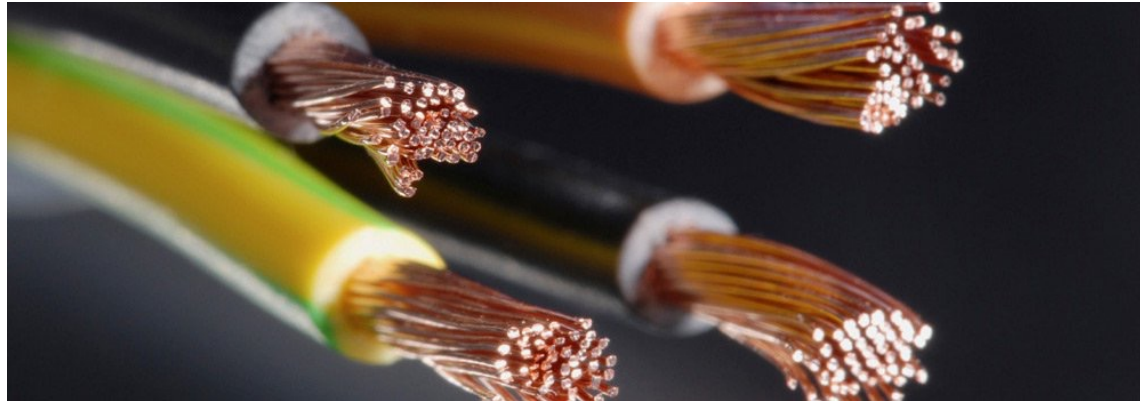
part of our NSG lab

* <https://www.barefootnetworks.com/products/brief-tofino-2/>

Links connect end-systems to switches
and switches to each other

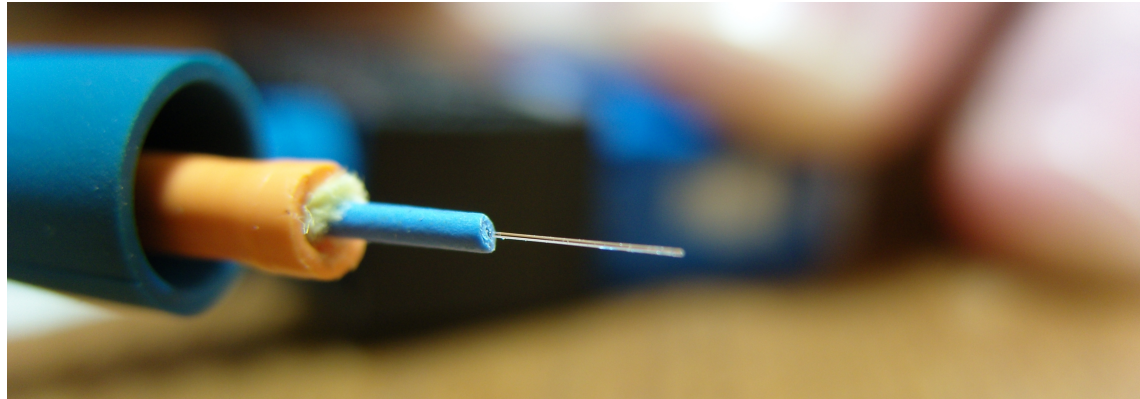


Links, too, vary in size and usage



Copper

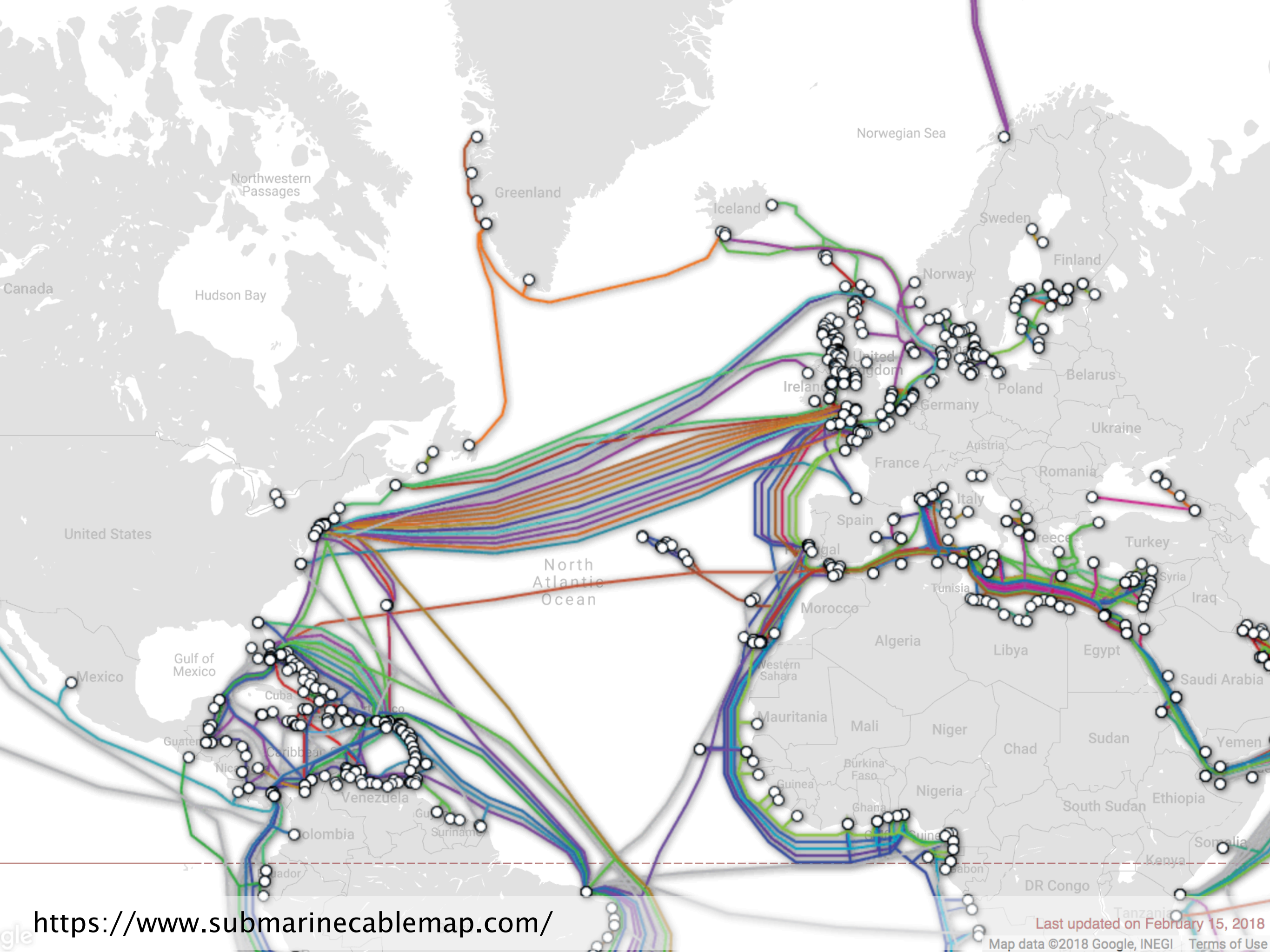
ADSL, RJ-45,...



Optical fibers



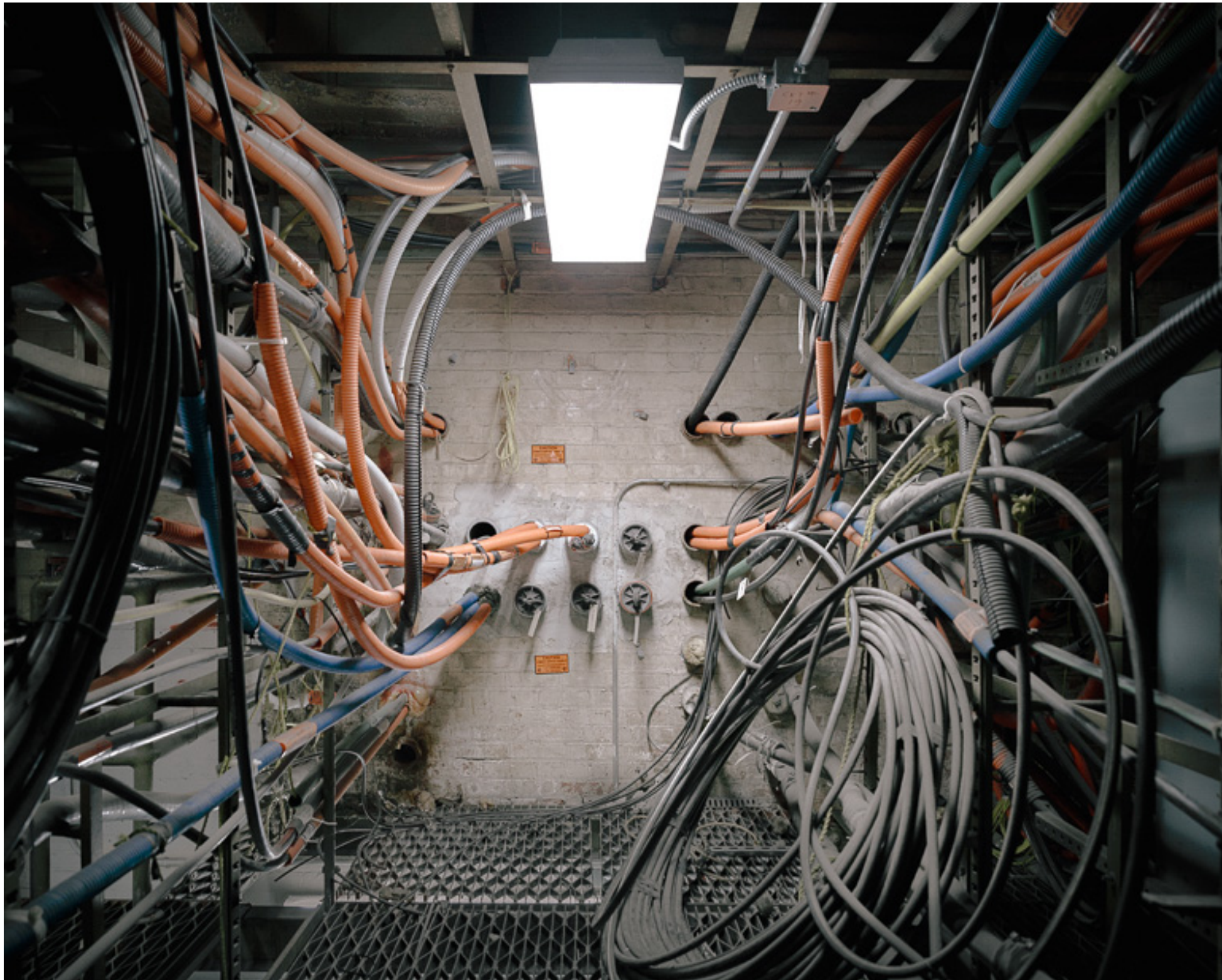
Wireless link







<https://www.wired.com/story/google-cramming-more-data-new-atlantic-cable>



Somewhere in Manhattan...

<http://www.petergarritano.com/the-internet.html>

There exists a huge amount of **access technologies**

Ethernet	most common, symmetric
DSL	over phone lines, asymmetric
CATV	via cable TV, shared
Cellular	smart phones
Satellite	remote areas
FTTH	household
Fibers	Internet backbone
Infiniband	High performance computing

Communication Networks

Part 1: Overview



What is a network made of?

#2

How is it shared?

How is it organized?

How does communication happen?

How do we characterize it?

So far, we've been discussing what
the "last mile" of the Internet looks like

What about the rest of the network?

3 must-have requirements of a good network topology

Tolerate failures

several paths between each source and destination

Possess enough sharing to be feasible & cost-effective

number of links should not be too high

Provide adequate per-node capacity

number of links should not be too small

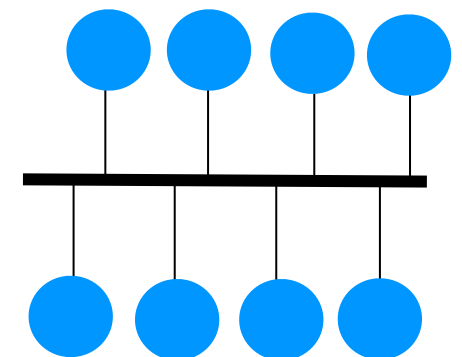
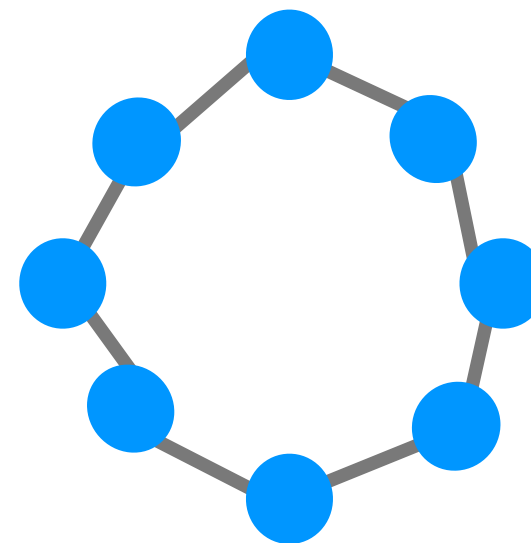
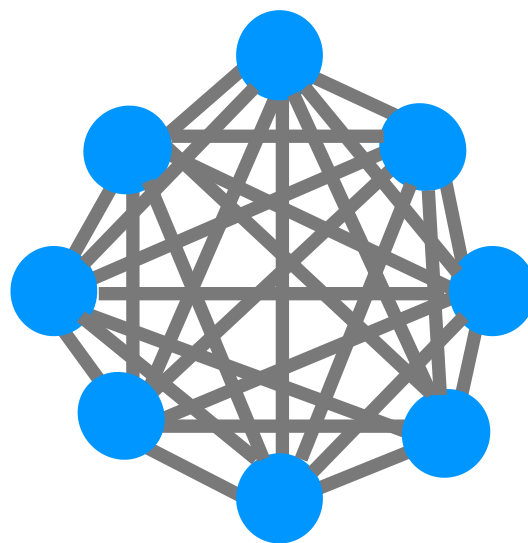
Compare these three designs in terms of
sharing, resiliency, and per-node capacity

design

full-mesh

chain

bus



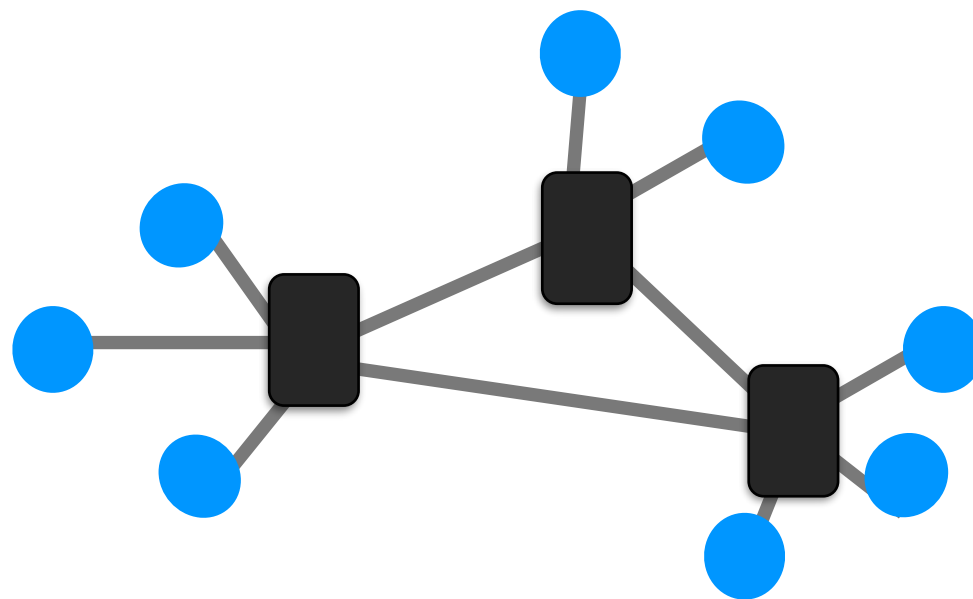
advantages

disadvantages

Switched networks provide
reasonable and **flexible** compromise

design

switched



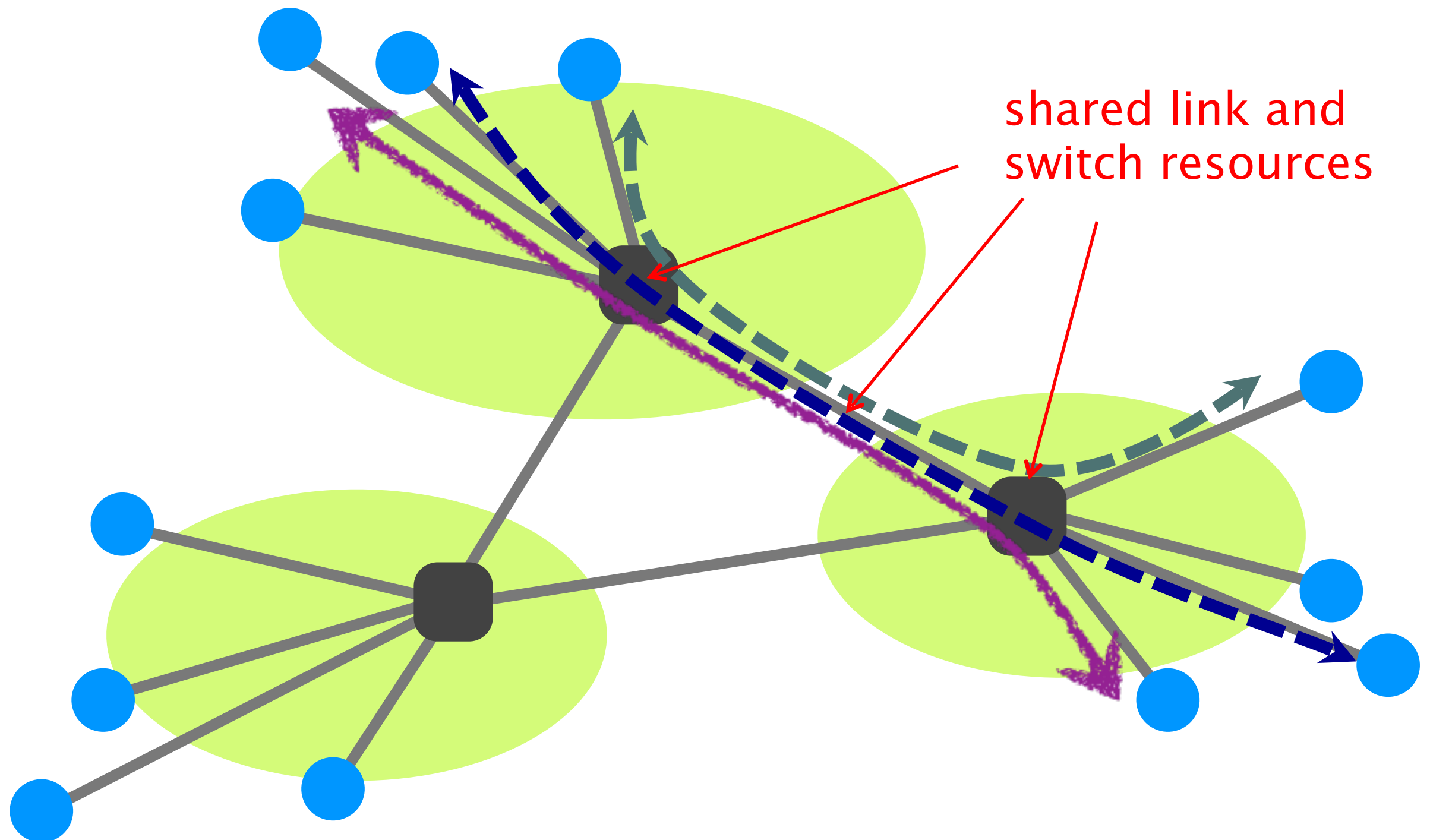
advantages

sharing and per-node capacity can be adapted
to fit the network needs

disadvantages

require smart devices to perform:
forwarding, routing, **resource allocation**

Links and switches are shared between flows



There exist two approaches to sharing:
reservation and **on-demand**



Reservation



On-demand

principle

reserve the bandwidth
you need in advance

send data when you need

Both are examples of **statistical multiplexing**

Reservation

On-demand

multiplexing

at the flow-level

at the packet-level

The two approaches are implemented using circuit-switching or packet-switching, respectively

Reservation

On-demand

implem.

circuit-switching

packet-switching

Reservation

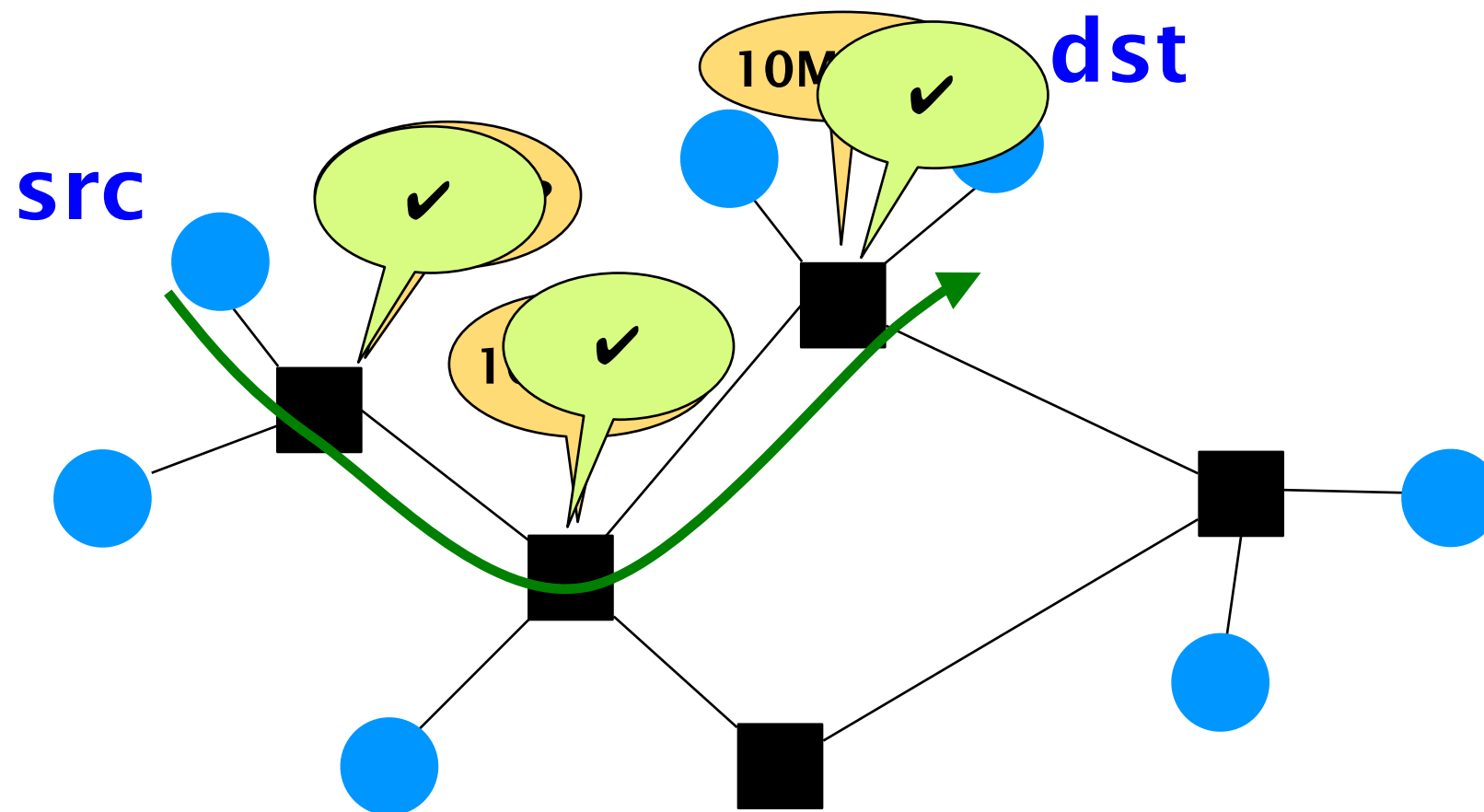
On-demand

implem.

circuit-switching

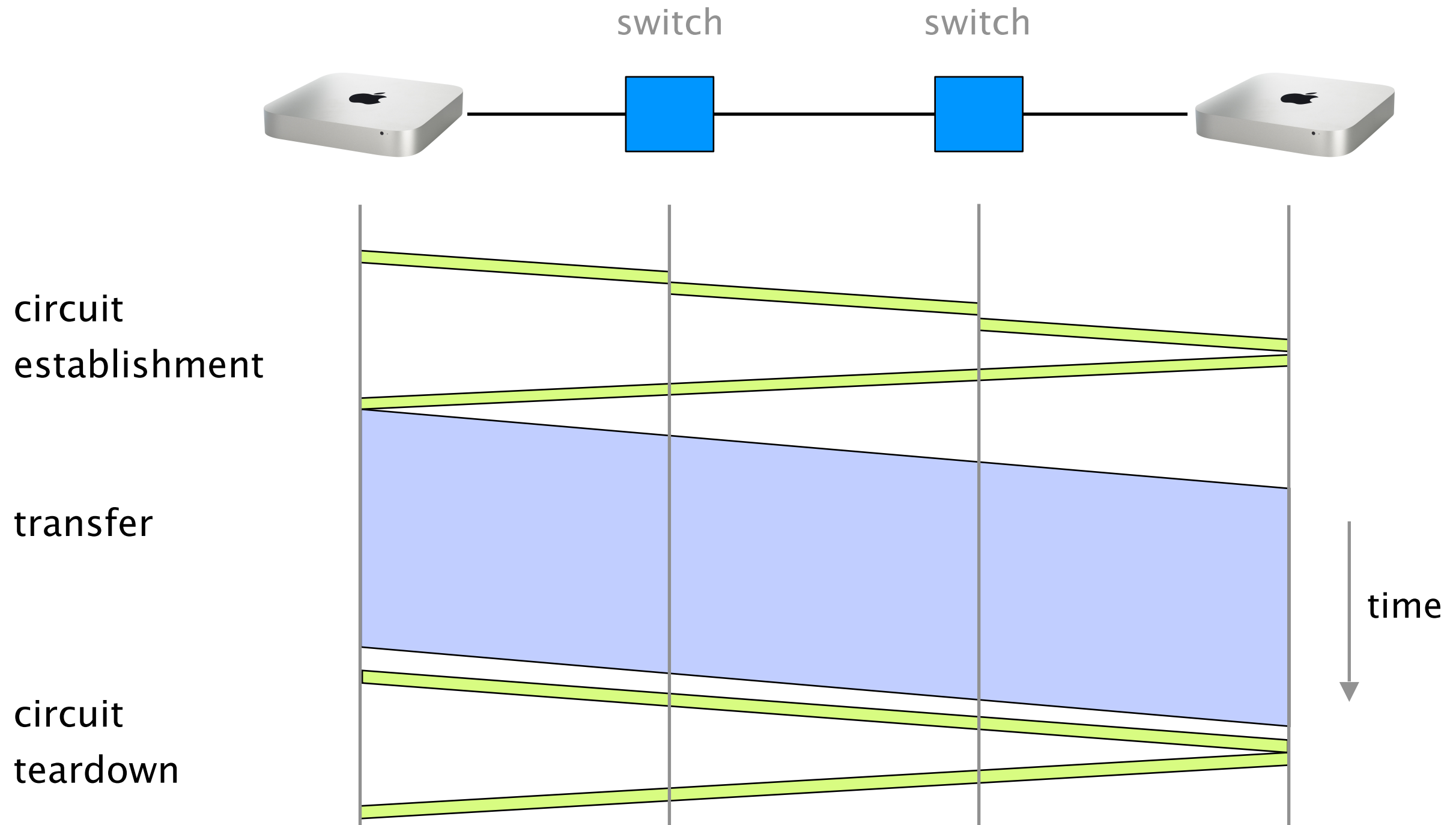
packet-switching

Circuit switching relies on the Resource Reservation Protocol



- (1) **src** sends a reservation request for 10Mbps to **dst**
- (2) switches “establish a circuit”
- (3) **src** starts sending data
- (4) **src** sends a “teardown circuit” message

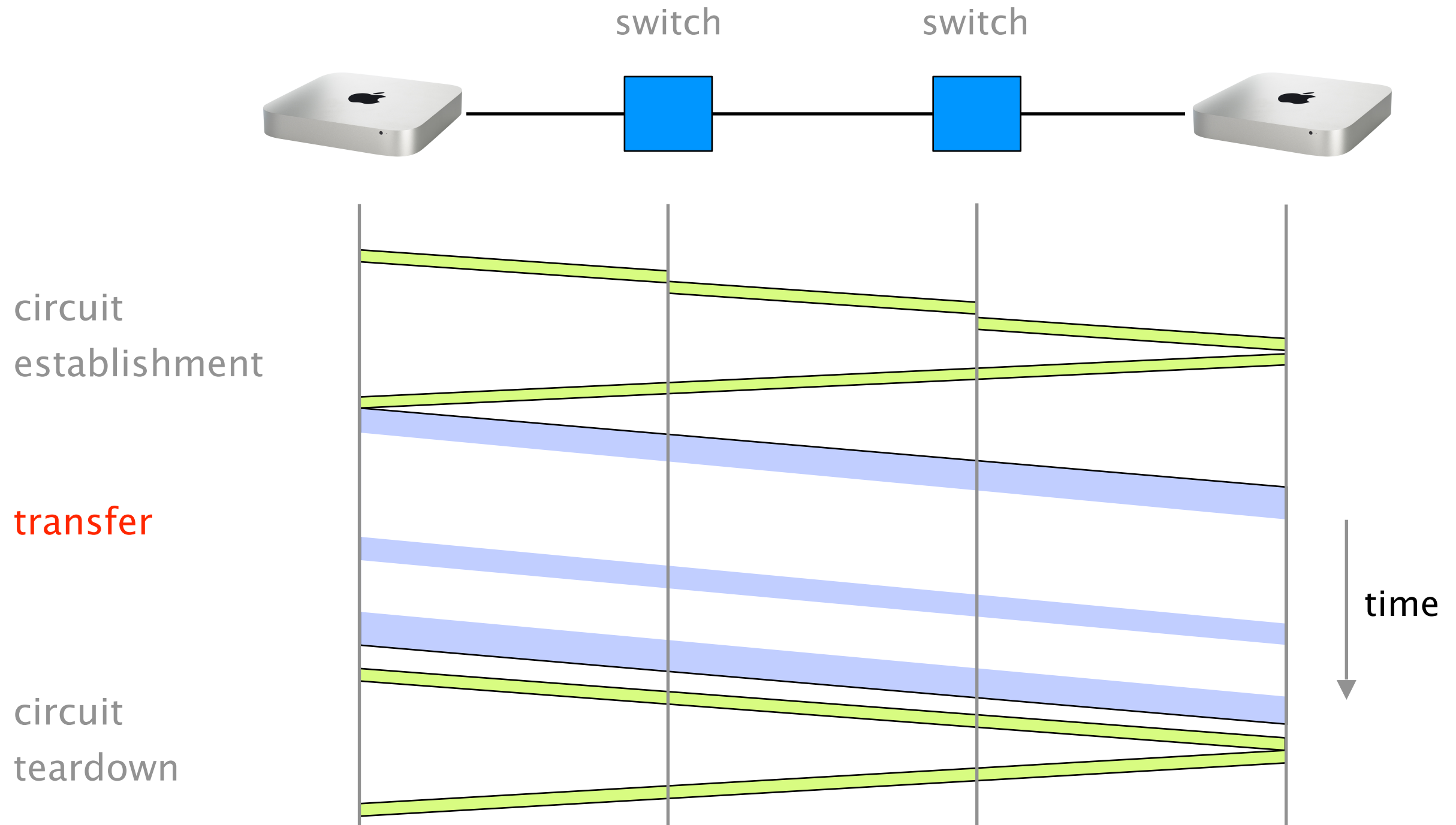
Let's walk through example of data transfer using circuit switching



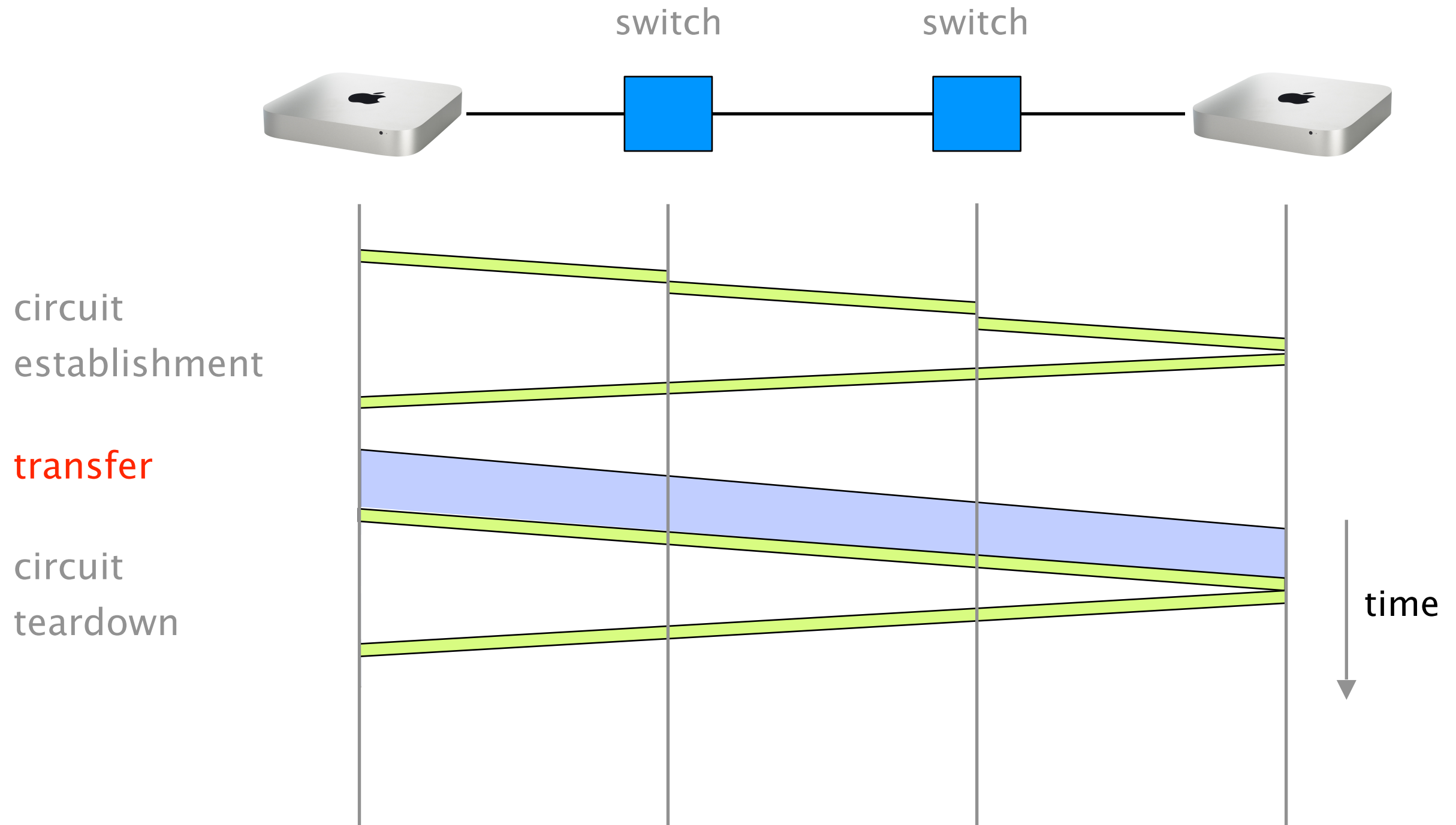
The efficiency of the transfer depends on how utilized the circuit is once established

This is an example of poor efficiency.

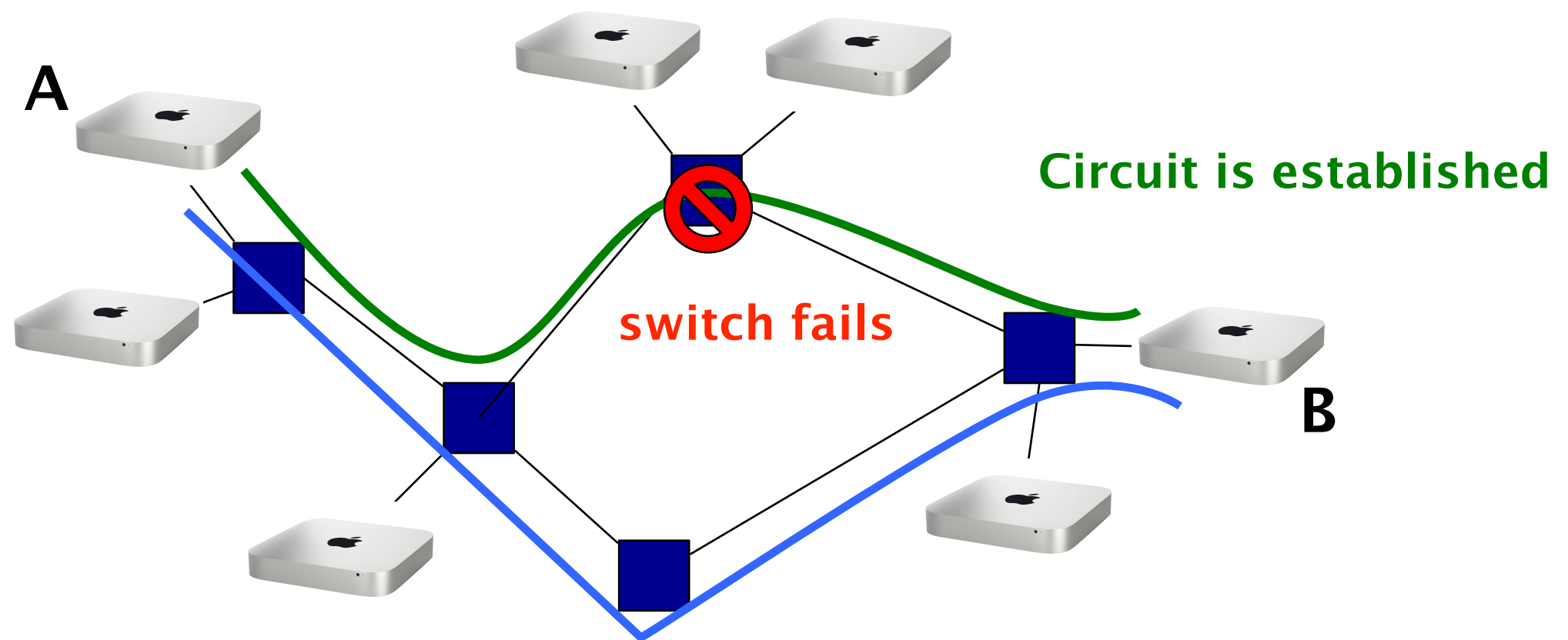
The circuit is mostly idle due to traffic bursts



This is another example of poor efficiency.
The circuit is used for a short amount of time



Another problem of circuit switching is that it doesn't route around trouble



A is forced to signal a new circuit to restore communication

Pros and cons of circuit switching

advantages

predictable performance

simple & fast switching
once circuit established

disadvantages

inefficient if traffic is bursty or short

complex circuit setup/teardown
which adds delays to transfer

requires new circuit upon failure

What about packet switching?



Reservation

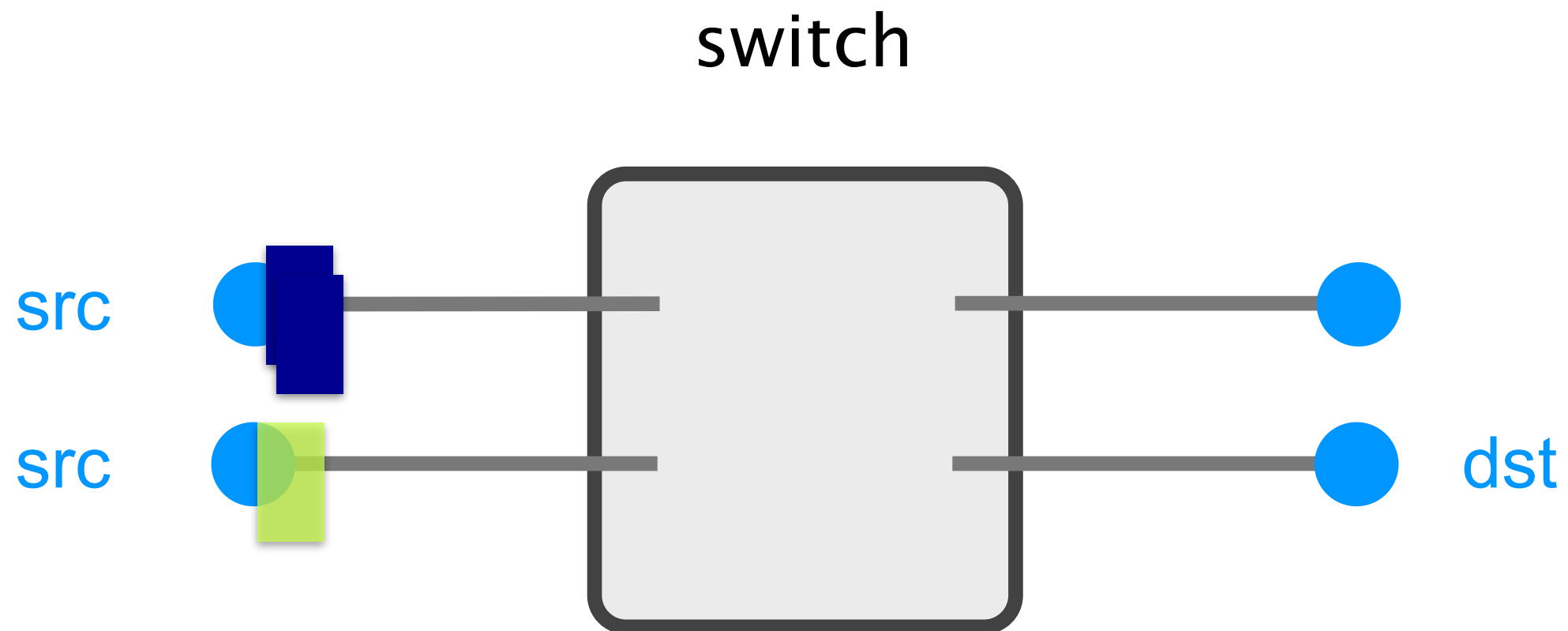
circuit-switching



On-demand

packet-switching

In packet switching,
data transfer is done using independent packets

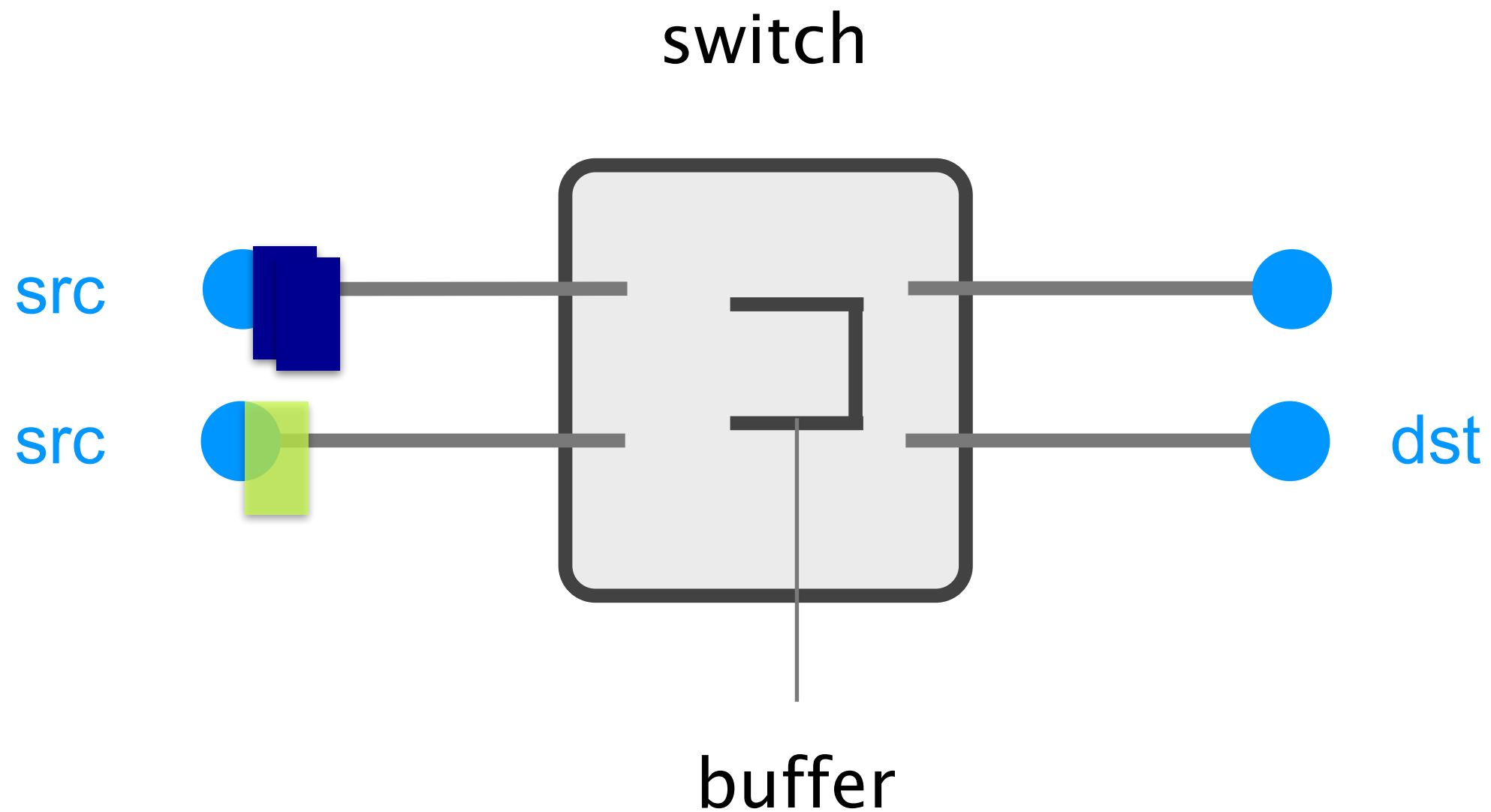


Each packet contains a destination (**dst**)

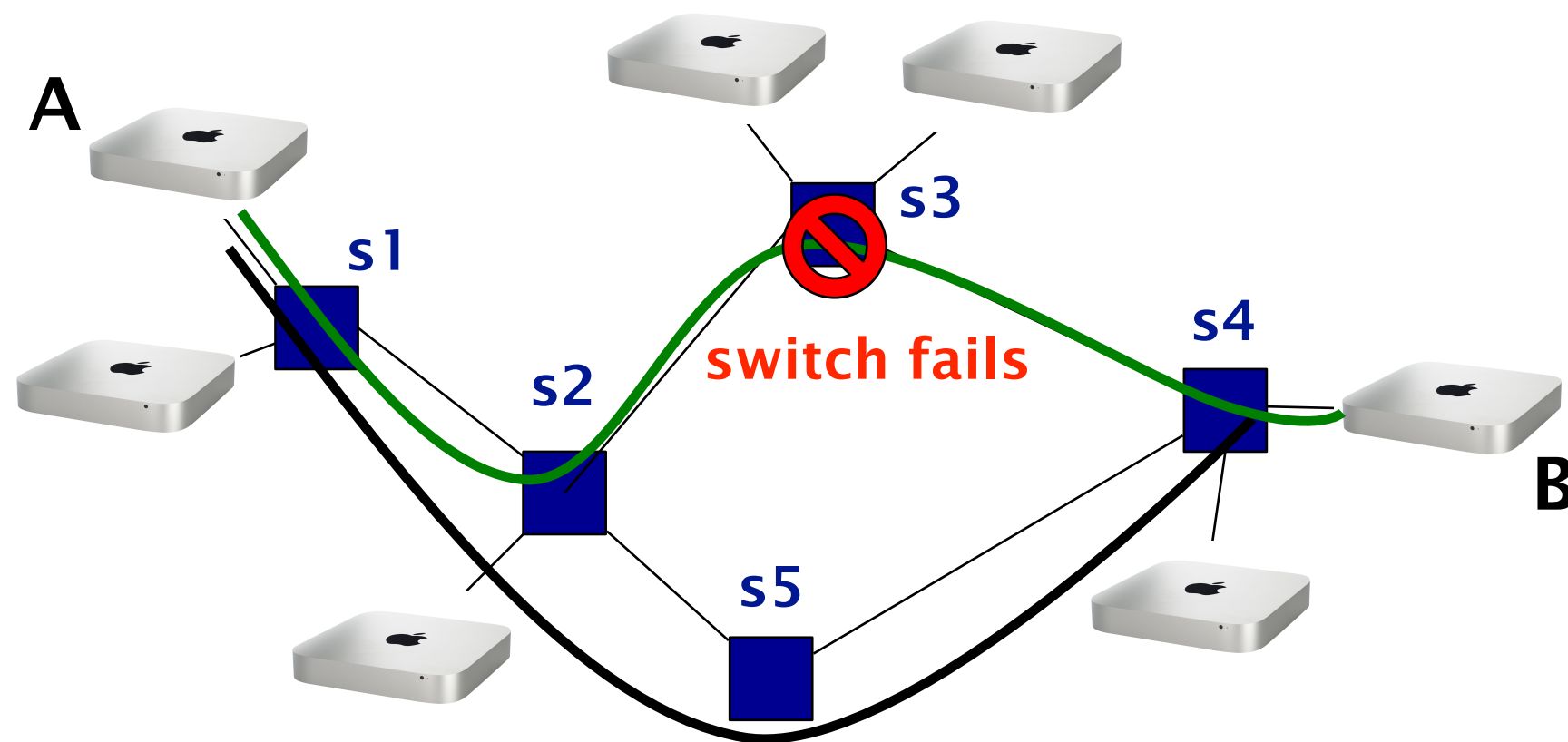
Since packets are sent without global coordination,
they can “clash” with each other

To absorb transient overload,
packet switching relies on buffers

To absorb transient overload,
packet switching relies on buffers



Packet switching routes around trouble



route recomputed
on the fly by s2

Pros and cons of packet switching

advantages

efficient use of resources

simpler to implement

route around trouble

disadvantages

unpredictable performance

requires buffer management and
congestion control

Packet switching beats circuit switching
with respect to *resiliency* and *efficiency*

Internet  packets

Packet switching will be our focus for the rest of the course

Communication Networks

Part 1: Overview



What is a network made of?

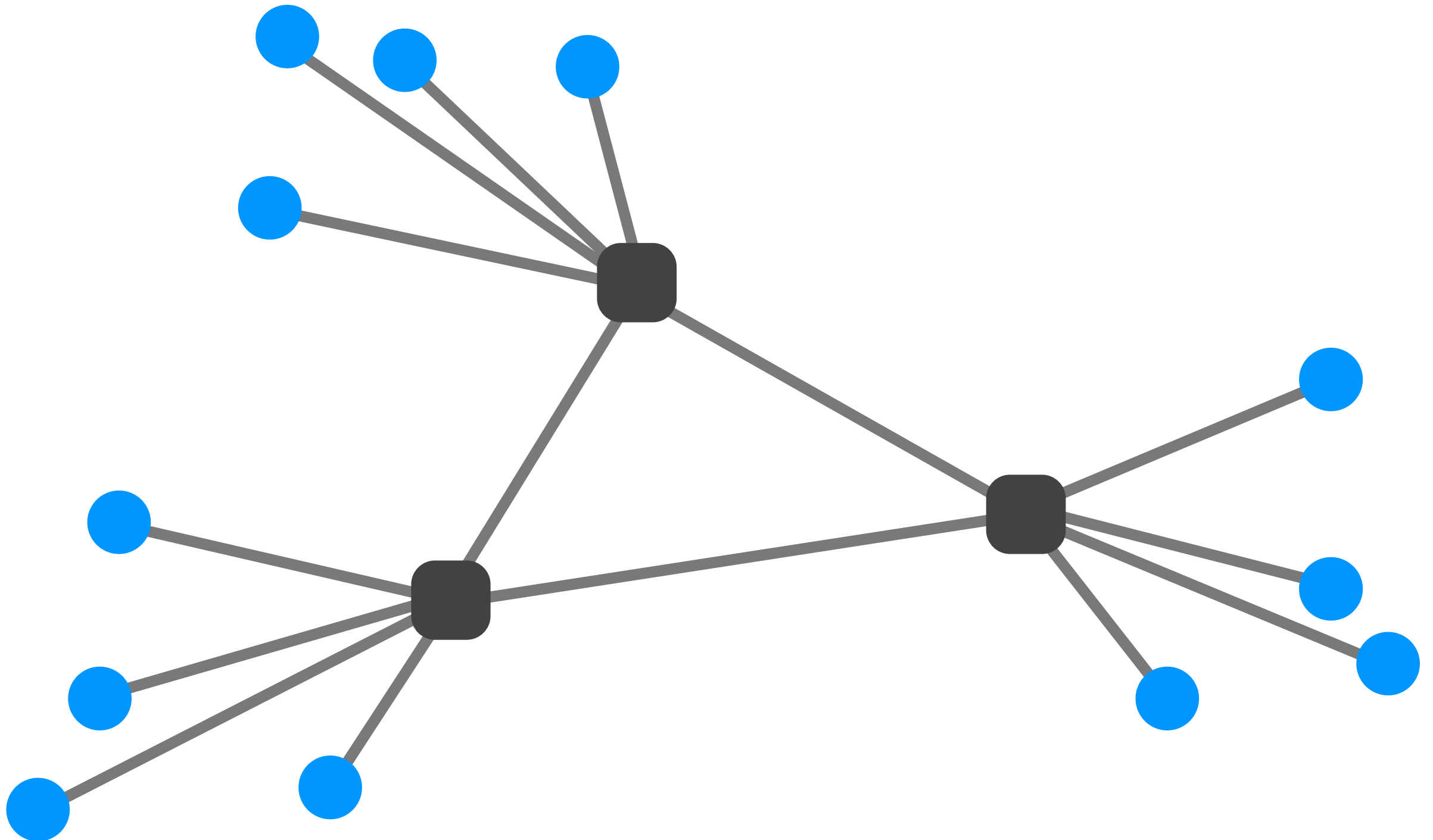
How is it shared?

#3 **How is it organized?**

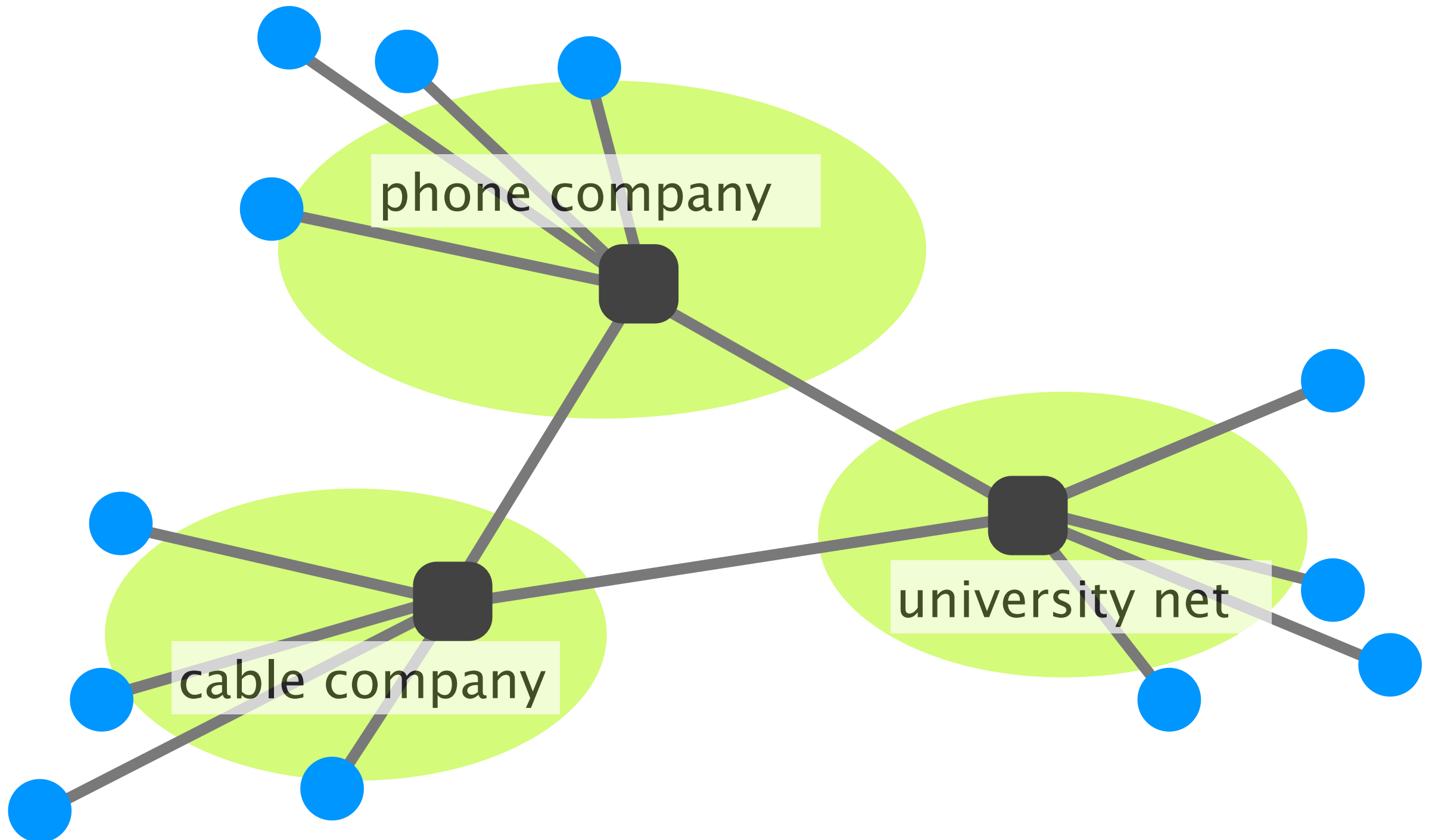
How does communication happen?

How do we characterize it?

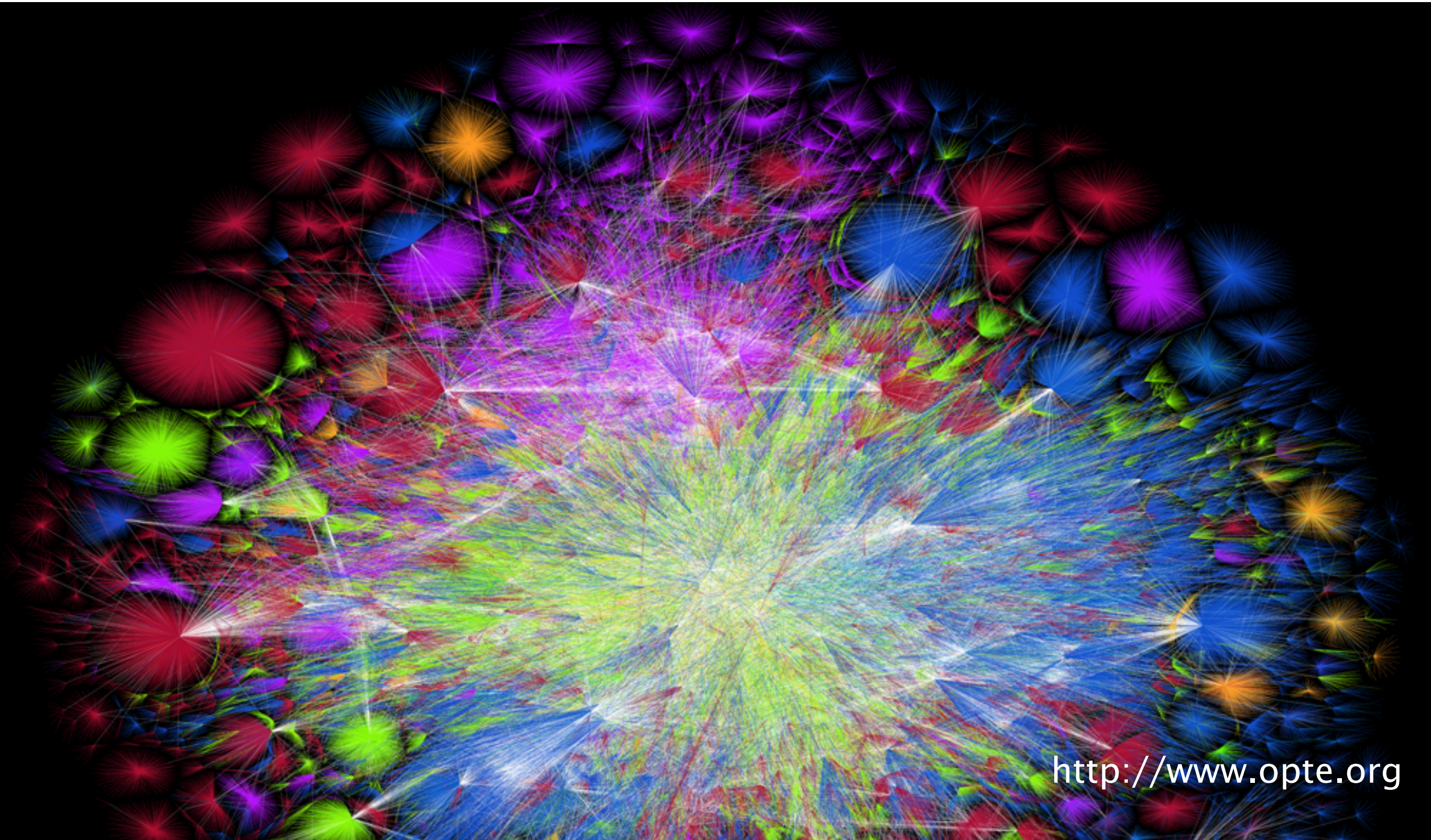
The *Inter*net is a network of networks

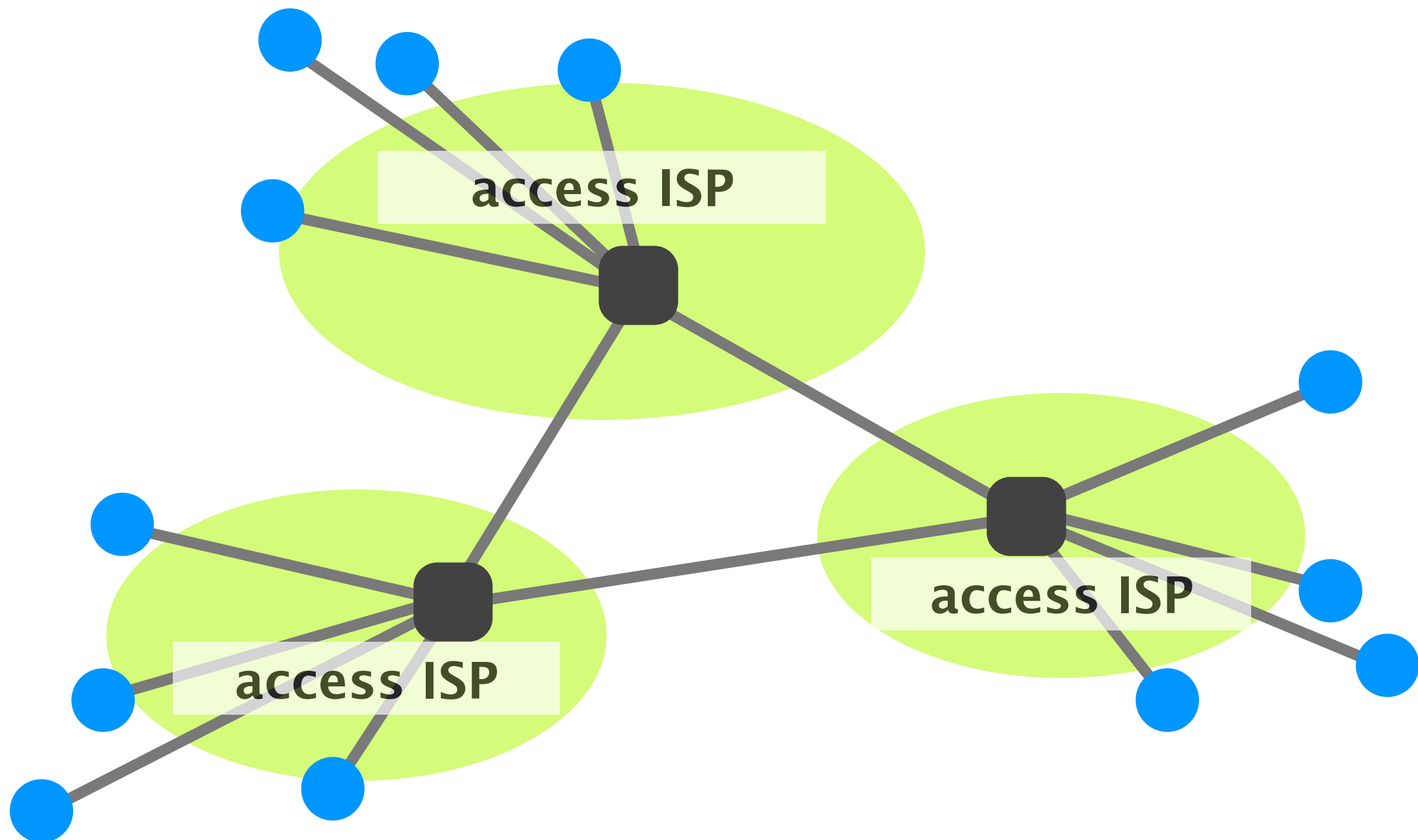


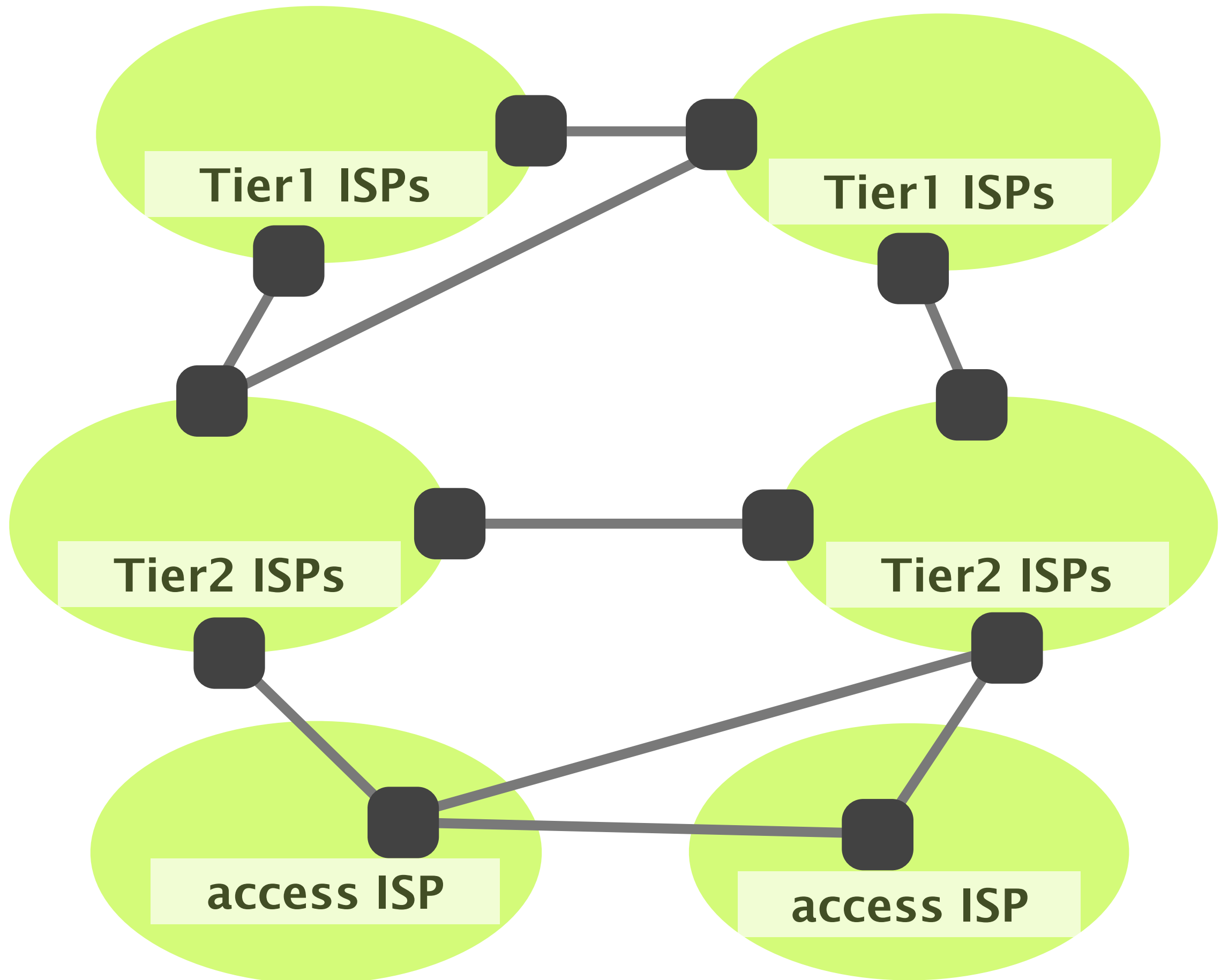
Internet Service Providers



The real Internet is a “tad” more complex







The Internet has a hierarchical structure

Tier-1

international

have no provider

Tier-2

national

provide transit to Tier-3s

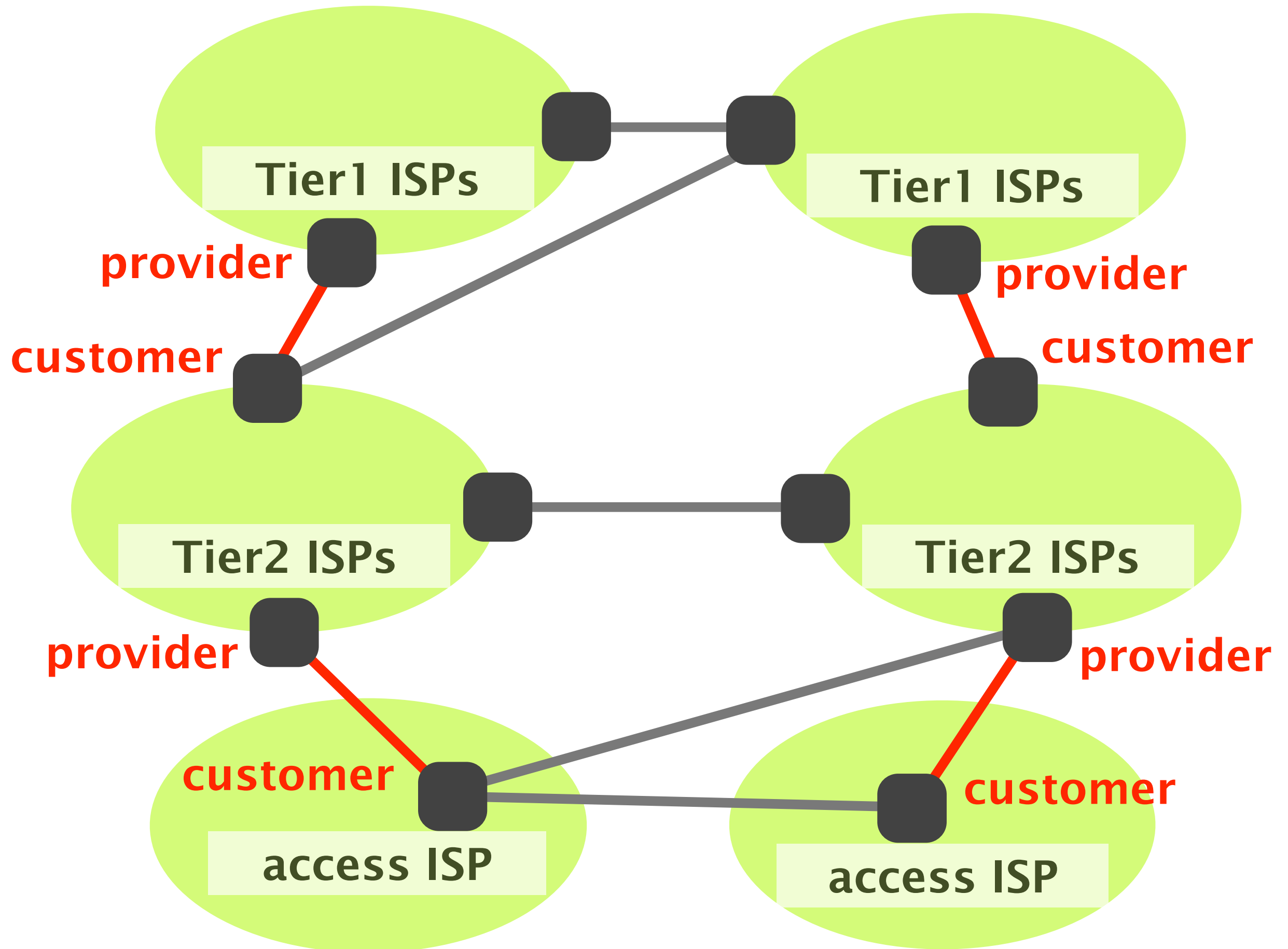
have at least one provider

Tier-3

local

do not provide any transit

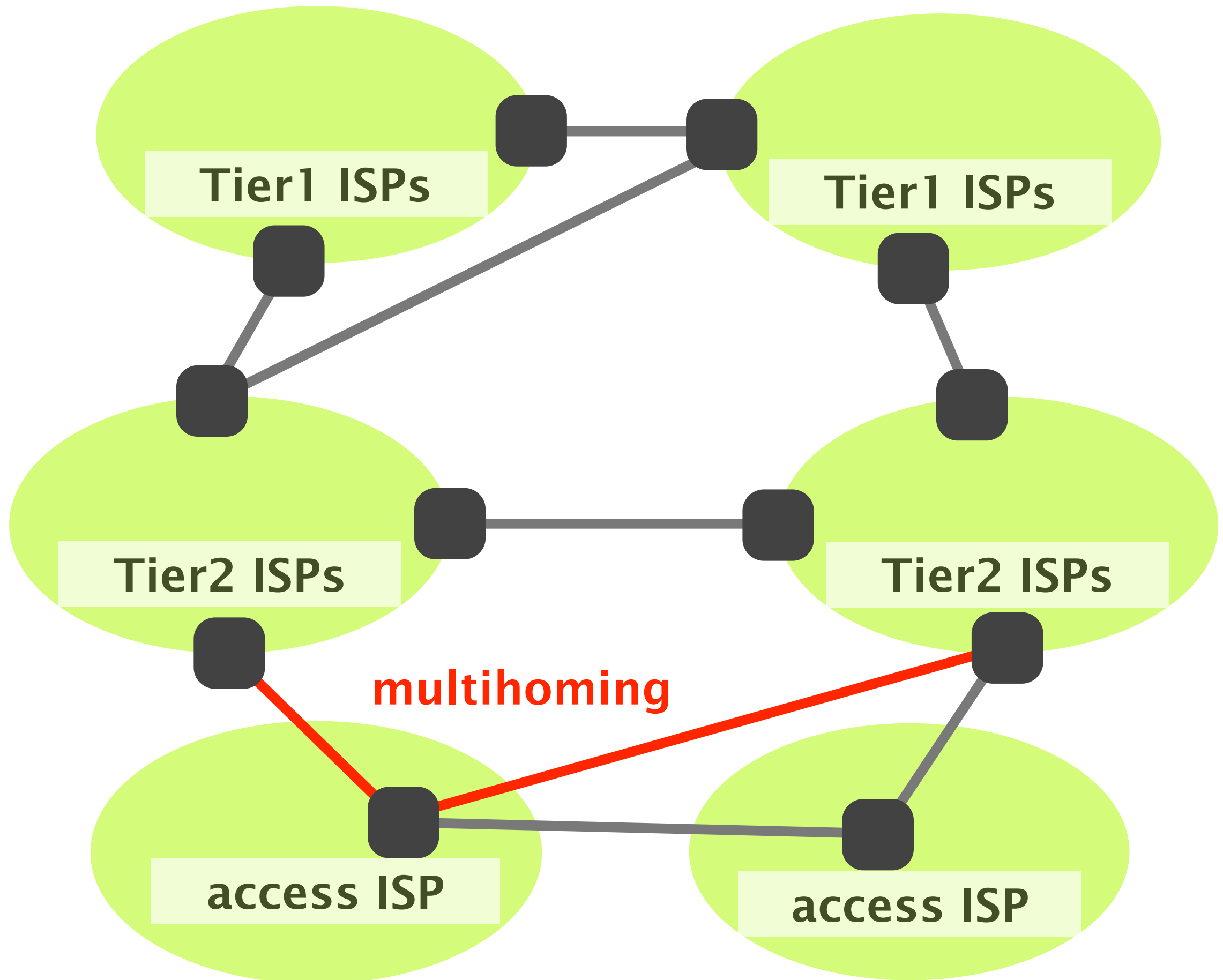
have at least one provider



The distribution of networks in Tiers is extremely skewed towards Tier-3s

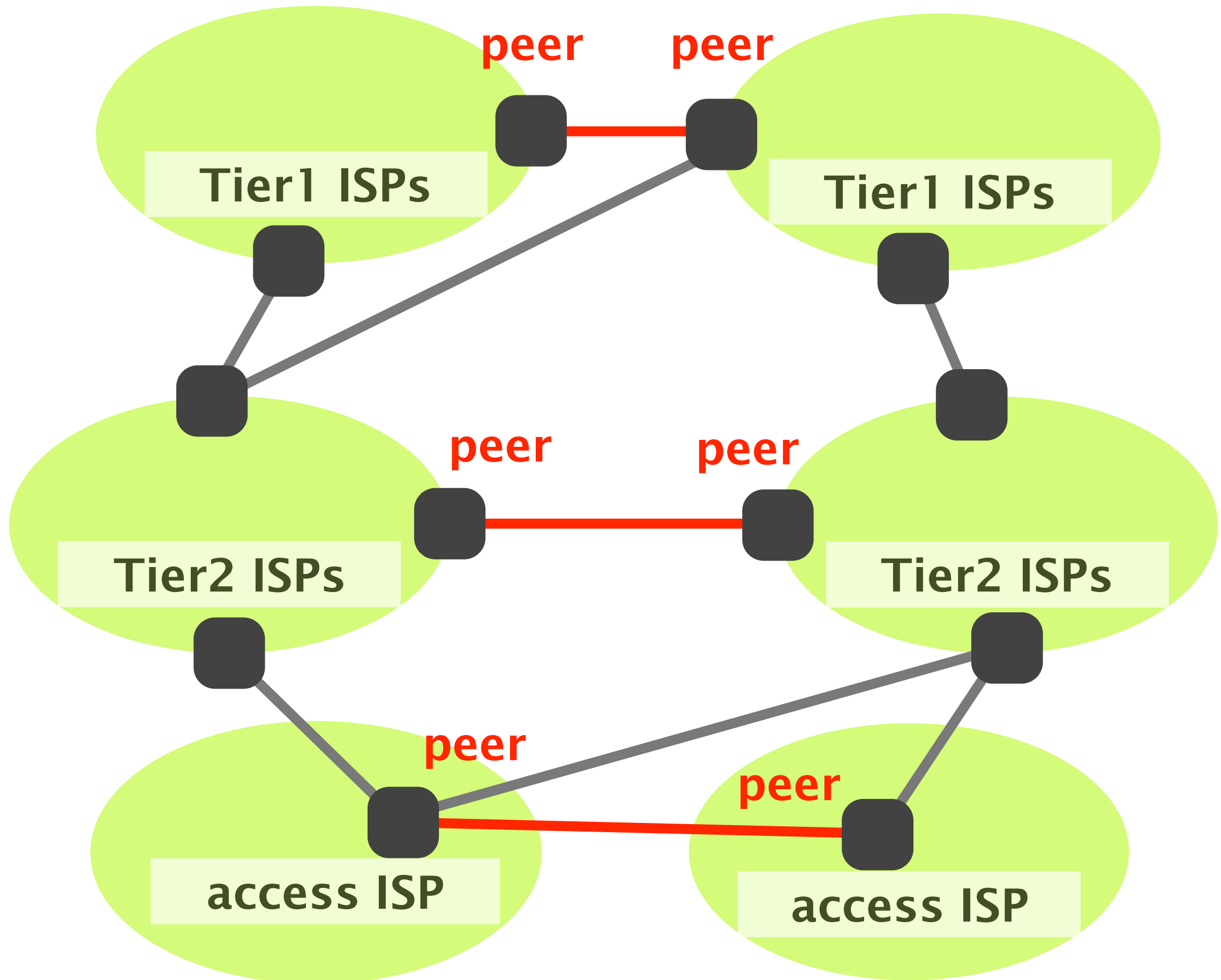
total ~60,000
networks

Tier-1 international	have no provider	~12
Tier-2 national	provide transit to Tier-3s have at least one provider	~1,000s
Tier-3 local	do not provide any transit have at least one provider	85-90%



Some networks have an incentive to connect directly,
to reduce their bill with their own provider

This is known as “peering”



Interconnecting each network to its neighbors one-by-one is not cost effective

Physical costs

of provisioning or renting physical links

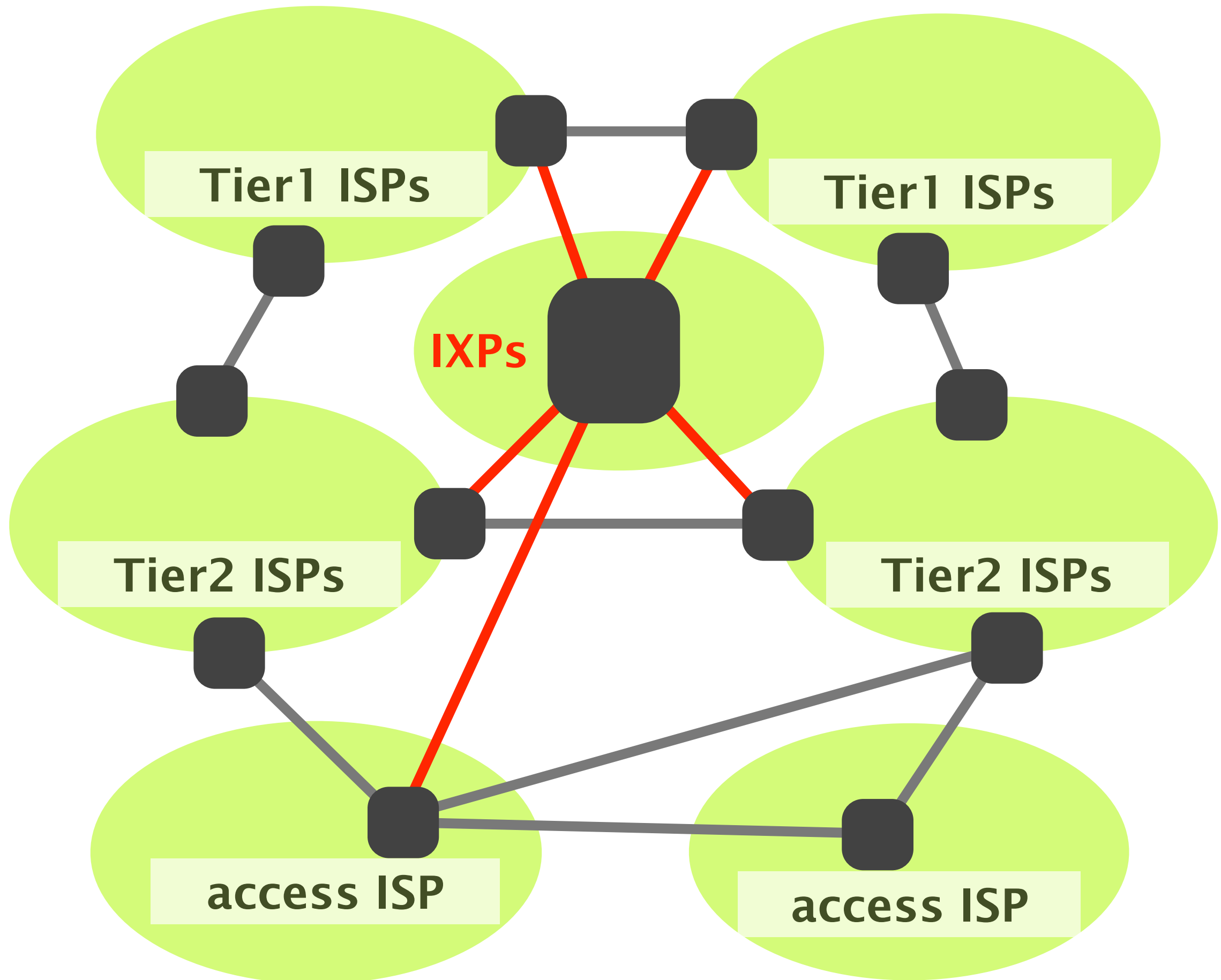
Bandwidth costs

a lot of links are not necessarily fully utilized

Human costs

to manage each connection individually

Internet eXchange Points (IXPs) solve these problems by letting *many* networks connect in one location



A brief overview of Internet history

The Internet history starts in the late 50's,
with people willing to communicate differently

Telephone network is *the* communication system
entirely based on circuit switching

People start to want to use networks for other things
defense, (not personal) computers, ...

... but knew that circuit-switching will not make it
too inefficient for bursty loads and not resilient

From this wish arose three crucial questions

Paul Baran

RAND

How can we design a **more resilient** network?

lead to the invention of packet switching

Len Kleinrock

UCLA

How can we design a **more efficient** network?

(also) lead to the invention of packet switching

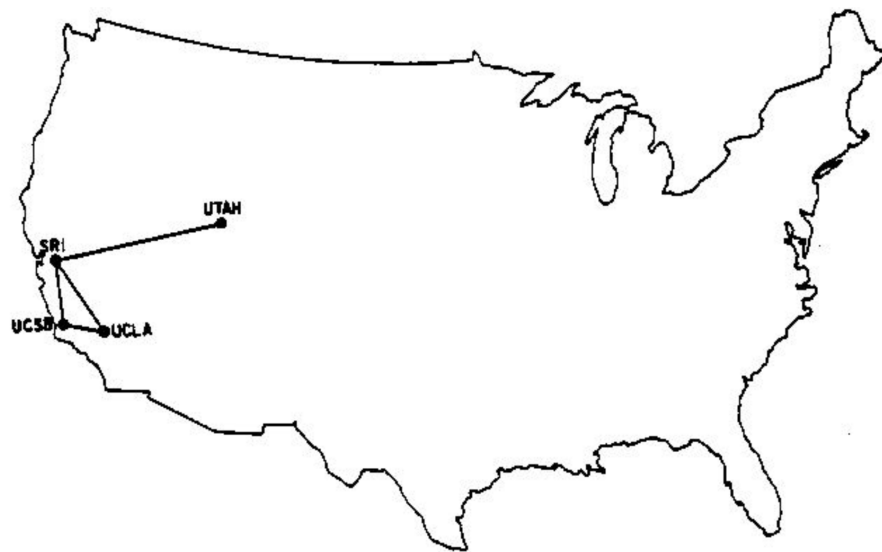
Bob Kahn

DARPA

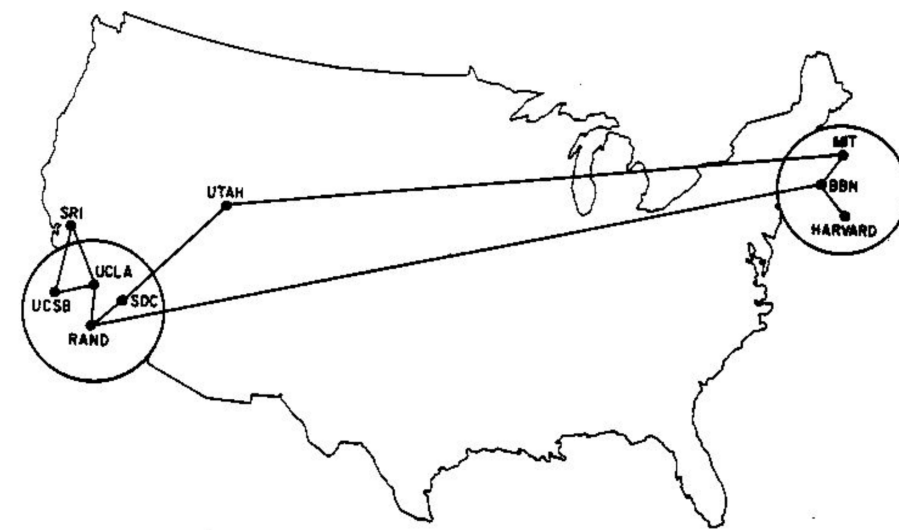
How can we **connect** all these networks together?

lead to the invention of the Internet as we know it

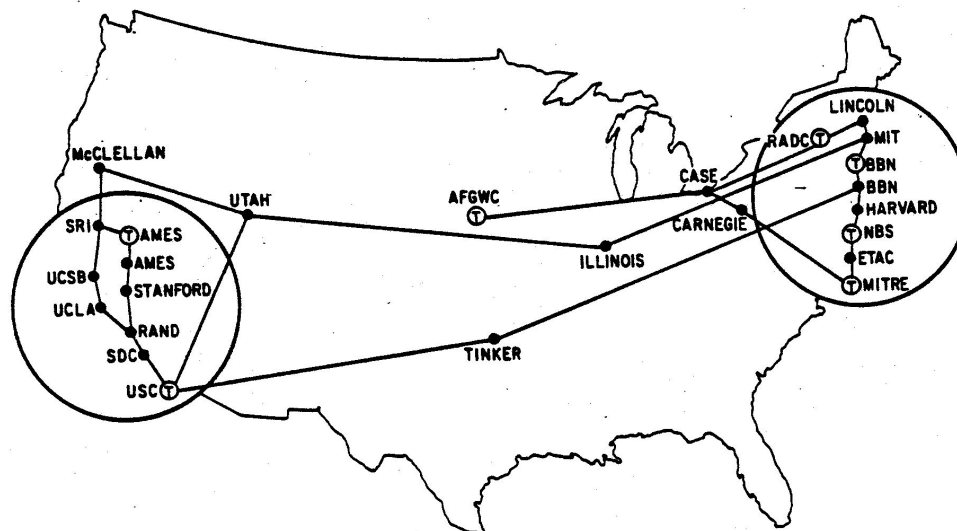
The 60s saw the creation of packet switching and the **A**dvanced **R**esearch **P**rojects **A**gency **N**etwork



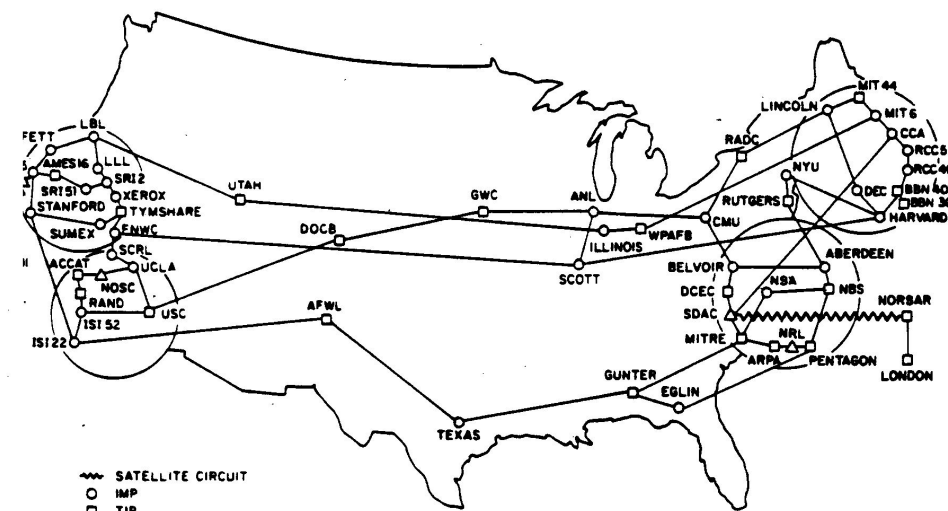
Dezember 1969



Juni 1970



März 1972



Juli 1977

The first message ever exchanged on the Internet was “lo”

Oct. 29 1969

Leonard Kleinrock @UCLA tries
to log in a Stanford computer

UCLA

We typed the L... Do you see it?

Yes! We see the L Stanford

We typed the O... Do you see it?

Yes! We see the O

We typed the G. **system crashes**

The 70s saw the creation of Ethernet, TCP/IP and the e-mail

1971	Network Control Program predecessor of TCP/IP
1972	Email & Telnet
1973	Ethernet
1974	TCP/IP paper by Vint Cerf & Bob Kahn

In the 80s, TCP/IP went mainstream

1983	NCP to TCP/IP Flag day Domain Name Service (DNS)
1985	NSFNet (TCP/IP) succeeds to ARPANET
198x	Internet meltdowns due to congestion
1986	Van Jacobson saves the Internet (with congestion control)

The 90s saw the creation of the Web as well as the Internet going commercial

1989 Arpanet is decommissioned

Birth of the Web

Tim Berners Lee (CERN)



Swiss made

1993 Search engines invented (Excite)

1995 NSFNet is decommissioned

1998 Google reinvents search

The new millennium brings the Web 2.0, focus on user-generated content

1998	IPv6 standardization
2004	Facebook goes online
2006	Google buys YouTube
2007	Netflix starts to stream videos
2007	First iPhone Mobile Internet access

Fast Internet access everywhere, every device needs an Internet connection

2009



2018

Mining of the Bitcoin genesis block

Fast mobile Internet access: 4G/LTE

Internet of Things (IoT) boom

Cars & refrigerators in the Internet

Only 26% of the Alexa Top 1000
websites reachable over IPv6

<http://www.worldipv6launch.org/measurements/>

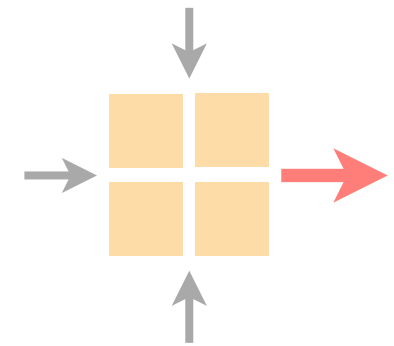
Soon?

Fully encrypted transport protocols

For example QUIC

Communication Networks

Part 1: Overview



- #1 What is a network made of?
- #2 How is it shared?
- #3 How is it organized?
- #4 How does communication happen?
- #5 How do we characterize it?

No exercise session

this Thursday

Next Monday on

Communication Networks

Routing concepts