

Communication Networks

Spring 2017



Laurent Vanbever

www.vanbever.eu

ETH Zürich (D-ITET)

February, 20 2017

The Internet

An exciting place

8 billion

8 billion

estimated* # of Internet connected devices
in 2016

* Cisco Visual Networking Index 2017

11.6 billion

estimated* # of Internet connected devices
in 2021

* Cisco Visual Networking Index 2017

~3 exabytes

estimated* **daily** global IP traffic
in 2016

* Cisco Visual Networking Index 2017

If



= 1 Gigabyte



volume(Great Wall of China) = 1 exabyte

~3 exabytes

estimated* **daily** global IP traffic
in 2016

* Cisco Visual Networking Index 2017

~6 exabytes

estimated* **daily** global IP traffic
in **2020**

* Cisco Visual Networking Index 2017

A *few* Internet services
you *might* have heard of...

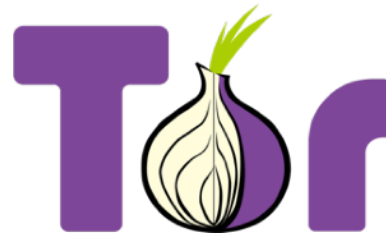


BitTorrent®

NETFLIX



bitcoin



The Internet

A tense place

Countries get disconnected

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, specifically the 'One Per Cent' blog. The main headline is 'Syria follows Egypt and disconnects from the internet', dated 17:20 20 July 2012, by Paul Marks, chief technology correspondent. The article features a photograph of a street in Syria with a damaged car in the foreground and armed men in the background. The page also includes a sidebar with 'Our other blogs' (Short Sharp Science, One Per Cent, New Scientist TV, CultureLab, Big Wide World), 'Bookmark&share' links (RSS, Facebook, Digg, Twitter, etc.), and a 'Categories' list (3D printing, AI, Aerospace, etc.).

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

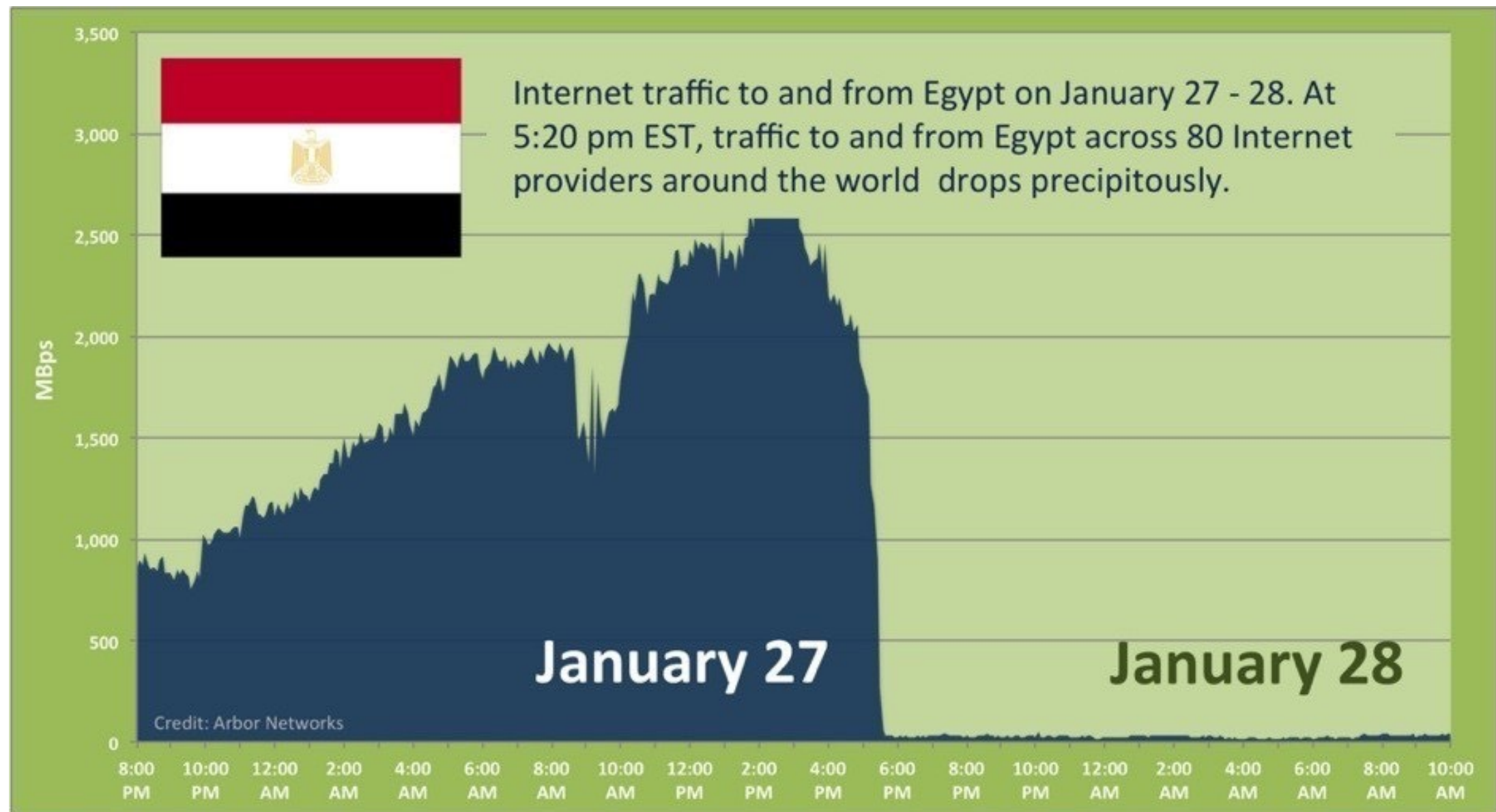
Bookmark&share

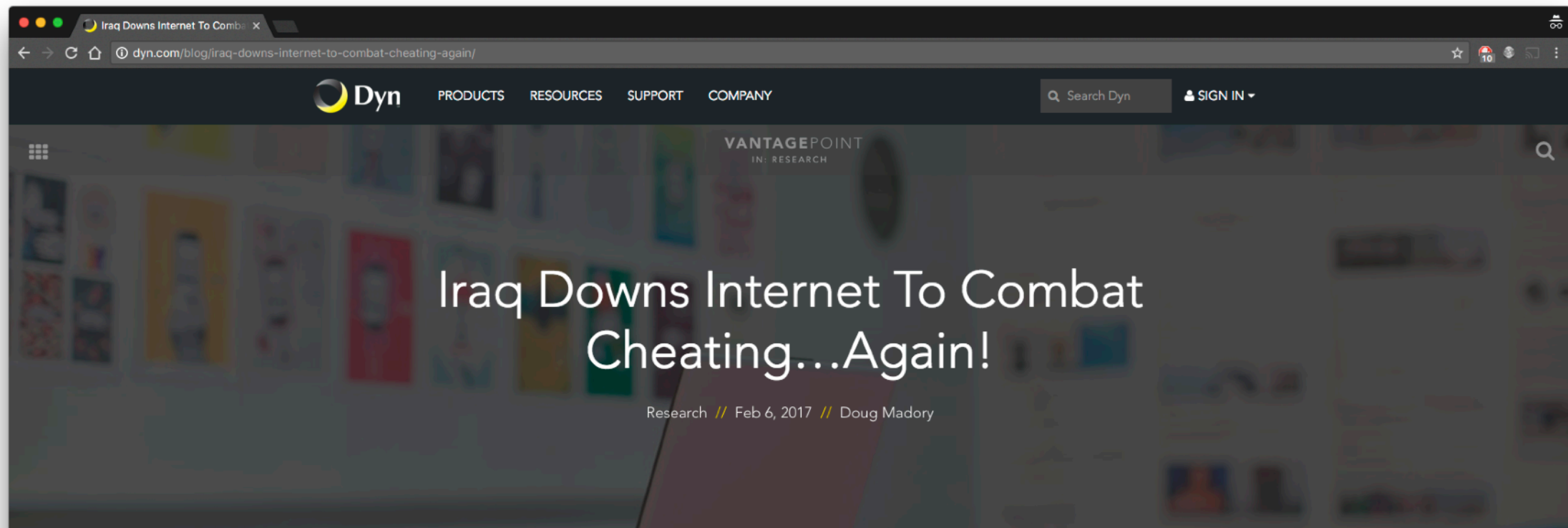
Categories

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

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

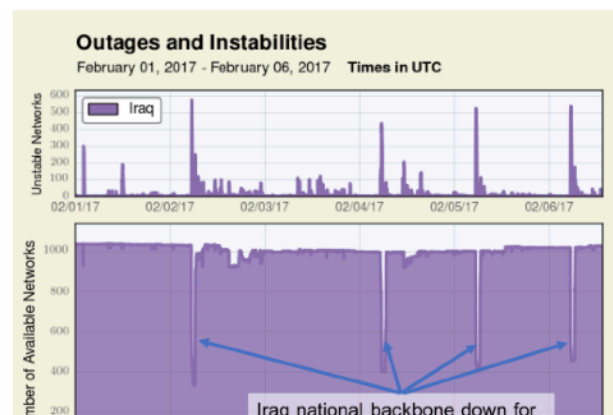
Internet traffic to/from Egypt in January 2011





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.

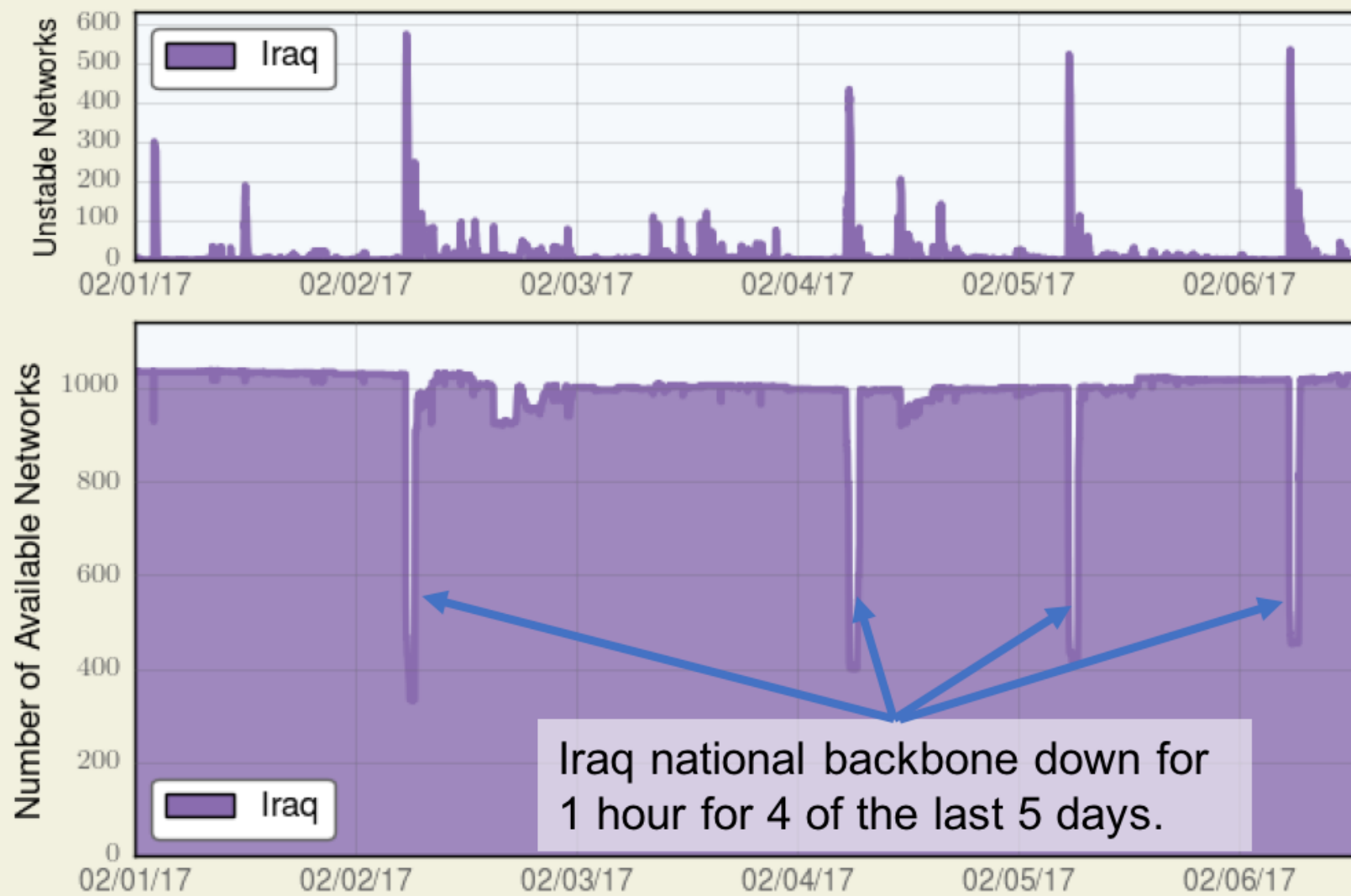
These recent outages are a continuation of a growing (and somewhat puzzling) trend by governments in many developing parts of the world to cut communications services in a desperate attempt to staunch rampant cheating on high-stakes student exams.



<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



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



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

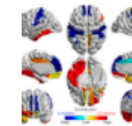
8/10

— Halo | 56 minutes ago



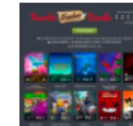
Apple's WWDC 2017 will return to San Jose in June

— WWDC | 1 hour ago



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

— Autism | 2 hours ago



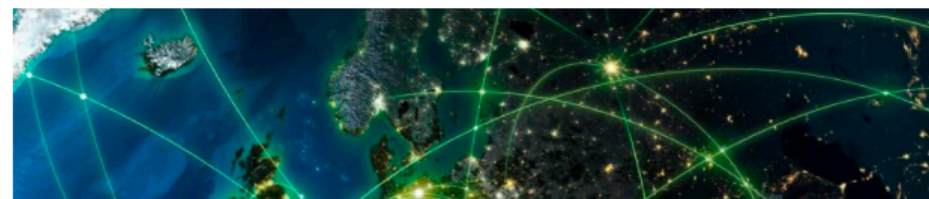
Humble collection migration

— 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



Communications get eavesdropped on...

top NSA infiltrates links to Yahoo X

The Washington Post (WP Company LLC) [US] https://www.washingtonpost.com/world/national-security/nsa-infiltrates-links-to-yahoo-google-d... ☆ 16

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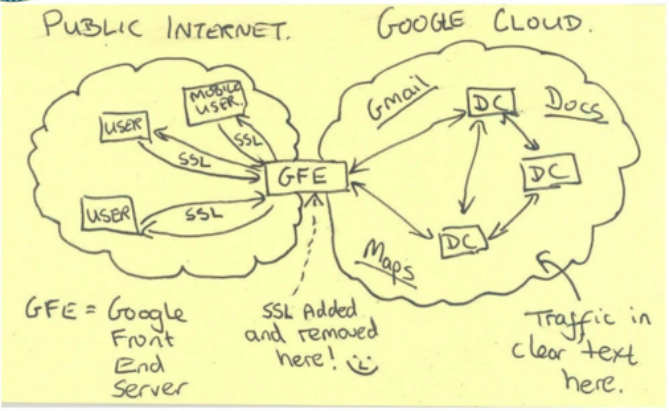
National Security

NSA infiltrates links to Yahoo, Google data centers worldwide, Snowden documents say

A 2896 Save for Later Reading List

TOP SECRET//SI//NOFORN

 Current Efforts - Google



TOP SECRET//SI//NOFORN

In this slide from a National Security Agency presentation on "Google Cloud Exploitation," a sketch shows where the "Public Internet" meets the internal "Google Cloud" where user data resides. Two engineers with close ties to Google exploded in profanity when they saw the drawing.

By **Barton Gellman** and **Ashkan Soltani** October 30, 2013 Follow @bartongellman


The National Security Agency has secretly broken into the main communications links that connect Yahoo and Google data centers around the world, according to documents obtained from former NSA contractor Edward Snowden and interviews with knowledgeable officials.


Most Read

- 1 U.S. says meeting for Syria cease-fire delayed, not canceled as Russia claims
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- 3 The so-called 'Islamic rape of Europe' is part of a long and racist history
- 4 The voyages of the Dawnlight: Where is it headed? And what is it carrying?
- 5 Islamic State faces new trouble in Fallujah as Sunni tribesmen revolt

Our Online Games

Play right from this page

 **Mahjongg Dimensions**
Genre(s): Strategy
It's 3D Mahjongg- you don't even need to wear 3D glasses!

 **The Sunday Crossword by Evan Birnholz**

http://wapo.st/1UVKamr to documents obtained from former NSA contractor Edward Snowden and interviews with knowledgeable officials.

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facebook



Hotmail

YAHOO!

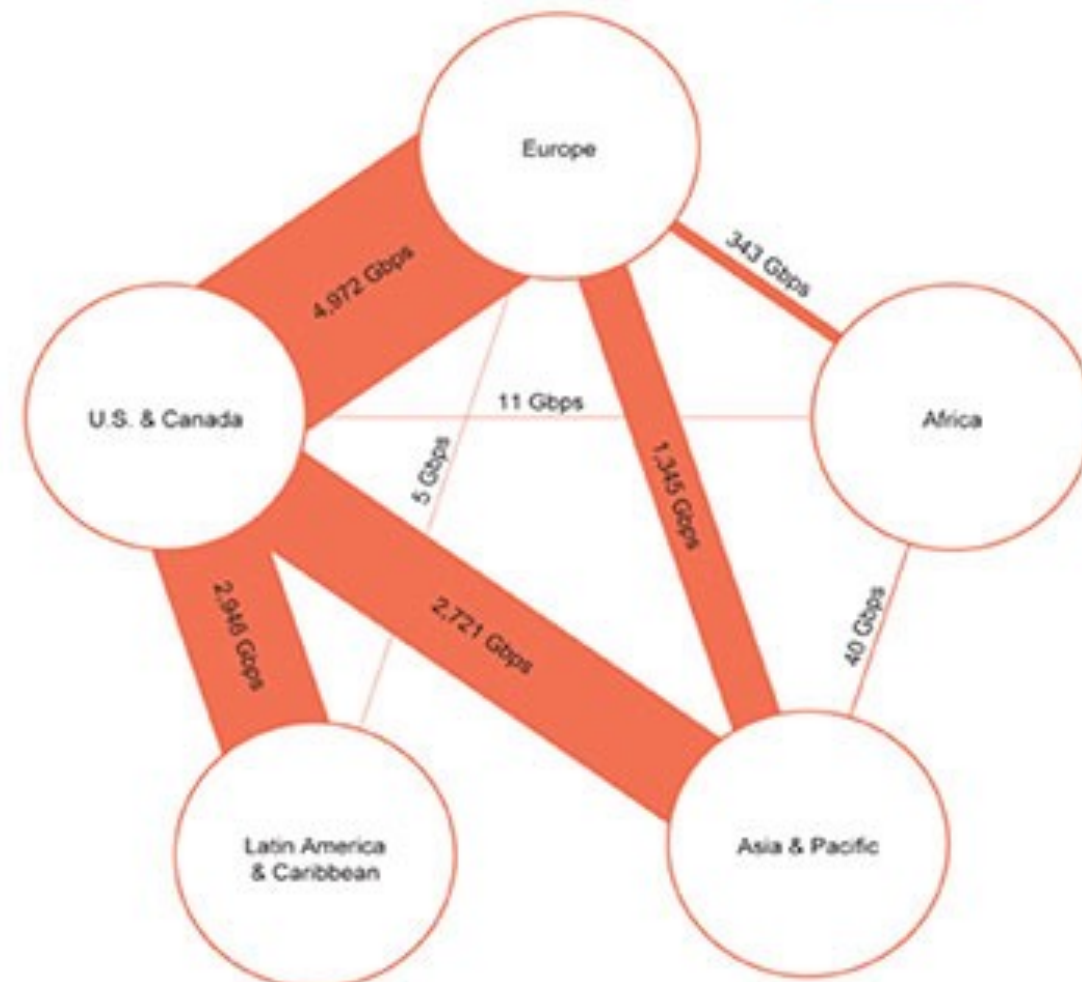


(TS//SI//NF) Introduction

U.S. as World's Telecommunications Backbone



- Much of the world's communications flow through the U.S.
- A target's phone call, e-mail or chat will take the **cheapest** path, **not the physically most direct** path – you can't always predict the path.
- Your target's communications could easily be flowing into and through the U.S.



International Internet Regional Bandwidth Capacity in 2011

Source: Telegeography Research

TOP SECRET//SI//ORCON//NOFORN

Some Internet communications
are interfered against or heavily congested





Can ISPs selectively slow down traffic?

The U.S. Federal Communications Commission (FCC) ordered Comcast to stop interfering with p2p traffic

The screenshot shows a web browser window displaying a Computerworld article. The browser's address bar shows the URL: www.computerworld.com/article/2532555/networking/fcc-rules-against-comcast-p-to-p-throttling.html. The Computerworld logo is prominently displayed at the top. The article is titled "FCC rules against Comcast P-to-P throttling" and is categorized under "NEWS". The byline reads "By Grant Gross" with a "FOLLOW" button and "IDG News Service | Aug 1, 2008 1:00 AM PT". To the left of the main text, there is a "RELATED TOPICS" section with links for "Networking", "Government IT", "Data Privacy", and "Internet", and a "COMMENTS" section with a red speech bubble icon. The main text of the article begins with "WASHINGTON - The U.S. Federal Communications Commission ordered Comcast Corp. to stop interfering with peer-to-peer traffic on its broadband network, with one FCC official saying the cable provider was 'invasive' in its network traffic management." It continues with details about the FCC's 3-2 vote to order Comcast to stop slowing P-to-P traffic by the end of the year and to come up with a new network management plan. A quote from FCC member Michael Copps is included: "Comcast's traffic management, unveiled by press reports in late 2007, was 'discriminatory and not narrowly tailored to address Comcast's concern about network congestion,'" said FCC member Michael Copps. "Today, we choose the open road." Another paragraph mentions that Comcast didn't tell its subscribers it was slowing BitTorrent and other P-to-P traffic until the press reports, and that FCC Chairman Kevin Martin, a Republican, joined the commission's two Democrats to approve the order. The article concludes with a quote from Martin: "Would you be OK with the post office opening your mail, deciding they didn't want to bother delivering it, and hiding that fact by sending it back to you stamped, 'address unknown -- return to sender?'" Martin said. "Or, if they opened letters mailed to you, decided that because the mail truck is full

http://bit.ly/2ldKgJW

F.C.C. Sets Net Neutrality Rule X

Securehttps://www.nytimes.com/2015/03/13/technology/fcc-releases-net-neutrality-rules.html

18

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The New York Times

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 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

 TECH TIP Adding Facebook's Birthday List to a Calendar Program

 BITS Daily Pay e Break

TECHNOLOGY

F.C.C. Sets Net Neutrality Rules

By REBECCA R. RUIZ MARCH 12, 2015





The New Net Neutrality Rules

By NATALIA V. OSIPOVA and CAITLIN PRENTKE



00:03

1:13

HD



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](#)

<iframe title=" ">

Embed

RELATED COVERAGE

 F.C.C. Approves Net Neutrality Rules, Classifying Broadband Internet Service as a Utility FEB. 26, 2015

 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 applied to utilities, for example. But the full text of the new order also raised uncertainties about broad and subjective regulation. One catchall provision, requiring “just and reasonable” conduct, allows the [F.C.C.](#) to decide what is acceptable on a case-by-case basis.

Opponents of the rules, including many of the leading Internet providers, spent Thursday poring over the document. It was not known who would file the first legal challenges, or exactly what legal arguments would be made. Many experts, though, said the document included plenty of opportunity for

http://nyti.ms/2kZUnDA



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

TECH TIP Adding Facebook's Birthday List to a Calendar Program



BITS Daily Pay & Break

TECHNOLOGY

Trump's F.C.C. Pick Quickly Targets Net Neutrality Rules

By CECILIA KANG FEB. 5, 2017



Ajit Pai, the new chairman of the Federal Communications Commission, has taken a first swipe at net neutrality. Christopher Gregory/The New York Times

The Trump White House

Stories about President Trump's administration.

- Trump's Pick to Replace Flynn Turns Down the Job FEB 16
- Did Trump Drop 2-State Policy? Mideast Experts Say Don't Be So Sure FEB 16
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WASHINGTON — In his first days as President Trump's pick to lead the [Federal Communications Commission](#), [Ajit Pai](#) has aggressively moved to roll back consumer protection regulations created during the Obama presidency.

Mr. Pai took a first swipe at [net neutrality](#) rules designed to ensure equal access to content on the internet. He stopped nine companies from providing [discounted high-speed internet service](#) to low-income individuals. He withdrew an [effort](#) to keep prison phone rates down, and he scrapped a [proposal](#) to break open the cable box market.

In total, as the chairman of the F.C.C., Mr. Pai released about a dozen actions in the last week, many buried in the agency's website and not publicly announced, stunning consumer advocacy groups and telecom analysts. They said Mr. Pai's message was clear: The F.C.C., an independent agency, will mirror the Trump administration's rapid unwinding of government regulations that businesses fought against during the Obama administration.

"With these strong-arm tactics, Chairman Pai is showing his true stripes," said Matt Wood, the policy director at the consumer group Free Press.

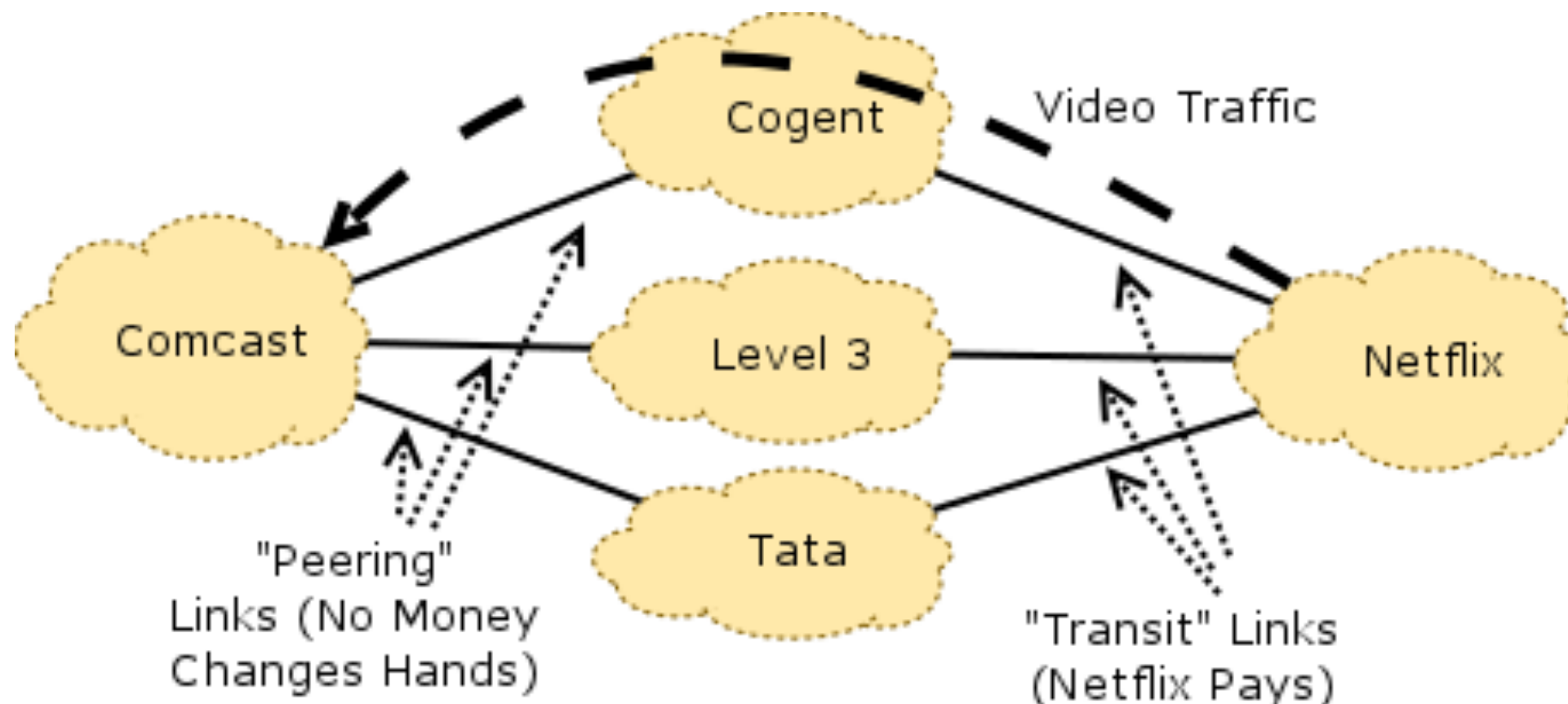
<http://nyti.ms/2kyROGJ>

Some Internet communications
are interfered against or heavily congested



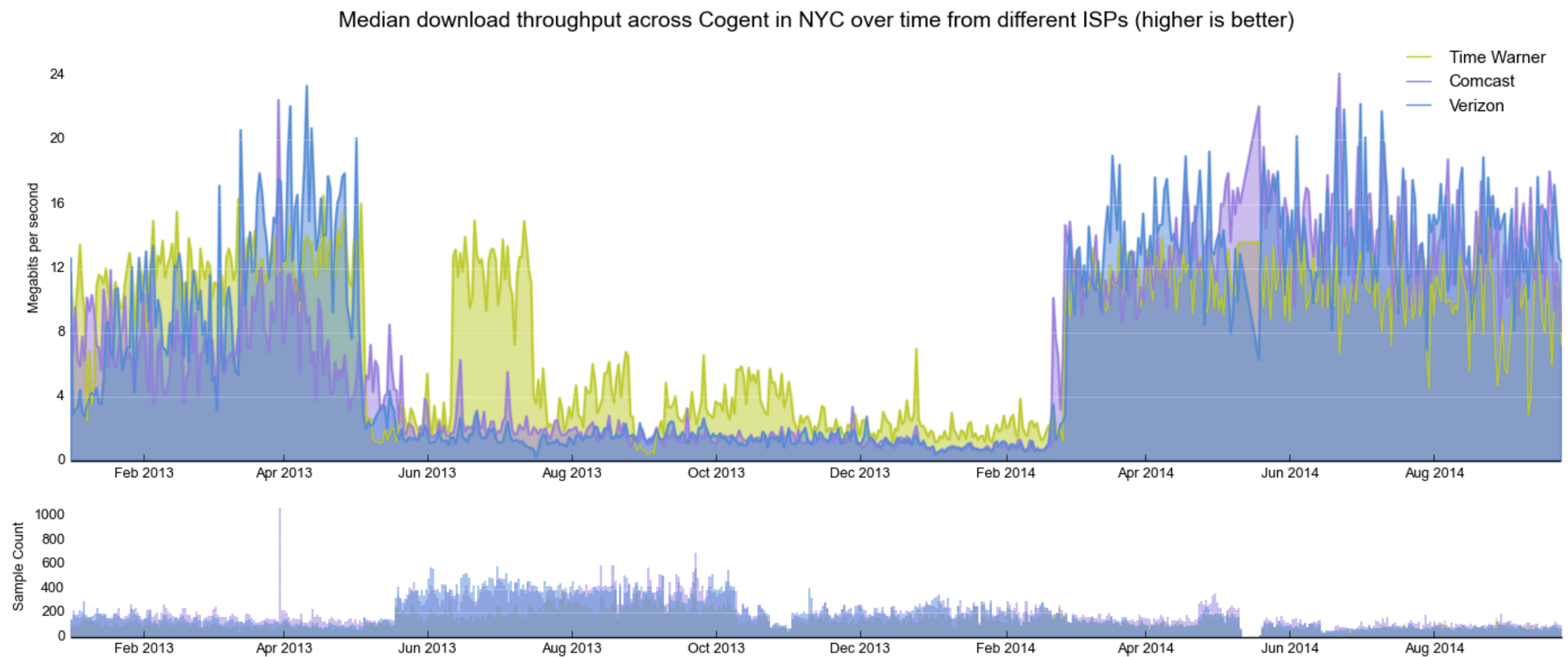
Who should pay the other for Internet connectivity?

A primer on the conflict between Netflix and Comcast



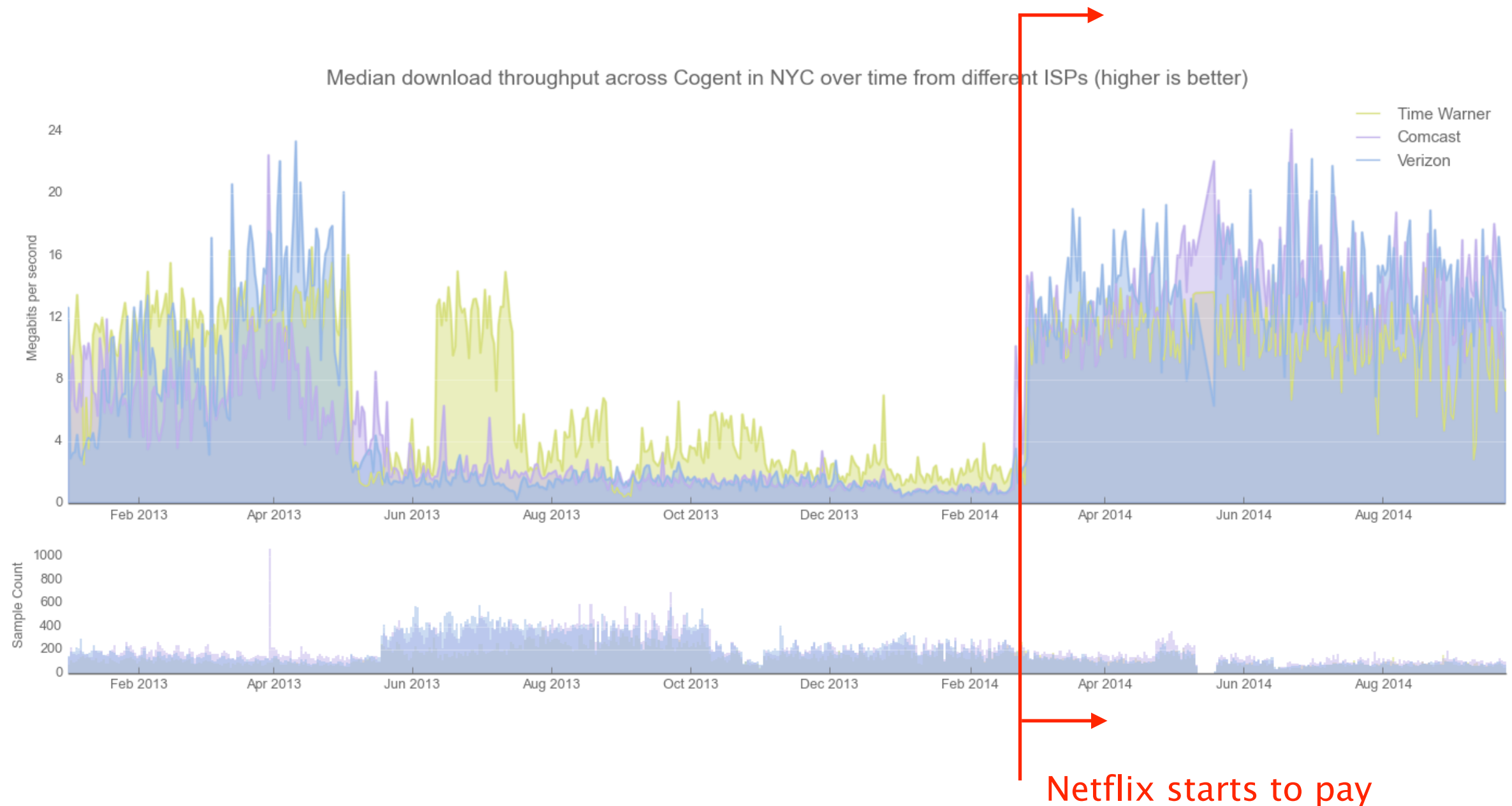
<https://freedom-to-tinker.com/blog/feamster/why-your-netflix-traffic-is-slow-and-why-the-open-internet-order-wont-necessarily-make-it-faster/>

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



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

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



The Internet infrastructure is
a fragile environment

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.



The outage was due to
one faulty Internet device

Facebook, Tinder, Instagram suffer widespread issues

3.1k
SHARES

Share on Facebook

Share on Twitter



IMAGE: GETTY IMAGES



BY JENNI RYALL
AUSTRALIA

JAN 27, 2015

UPDATED: Tuesday, Jan. 27 / 4:32 a.m. EST — A Facebook spokeswoman told *Mashable* that the outage was due to a change to the site's configuration systems, and not a hacker attack. "Earlier this evening many people had trouble accessing Facebook and Instagram. This was not the result of a third party attack but instead occurred after we introduced a change that affected our configuration systems. We moved quickly to fix the problem, and both services are back to 100% for everyone.", she said.

UPDATED: Tuesday, Jan. 27 / 2:14 a.m. EST — Facebook, Tinder and Twitter appear to be back to normal after a 40 minute outage and mass freak out.

The outage was due to a **change** to
the site's configuration systems

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

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

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

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

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

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

Internet advertisements rates
suggest that

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

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

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

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

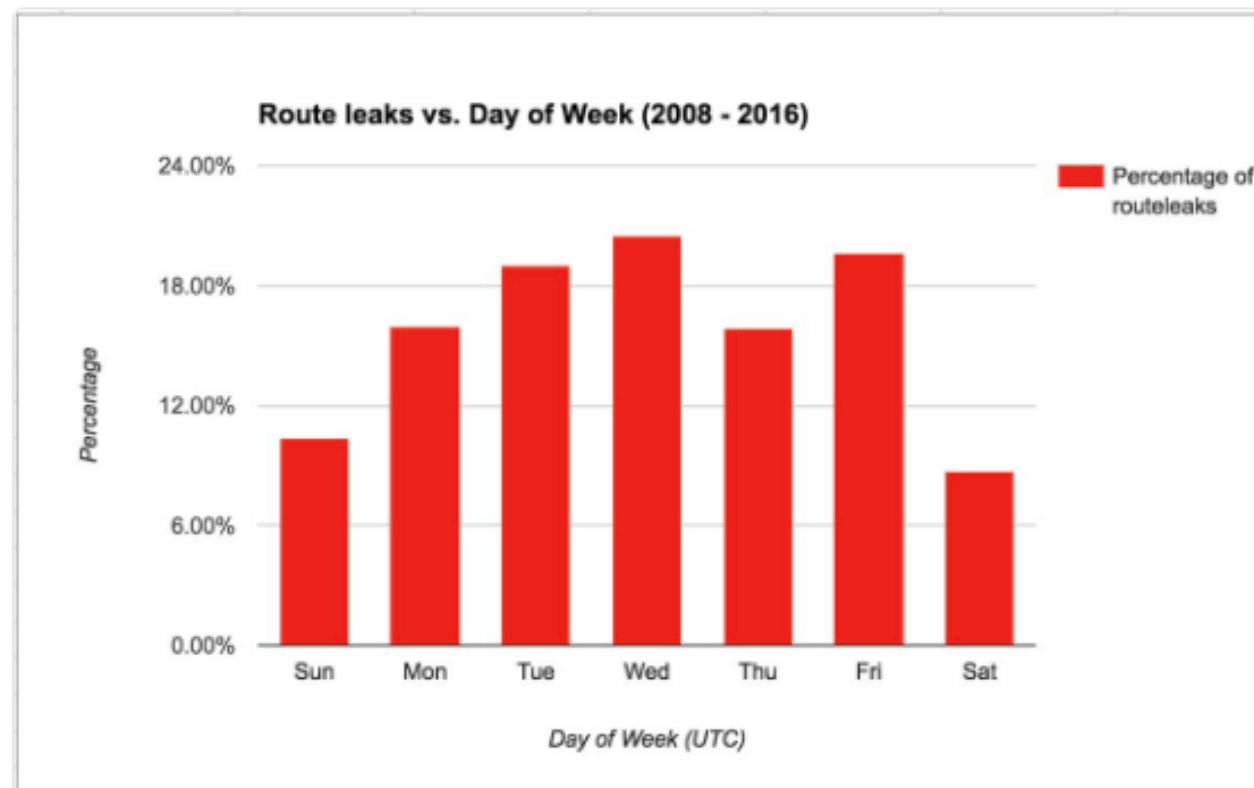


Job Snijders
@JobSnijders



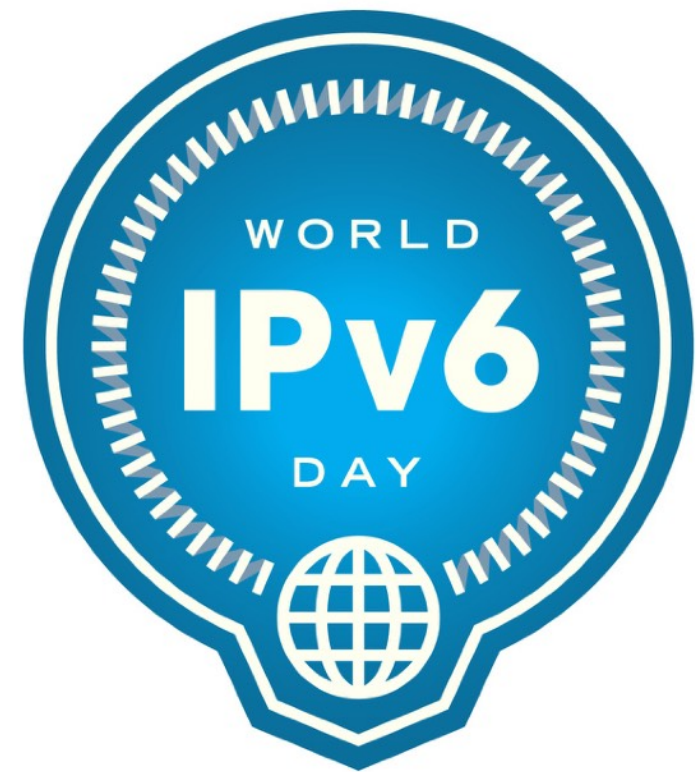
 Follow

Fun fact: most BGP route leaks happen on Wednesdays, but in the weekend us humans collectively take a break! :-)



Internet scalability is at risk with
no more IPv4 addresses and a slow IPv6 deployment

IPv4

A thick, black, jagged arrow pointing downwards and to the right, starting from the 'v' in 'IPv4' and ending with a solid arrowhead.

Communication Networks

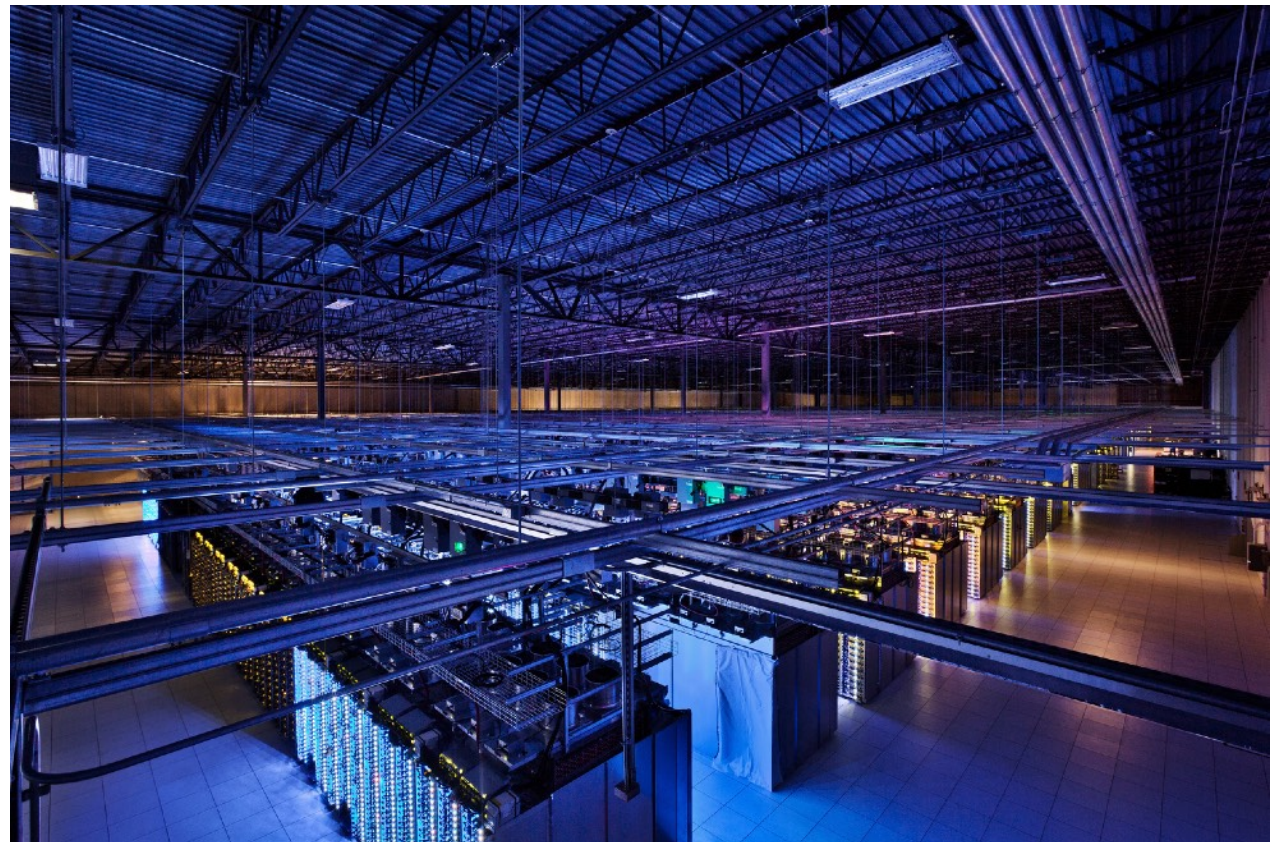
Course goals

Knowledge

Understand how the Internet works **and why**



from your
network plug...



...to Google's data-center

Insight

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**

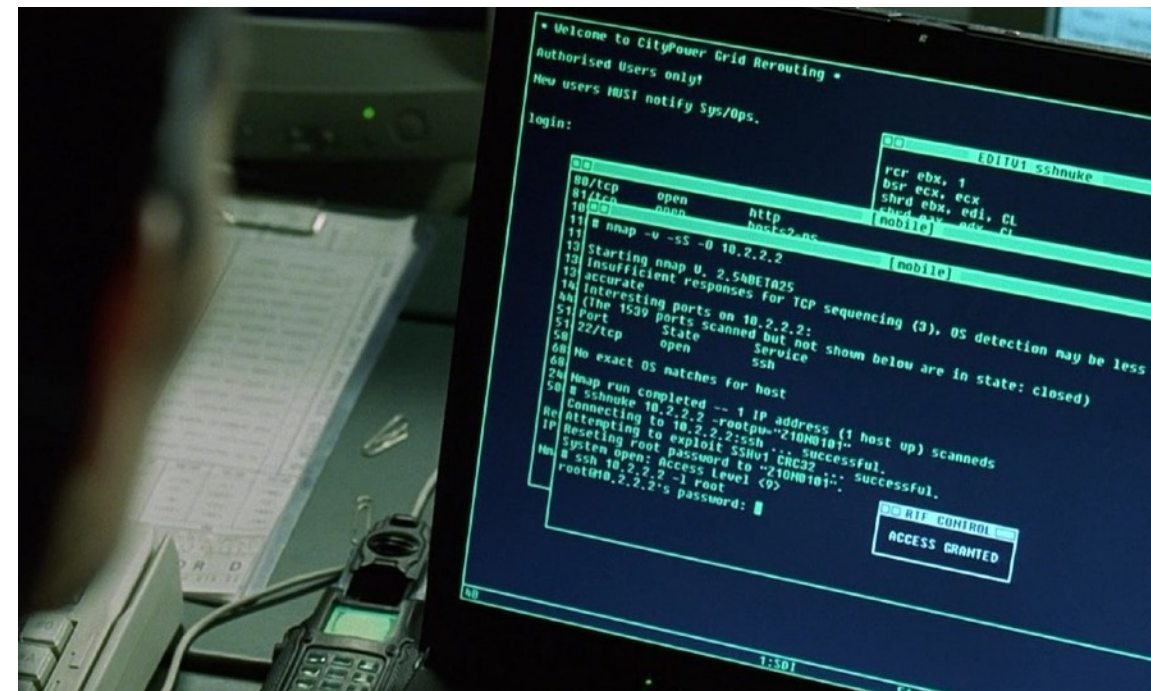
How do you **divide scarce resources among competing parties?**

Skill

Build, operate and configure networks

Skill

Build, operate and configure networks



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

Software-Defined Network

Software-Defined Network

enable network programmability

So far, network devices
have been completely locked down

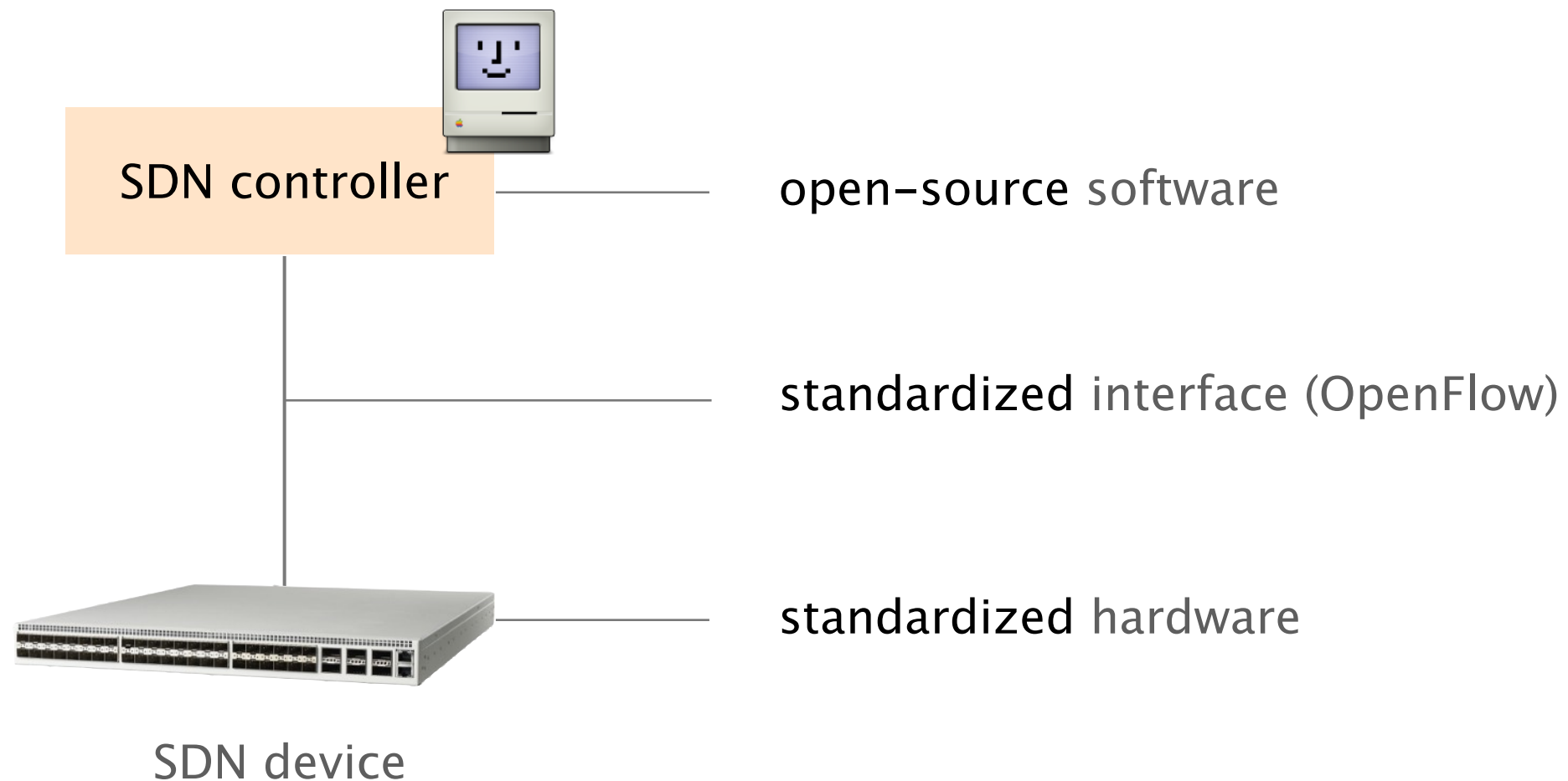


closed software

closed hardware

Cisco™ device

SDN opens up the network devices, enabling network innovation



The hype around SDN is huge, both in the industry and in academia

VMware Acquires Once-Secretive Start-Up Nicira for \$1.26 Billion

JULY 23, 2012 AT 1:25 PM PT



VMware, the software company best known for its virtualization technology that forms the backbones of so-called cloud computing today, said it will pay \$1.26 billion for Nicira, a networking start-up that has sought to do to networks what VMware has done to computers.

The news comes on the same day that VMware was to report quarterly earnings. And while I don't usually cover VMware's earnings, I may as well mention the results: The company reported revenue for the quarter ended June rose to \$1.12 billion, while earnings on a per-share basis were 68 cents. Analysts had been expecting sales of \$1.12 billion and earnings of 66 cents.

Nicira had been running in stealth mode for quite awhile; [I got to reveal](#) its plans to the world last February.

The deal amounts to a nice payoff for Nicira's investors including Andreessen Horowitz, Lightspeed Venture Partners and NEA, as well as VMware founder Diane Greene and venture capitalist Andy Rachleff.

The Nicira logo consists of the word "nicira" in a bold, lowercase, sans-serif font. Above the letters, there are several vertical bars of different colors (green, orange, red, blue) of varying heights, resembling a stylized bar chart or a network diagram.

With \$600M Invested in SDN Startups, the Ecosystem Builds



Scott Raynovich, June 10, 2014



More than \$600 million has been invested in at least two dozen [software-defined networking \(SDN\)](#) startups so far, according to Rayno Report research. You can expect that to continue to climb. With the SDN ecosystem starting to take hold with a broad range of alliances and distribution partnerships, we're just getting started.

The [Arista IPO](#) will help build visibility for next-generation, software-driven networking. But [Arista](#) is selling its own hardware and is not an SDN pure-play. A new line of [SDN startups](#), with a more radical approach to software-based networking, is building momentum. These newer SDN startups are just getting their gear into customers' hands and starting to build sales channels, so you can expect a long revenue ramp.

This excitement is boosting startup valuations, according to [Rayno Report research](#). There are now at least ten [SDN startups](#) with valuations over \$100 million. As I reported in April, a recent investment in [Cumulus Networks](#) pushed up the valuation of the private company [north of \\$300 million](#), according to industry sources. [Big Switch](#), which did a deal in 2012 valuing it near \$170 million, took money from [Intel](#) in 2013, most likely boosting its valuation to over \$200 million, according to several sources.

Related Articles

[How to Effectively Embed SDN in the Enterprise](#)

[NFV and SDN: What's the Difference Two Years Later?](#)

[sFlow Creator Peter Phaal On Taming The Wilds Of SDN & Virtual Networking](#)

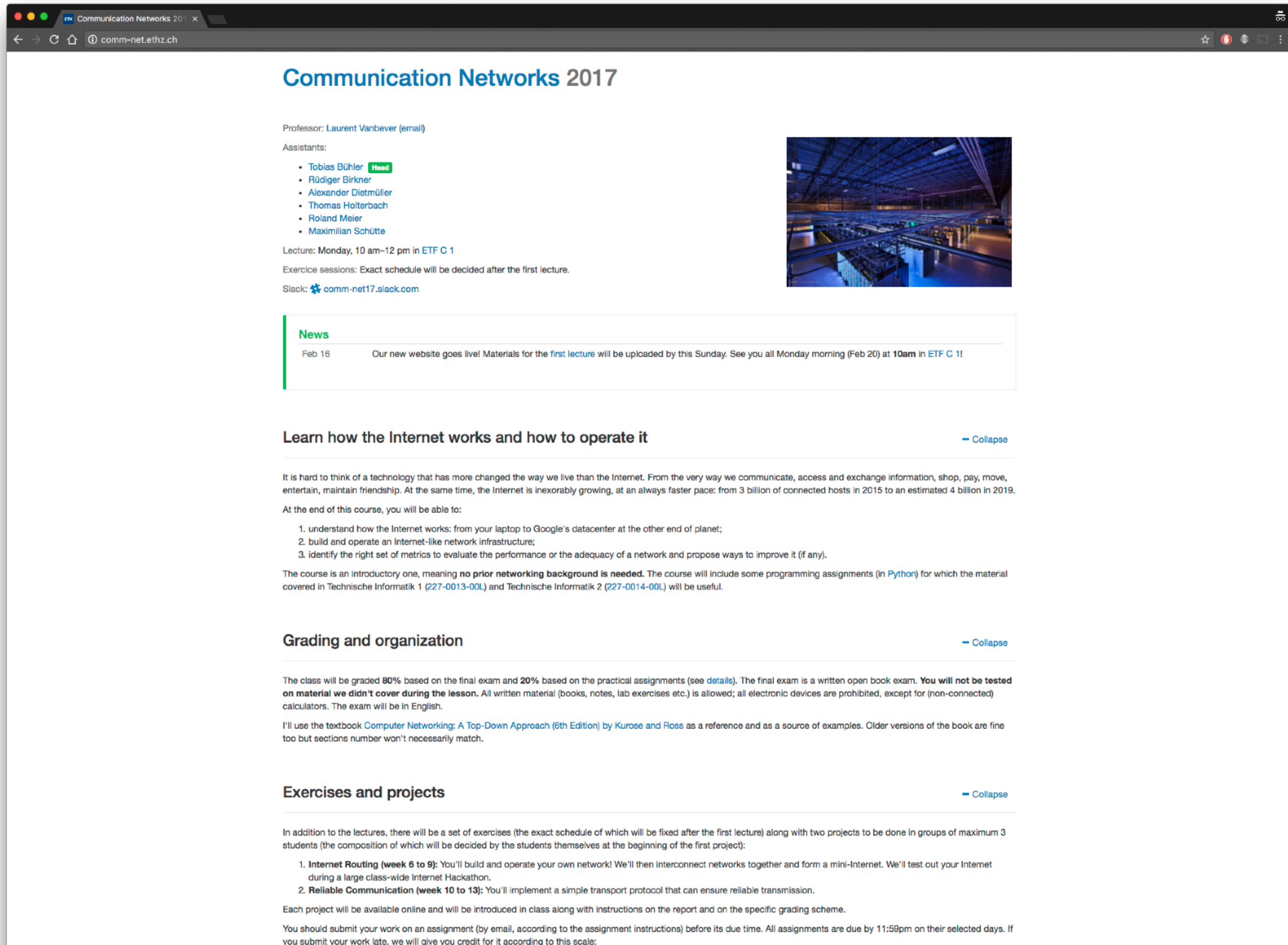
[Featured Article: Bringing Data-Driven SDN to the Network Edge](#)

[NFV Delivers Pervasive Intelligence for MNOs](#)

Communication Networks

Course organization

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



The screenshot shows a web browser window with the address bar displaying 'comm-net.ethz.ch'. The page title is 'Communication Networks 2017'. Below the title, it lists the professor as Laurent Vanbever and several assistants: Tobias Bühler, Rüdiger Birkner, Alexander Dietmüller, Thomas Holterbach, Roland Meier, and Maximilian Schütte. A lecture schedule is provided for Monday, 10 am–12 pm in ETF C 1. A Slack link is also present. A 'News' section dated Feb 16 announces the website's launch and the upload of materials for the first lecture. The page is divided into sections: 'Learn how the Internet works and how to operate it', 'Grading and organization', and 'Exercises and projects'. Each section has a 'Collapse' link. The 'Learn how the Internet works...' section describes the course's goals and prerequisites. The 'Grading and organization' section details the exam structure and the textbook used. The 'Exercises and projects' section outlines the practical work and group assignments.

Communication Networks 2017

Professor: Laurent Vanbever (email)

Assistants:

- Tobias Bühler
- Rüdiger Birkner
- Alexander Dietmüller
- Thomas Holterbach
- Roland Meier
- Maximilian Schütte

Lecture: Monday, 10 am–12 pm in ETF C 1

Exercise sessions: Exact schedule will be decided after the first lecture.

Slack: [comm-net17.slack.com](#)

News

Feb 16 Our new website goes live! Materials for the [first lecture](#) will be uploaded by this Sunday. See you all Monday morning (Feb 20) at 10am in ETF C 1!

Learn how the Internet works and how to operate it [Collapse](#)

It is hard to think of a technology that has more changed the way we live than the Internet. From the very way we communicate, access and exchange information, shop, pay, move, entertain, maintain friendship. At the same time, the Internet is inexorably growing, at an always faster pace: from 3 billion of connected hosts in 2015 to an estimated 4 billion in 2019.

At the end of this course, you will be able to:

1. understand how the Internet works: from your laptop to Google's datacenter at the other end of planet;
2. build and operate an Internet-like network infrastructure;
3. identify the right set of metrics to evaluate the performance or the adequacy of a network and propose ways to improve it (if any).

The course is an introductory one, meaning **no prior networking background is needed**. The course will include some programming assignments (in [Python](#)) for which the material covered in Technische Informatik 1 ([227-0013-00L](#)) and Technische Informatik 2 ([227-0014-00L](#)) will be useful.

Grading and organization [Collapse](#)

The class will be graded **80%** based on the final exam and **20%** based on the practical assignments (see [details](#)). The final exam is a written open book exam. **You will not be tested on material we didn't cover during the lesson.** All written material (books, notes, lab exercises etc.) is allowed; all electronic devices are prohibited, except for (non-connected) calculators. The exam will be in English.

I'll use the textbook [Computer Networking: A Top-Down Approach \(6th Edition\)](#) by Kurose and Ross as a reference and as a source of examples. Older versions of the book are fine too but sections number won't necessarily match.

Exercises and projects [Collapse](#)

In addition to the lectures, there will be a set of exercises (the exact schedule of which will be fixed after the first lecture) along with two projects to be done in groups of maximum 3 students (the composition of which will be decided by the students themselves at the beginning of the first project):

1. **Internet Routing (week 6 to 9):** You'll build and operate your own network! We'll then interconnect networks together and form a mini-Internet. We'll test out your Internet during a large class-wide Internet Hackathon.
2. **Reliable Communication (week 10 to 13):** You'll implement a simple transport protocol that can ensure reliable transmission.

Each project will be available online and will be introduced in class along with instructions on the report and on the specific grading scheme.

You should submit your work on an assignment (by email, according to the assignment instructions) before its due time. All assignments are due by 11:59pm on their selected days. If you submit your work late, we will give you credit for it according to this scale:

The course will be split into three parts

Part 1

Overview

2 lectures

Part 2

Concepts

2 lectures

Part 3

Today's Internet

~9 lectures

The lectures will be accompanied by exercises,
there will be two sessions per week (to ease scheduling)

available
slots

Tue

8-10

10-12

13-15

15-17

Wed

13-15

15-17

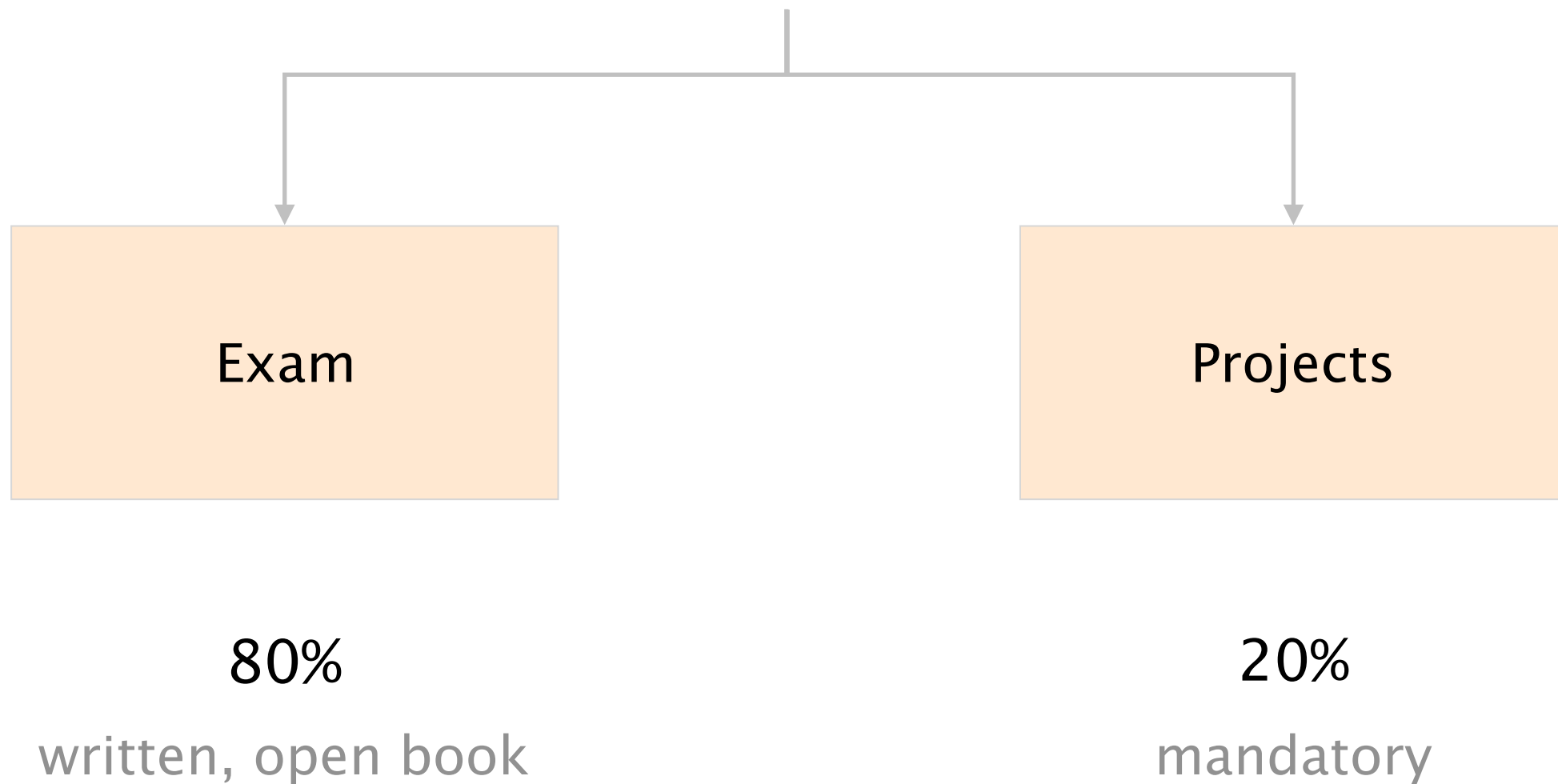
Thur

13-15

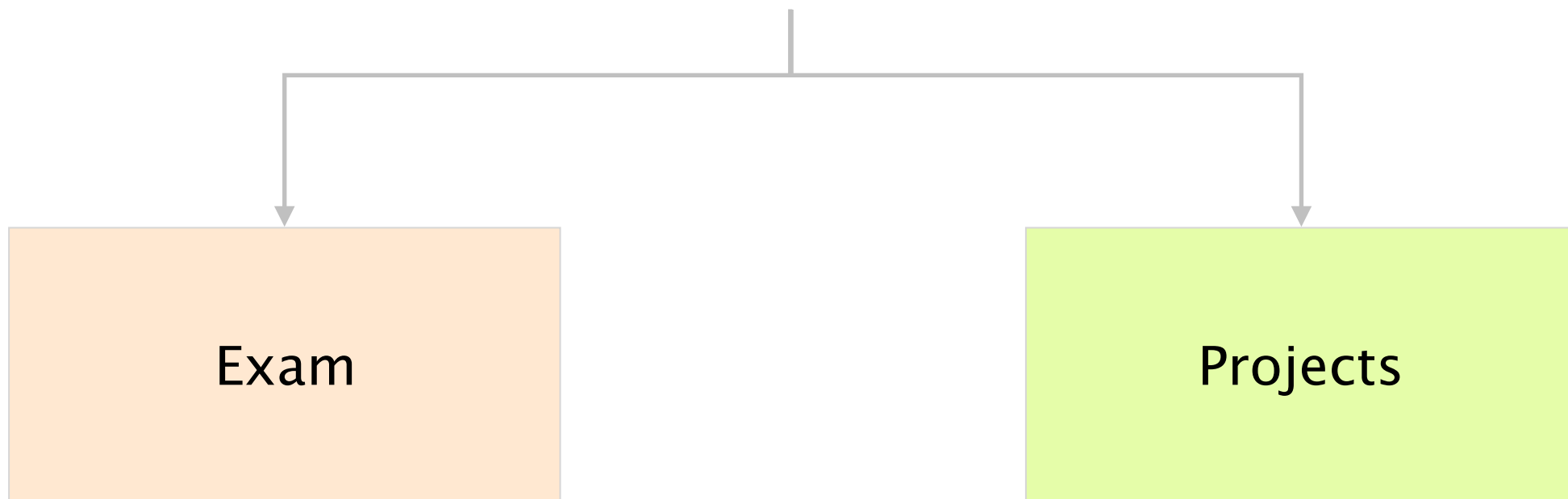
15-17

vote *today* on
comm-net.ethz.ch

Your final grade



Your final grade



80%

written, open book

20%

mandatory

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

#1 Build and operate a small Internet

#2 Implement an interoperable reliable protocol

Detailed instructions will follow

“Internet Hackathon”

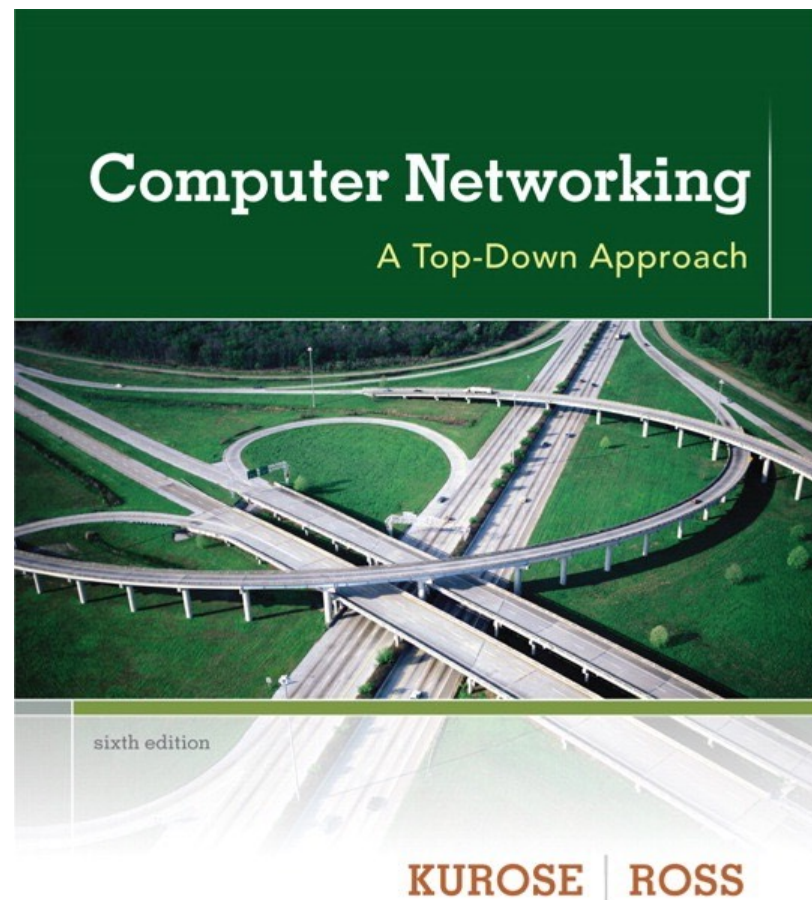
sometime in week 8

2016 edition



The course follows the textbook

Computer Networking: a Top-Down Approach

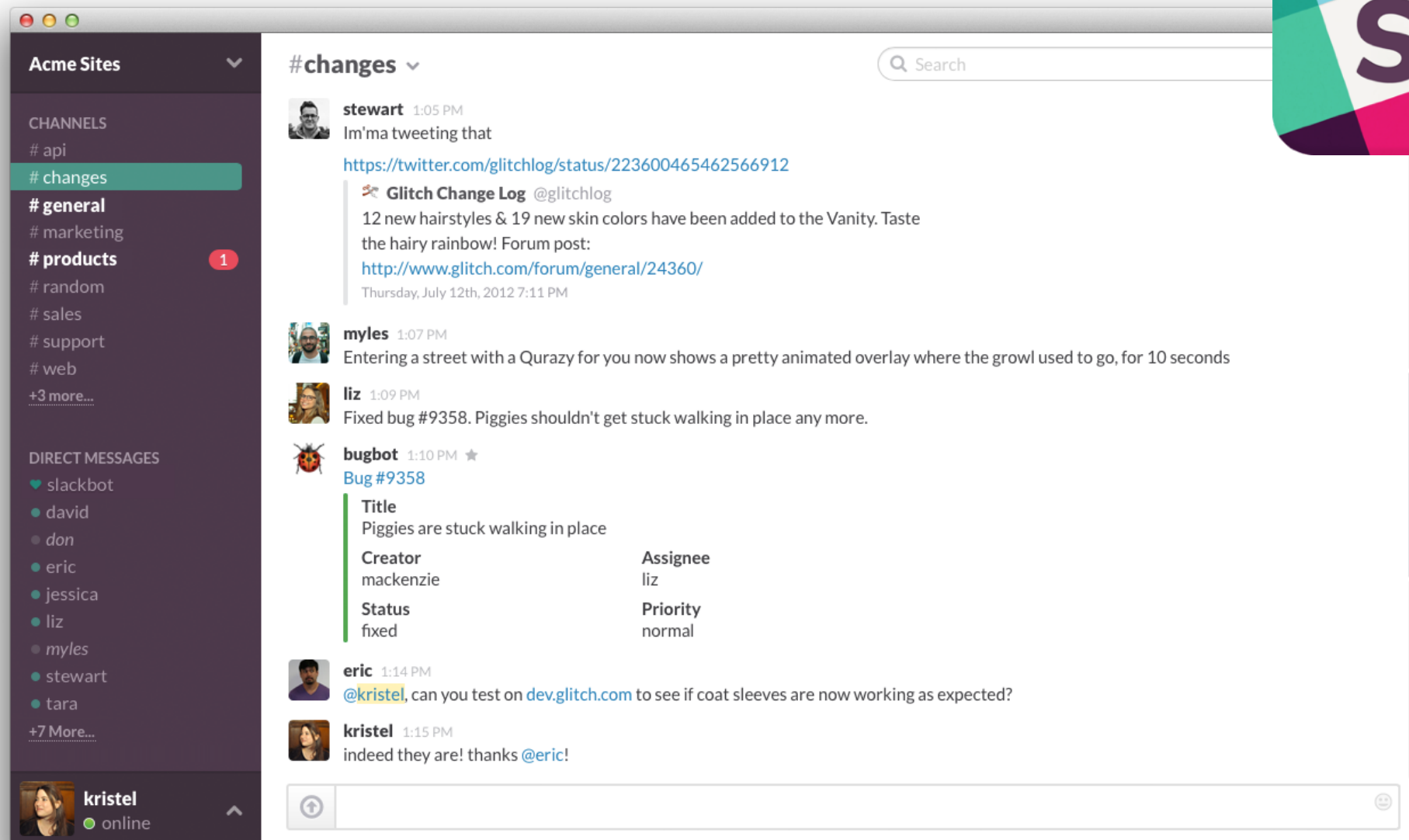


6th edition

ok to use the 5th

see sections indicated
on comm-net.ethz.ch

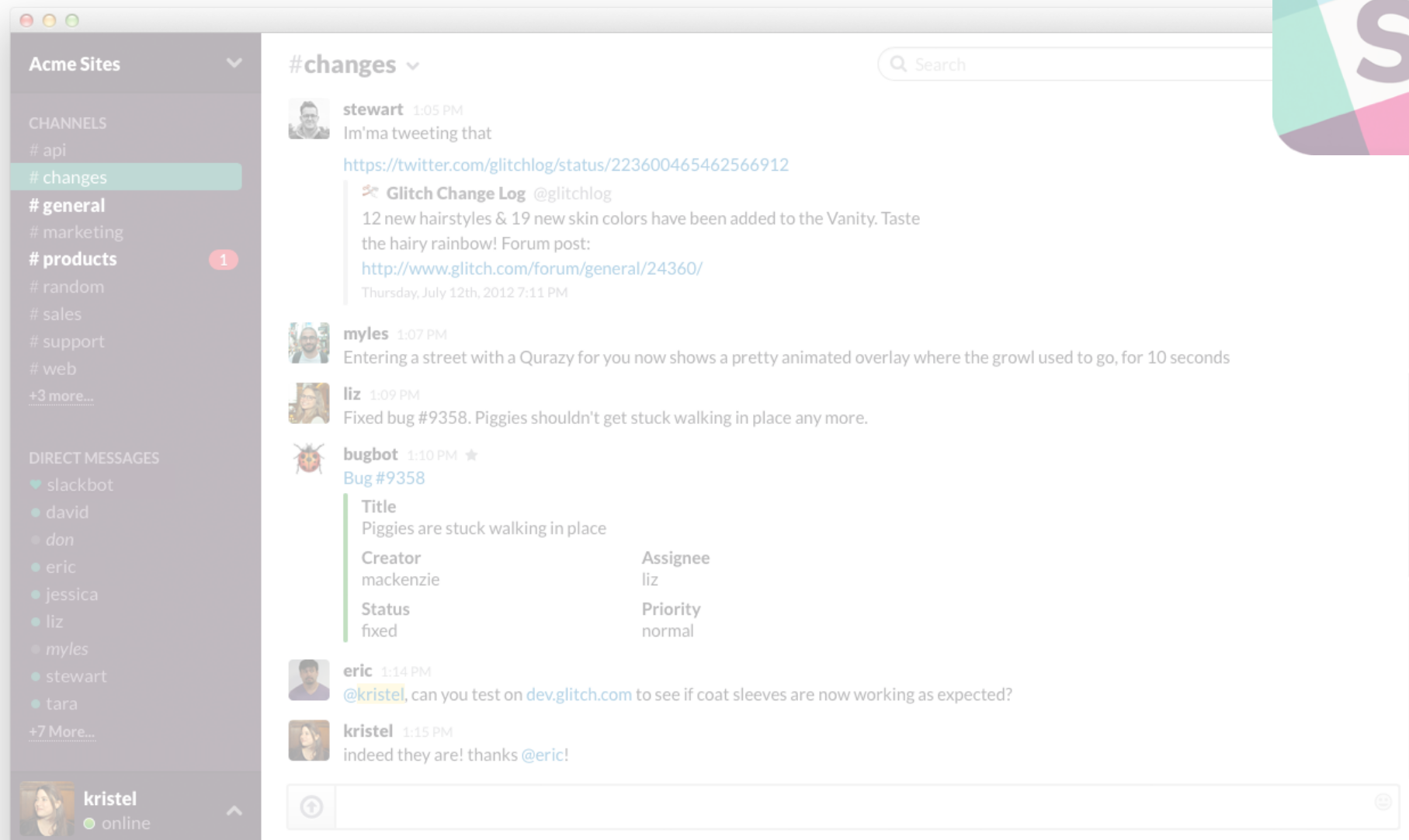
We'll use **Slack** (chat client) to discuss about the course and assignments



Web, smartphone and desktop clients available

Register **today** using your *real* name

> <https://comm-net17.slack.com/signup>



Web, smartphone and desktop clients available

Communication Networks

List any
technologies, principles, applications...
used after typing in:

> www.google.ch

and pressing enter in your browser

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?

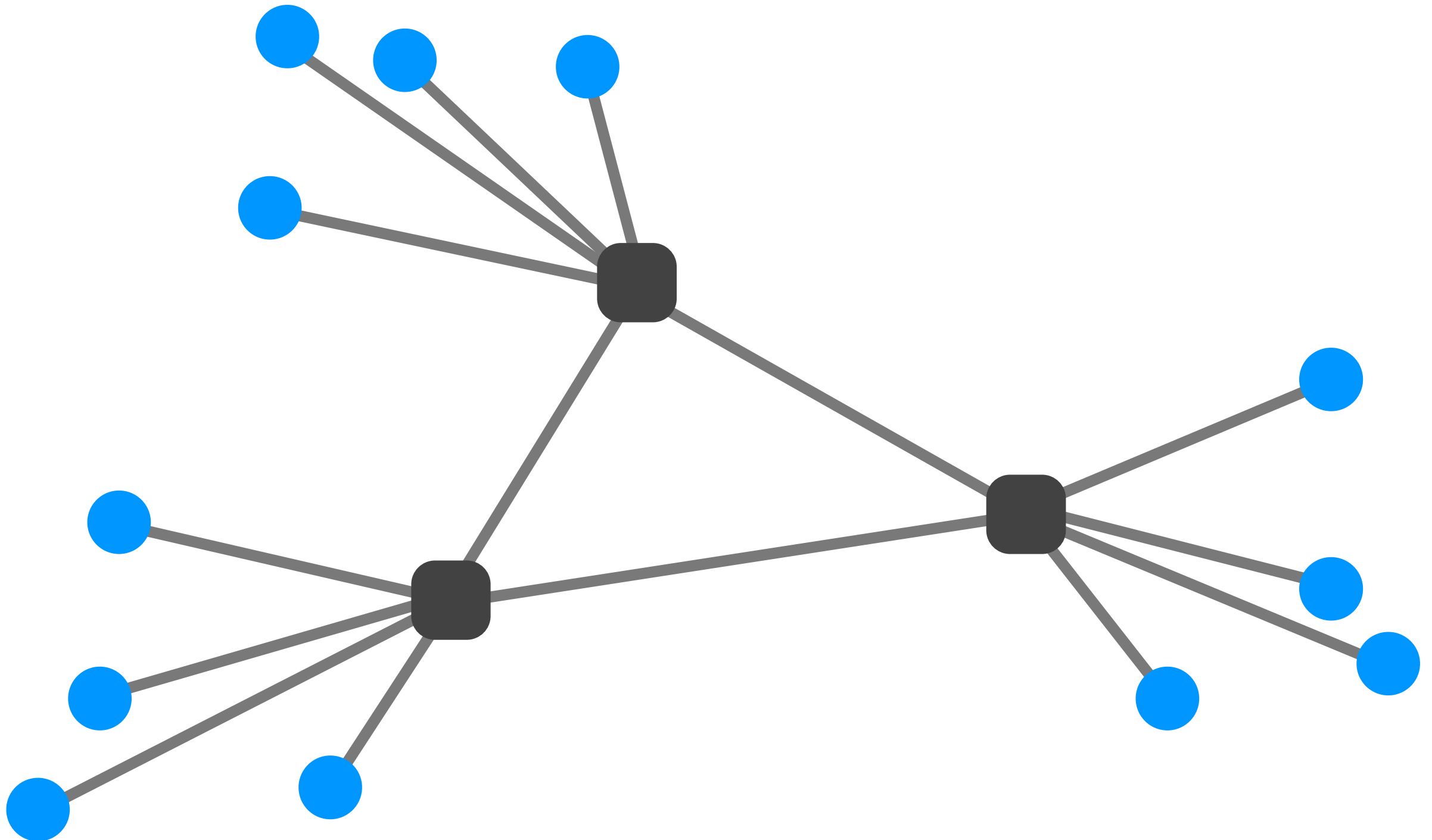
How is it shared?

How is it organized?

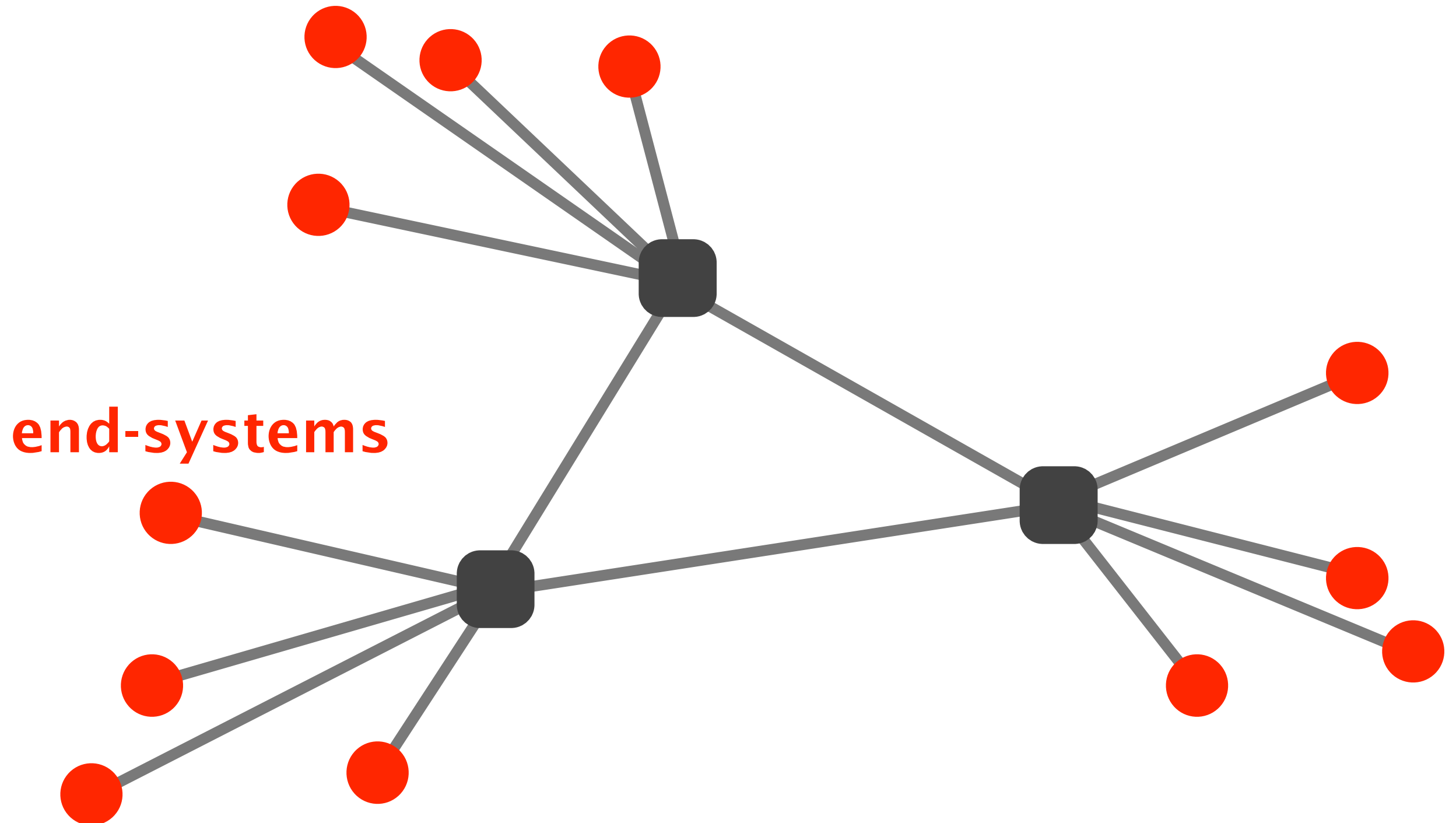
How does communication happen?

How do we characterize it?

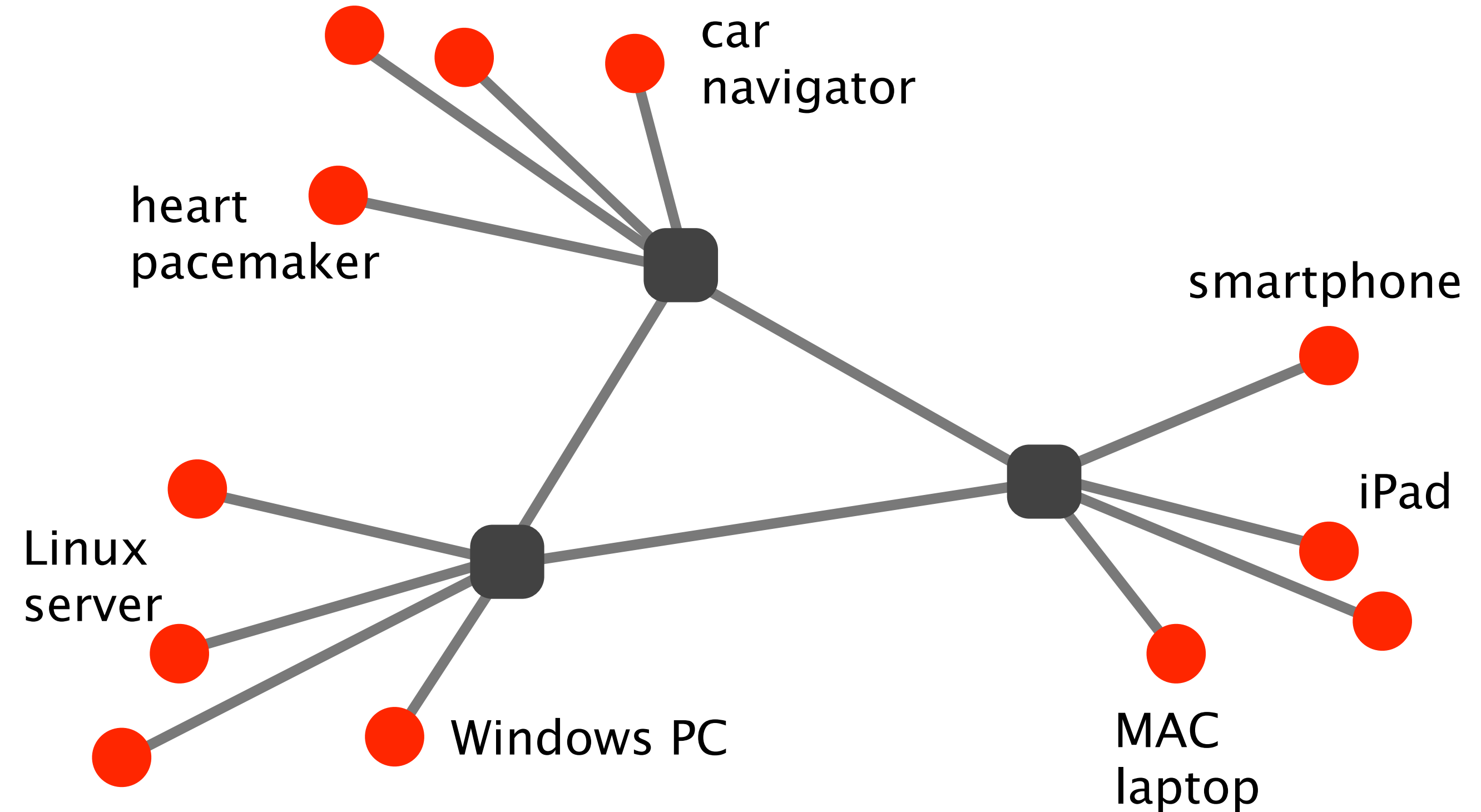
Networks are composed of three basic components



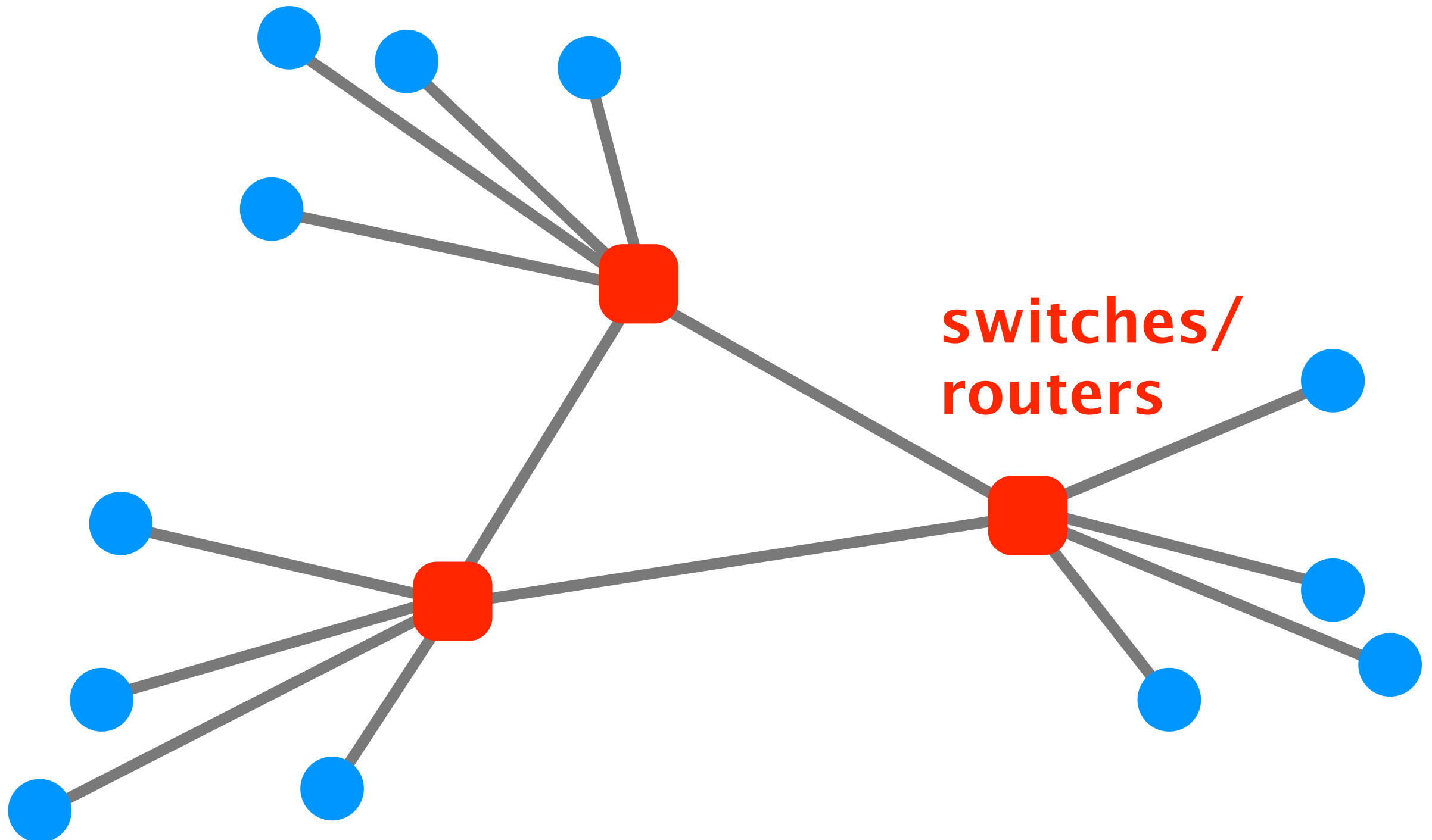
End-systems send & receive data



End-systems come in a wide-variety



Switches & routers forward data to the destination



Routers vary in size and usage

Home
router



~20 cm

0,5 kg

1 Gbps

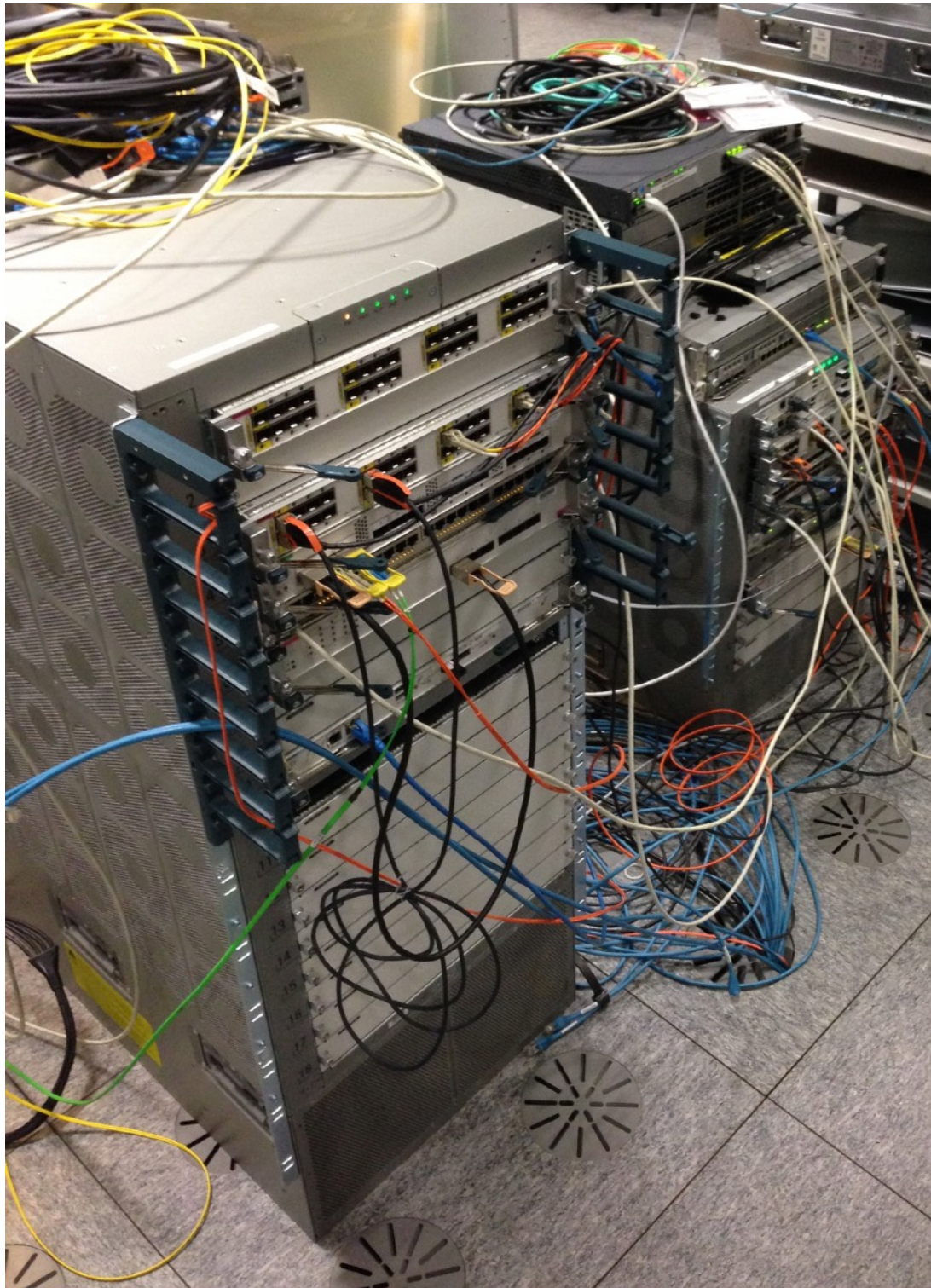
Internet core
router

>200cm

700kg

1.2 Tbps

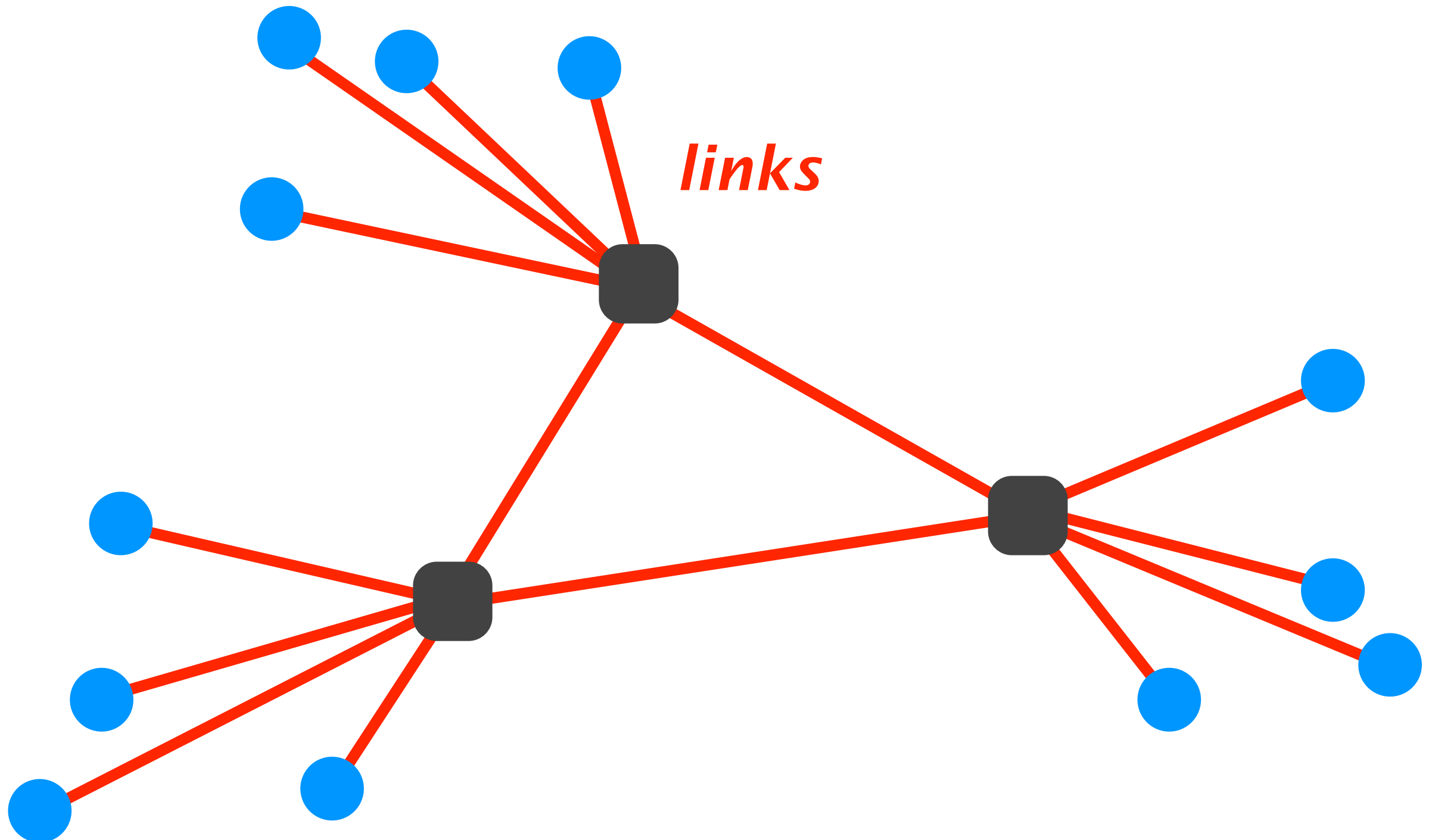




Cisco Nexus 7k
Routers @ETHZ

~25 deployed

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

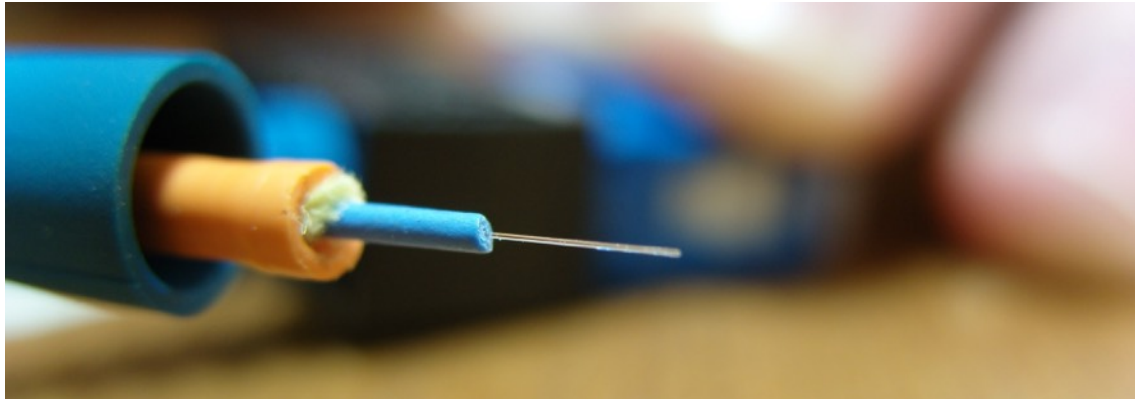


Links, too, vary in size and usage



Copper

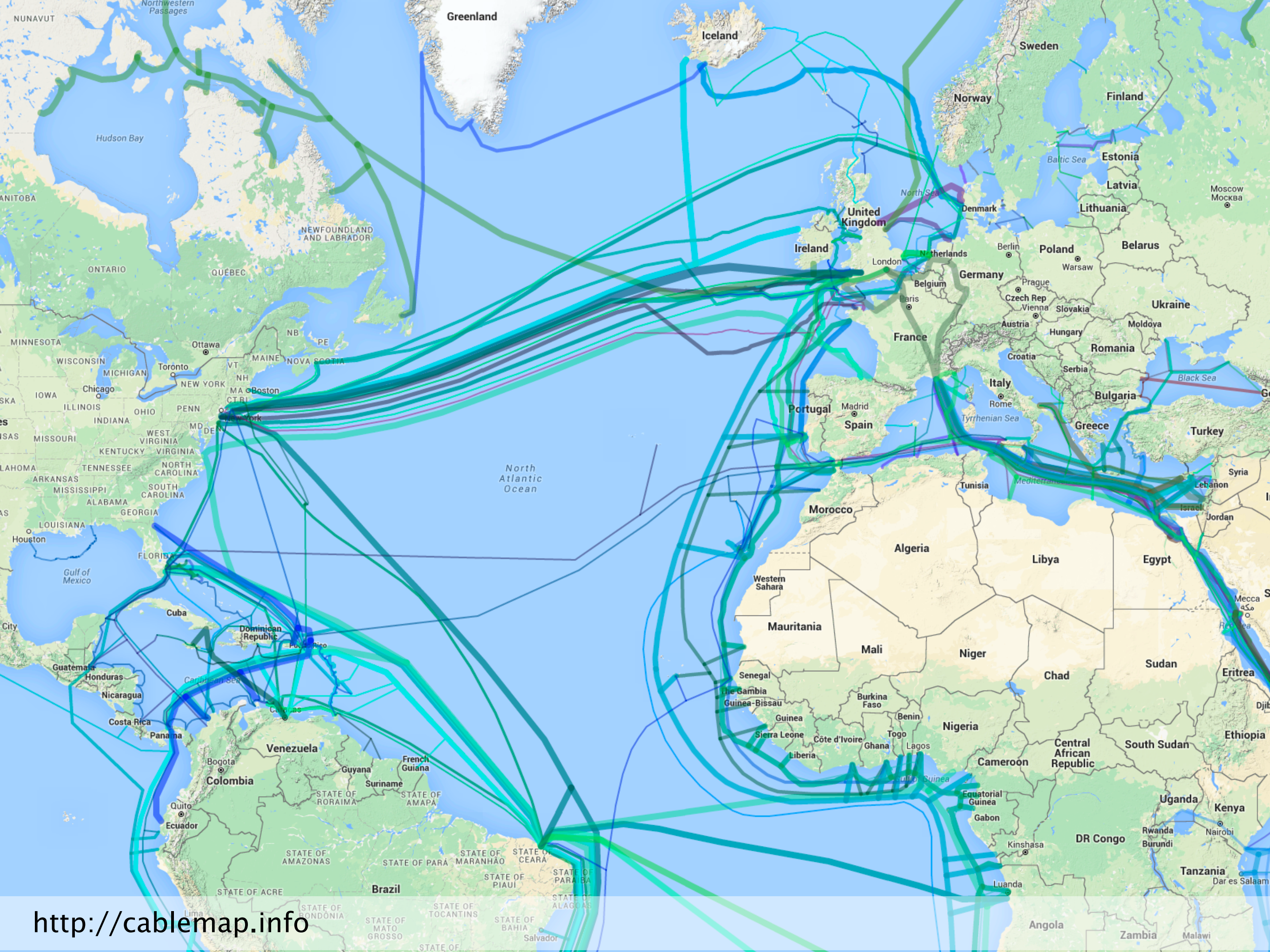
ADSL, RJ-45,...

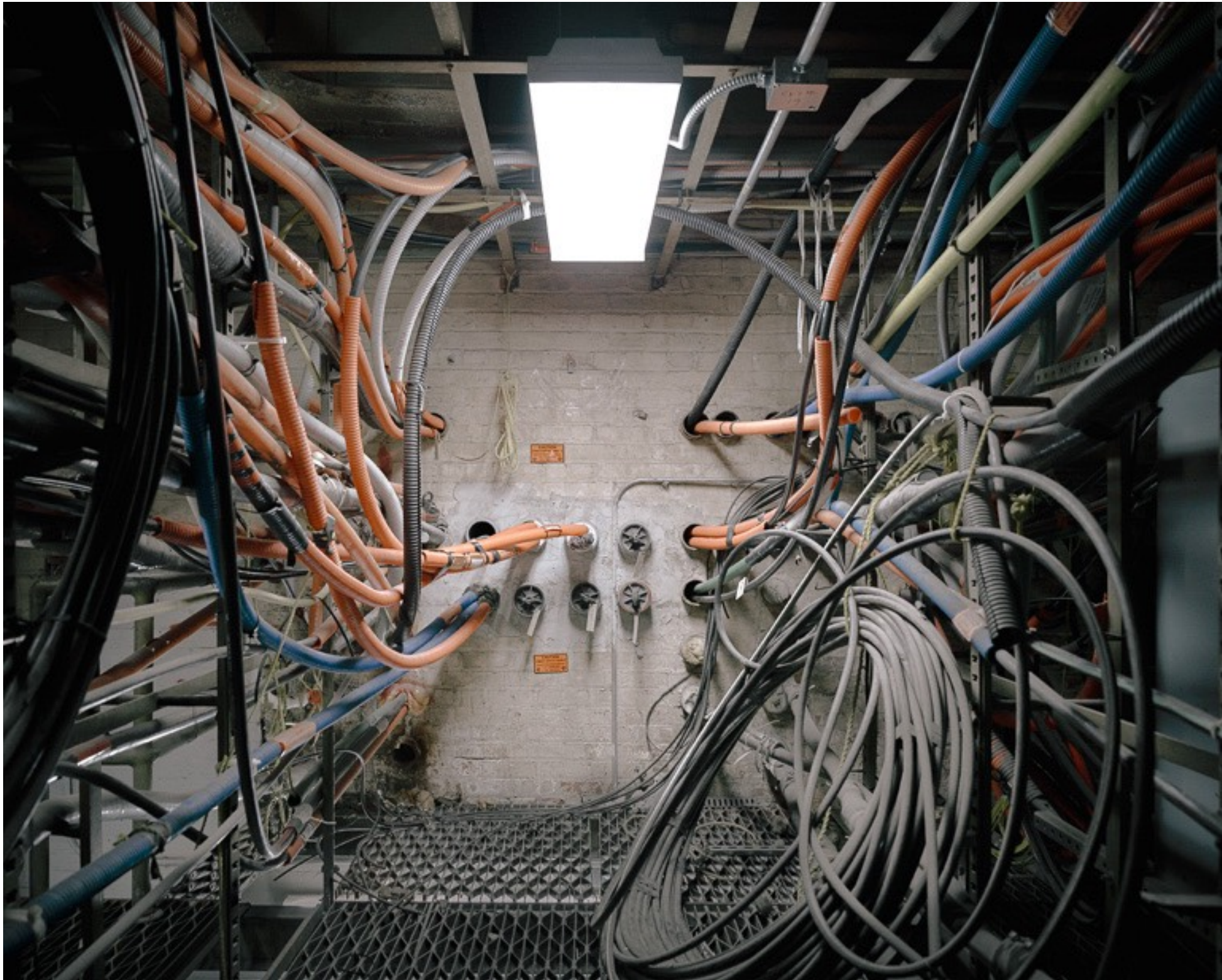


Optical fibers



Wireless link

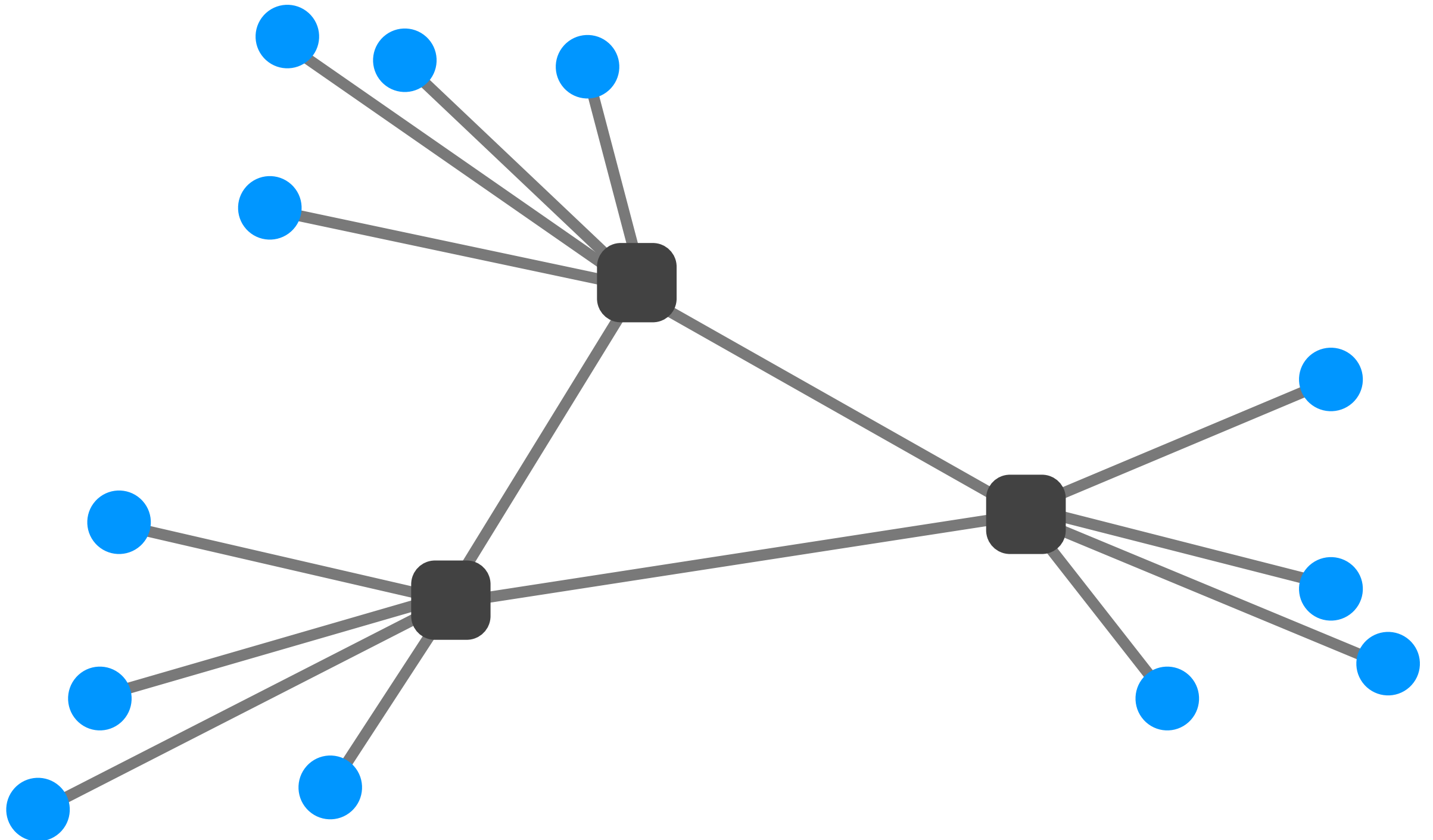




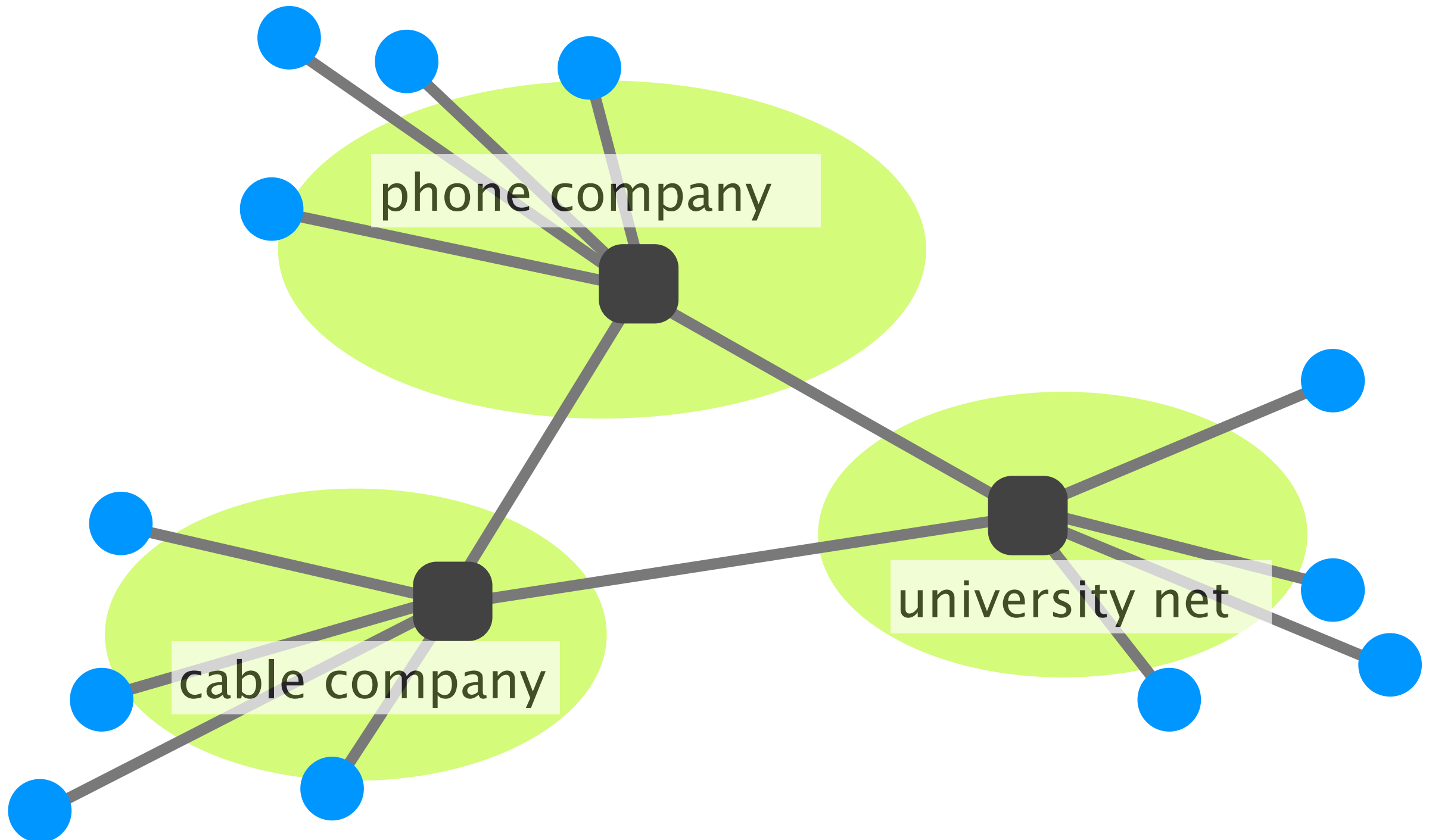
Somewhere in Manhattan...

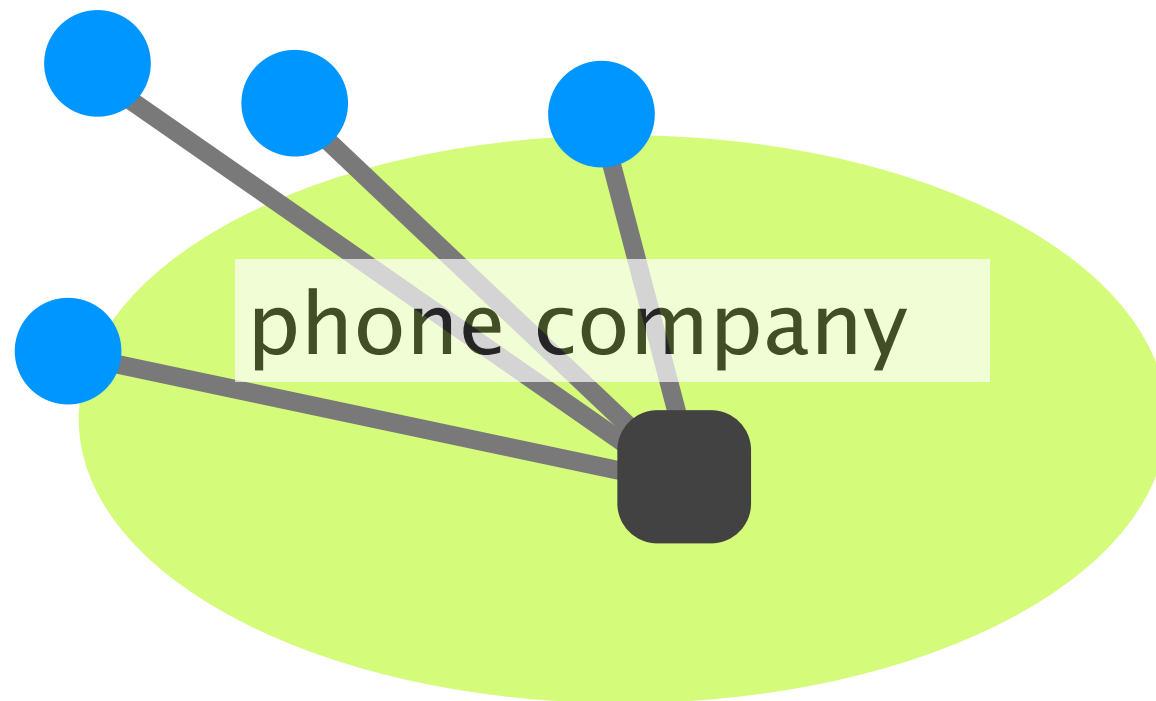
<http://www.petergarritano.com/the-internet.html>

The *Inter*net is a network of networks

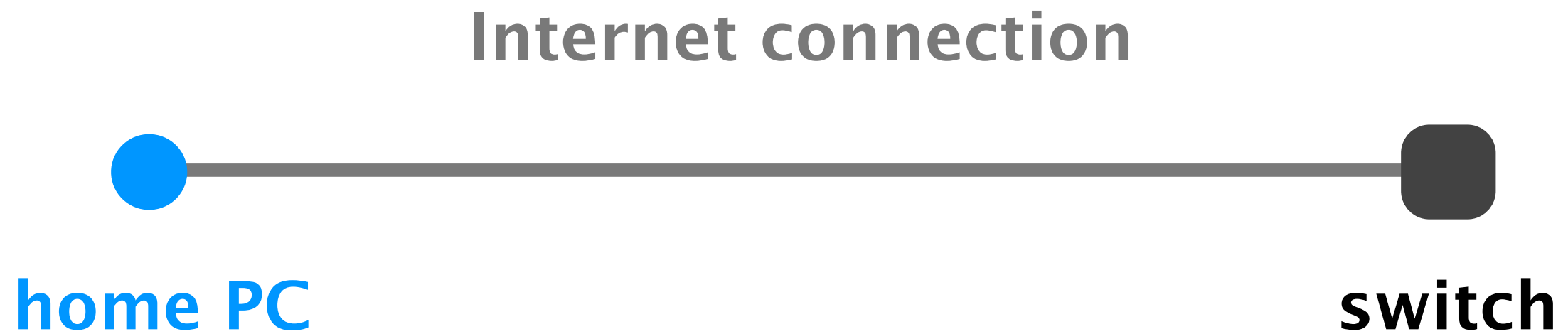


Internet Service Providers

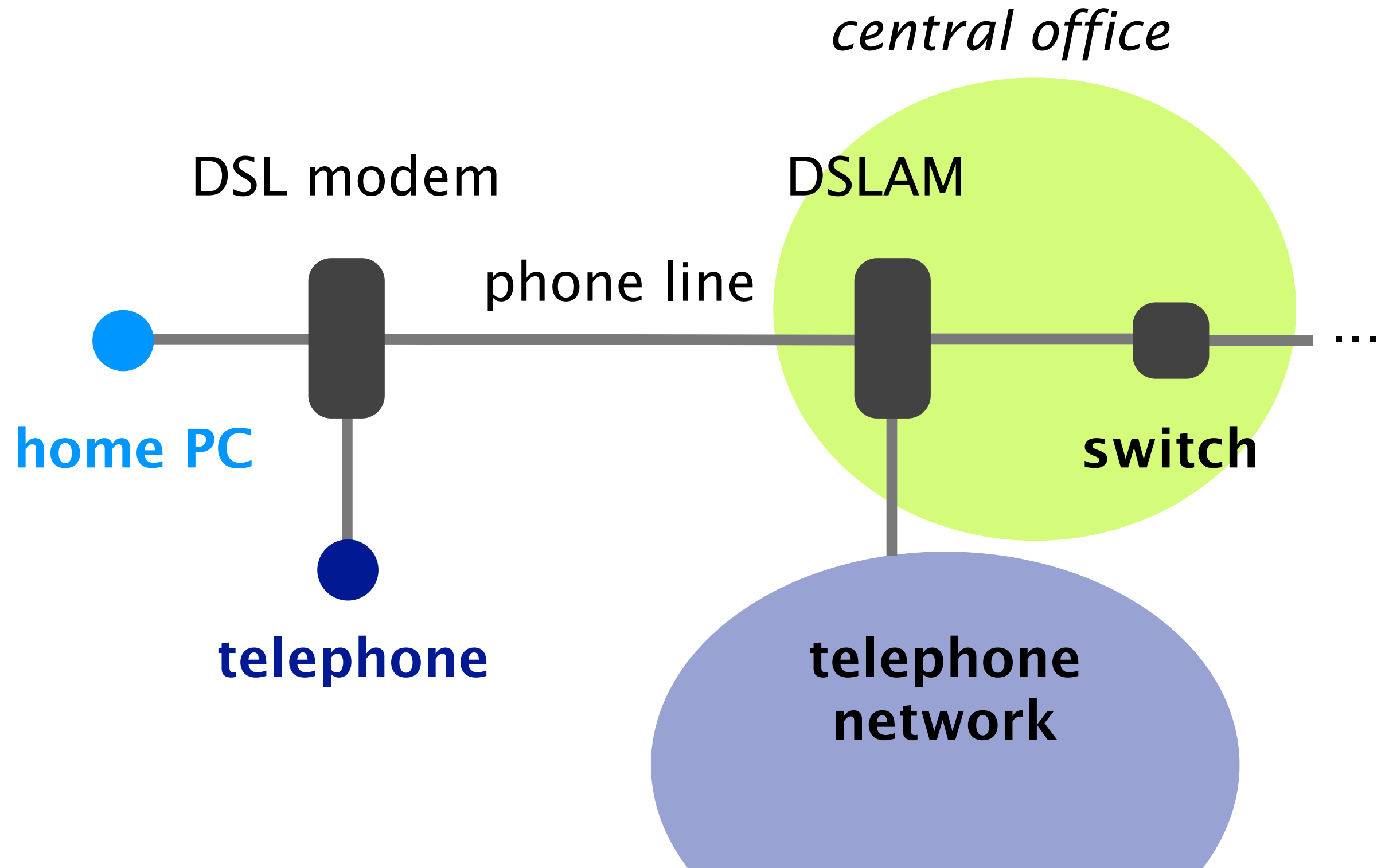




Conceptually, the last mile of the Internet looks like this



In practice, it looks more like this...



Digital Subscriber Line (DSL) brings
high BW to households over phone lines

Digital Subscriber Line (DSL) brings
high BW to households over **phone lines**



Why?

Digital Subscriber Line (DSL) brings high BW to households over phone lines

DSL is composed of 3 channels:

- downstream data channel tens to few hundred Mbps
- upstream data channel few Mbps to few tens Mbps
- 2-ways phone channel

DSL is composed of 3 channels:

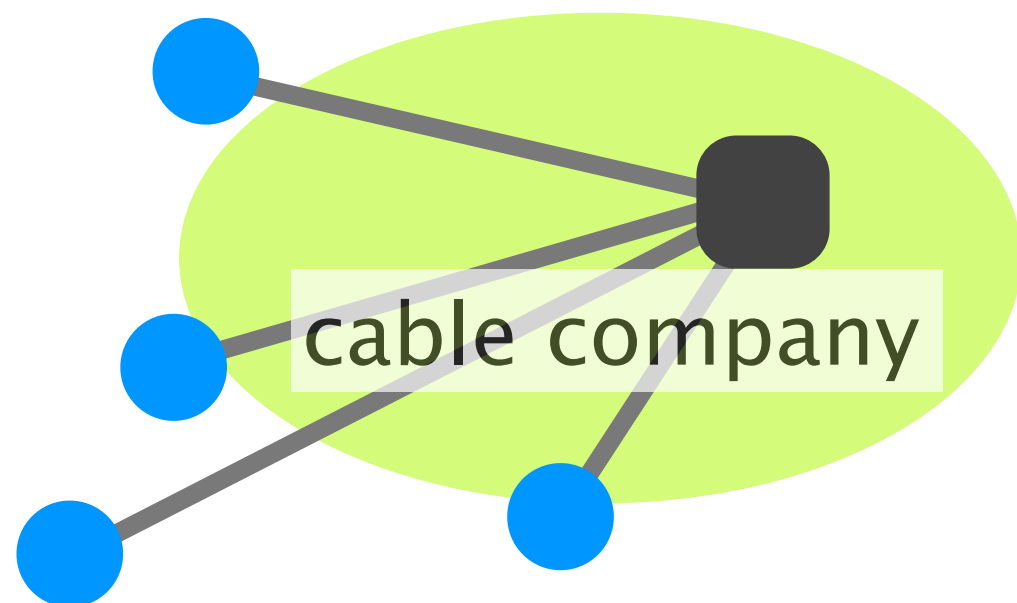
- downstream data channel
- upstream data channel
- 2-ways phone channel

tens to few hundred Mbps

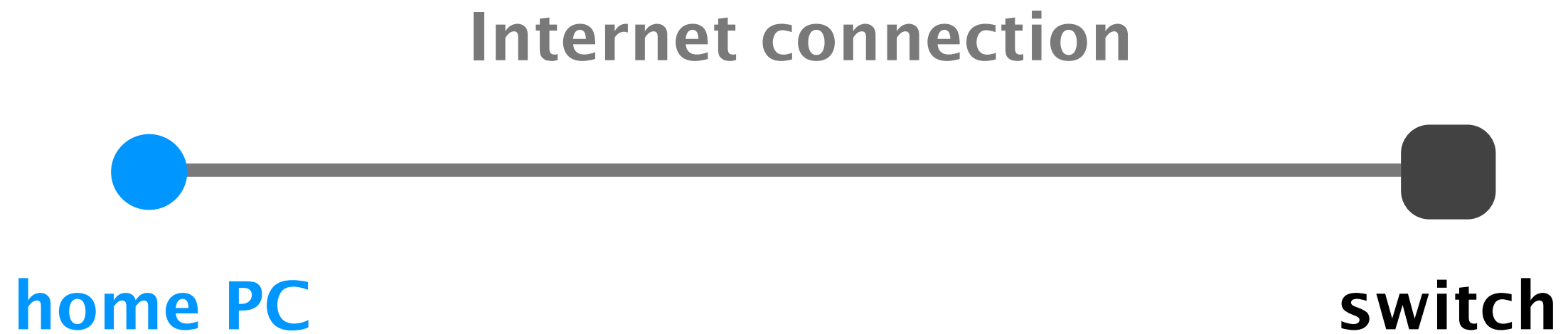
few Mbps to few tens Mbps



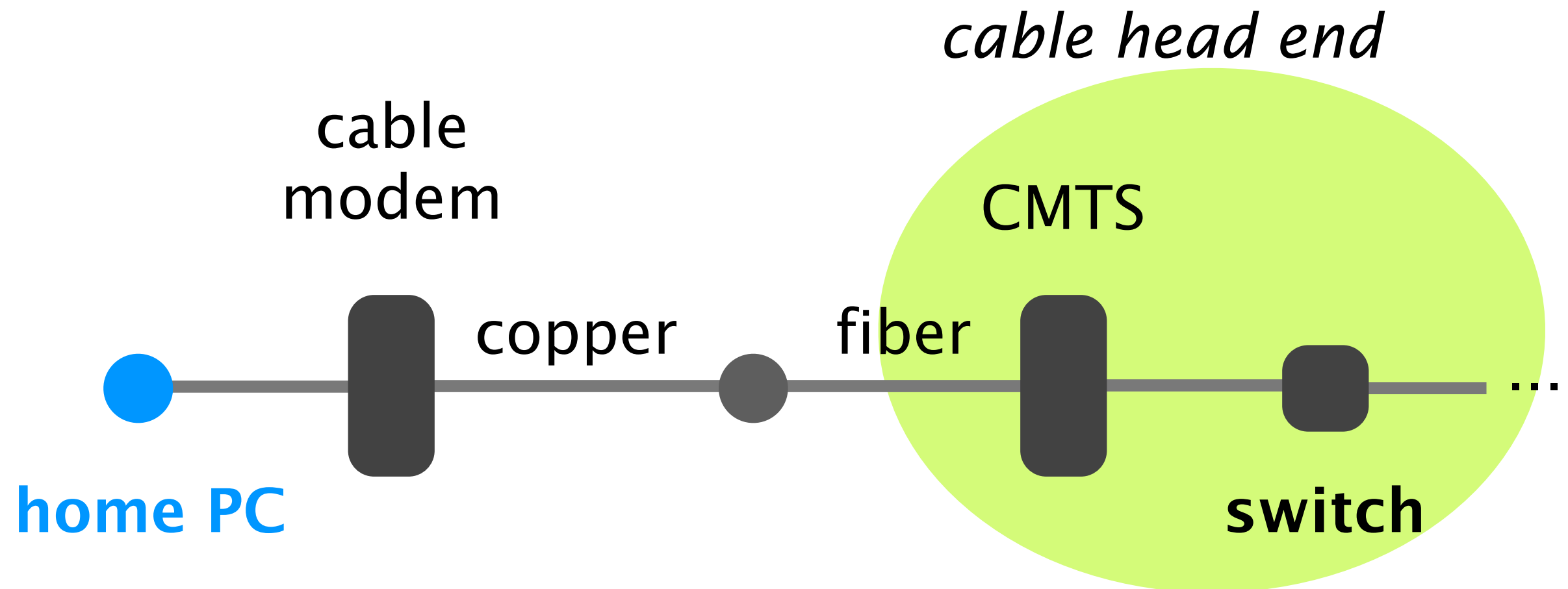
Why is there such an asymmetry?



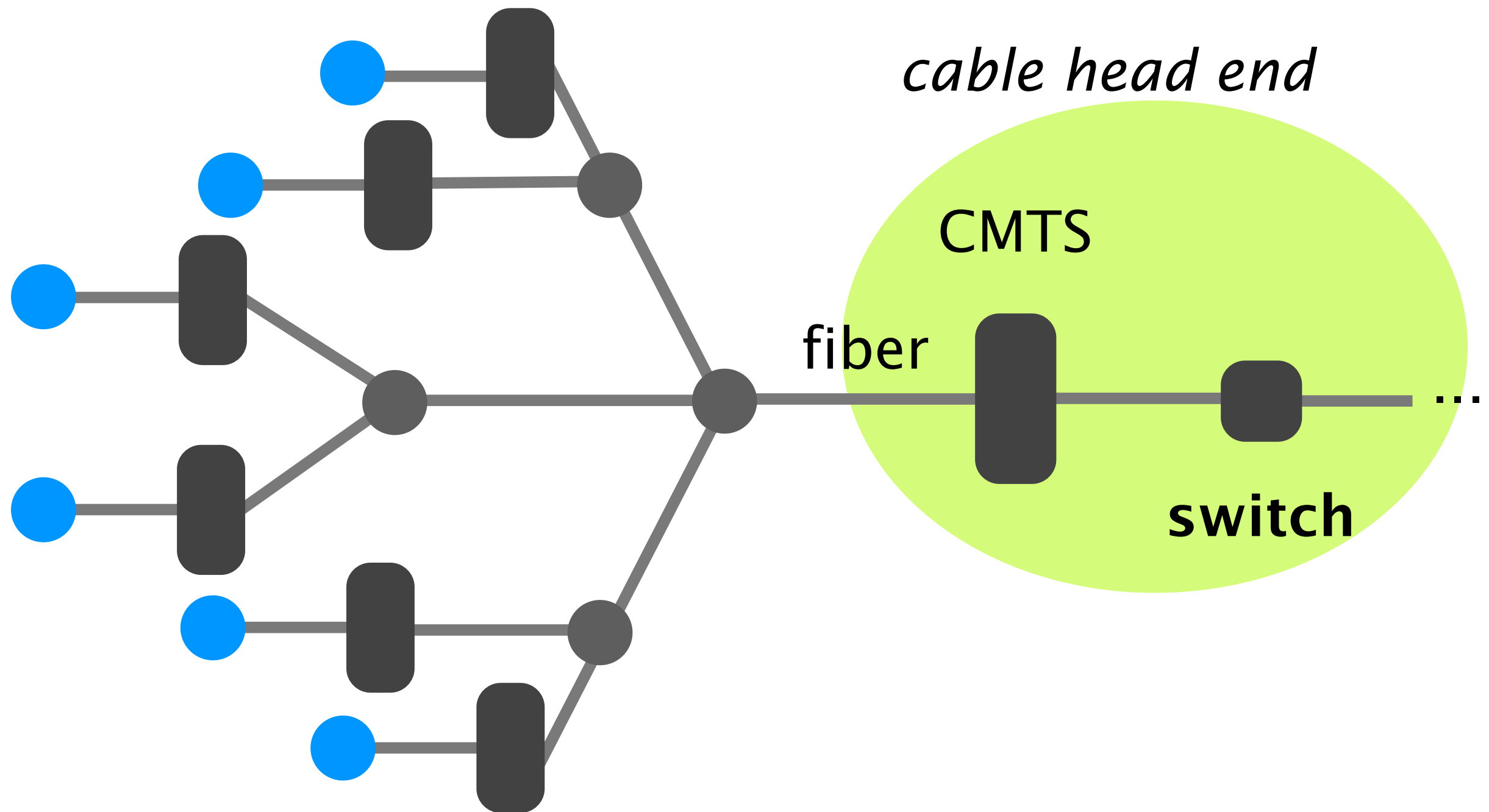
Conceptually, the last mile of the Internet looks like this



In practice, it looks more like this...



Many households share the same access



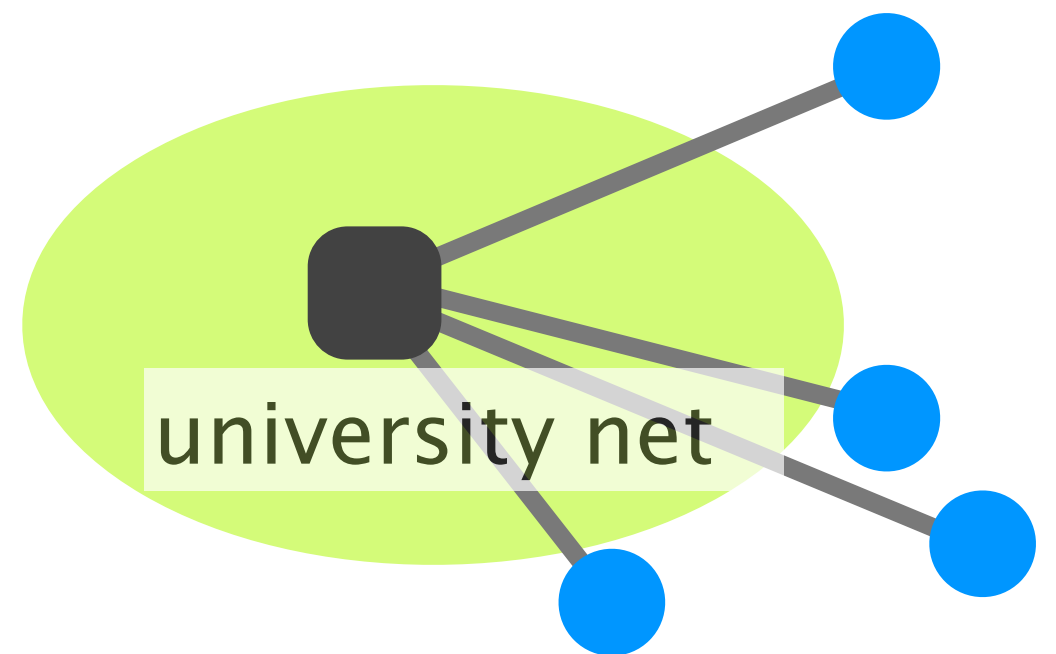
Cable Access Technologies (CATV) brings high BW to the households via cable TV



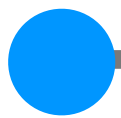
coaxial copper & fiber

- downstream data channel tends to hundreds of Mbps
- upstream data channel tens of Mbps

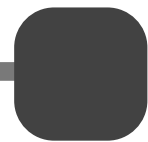
Unlike ADSL, the medium is **shared** between households



Internet connection

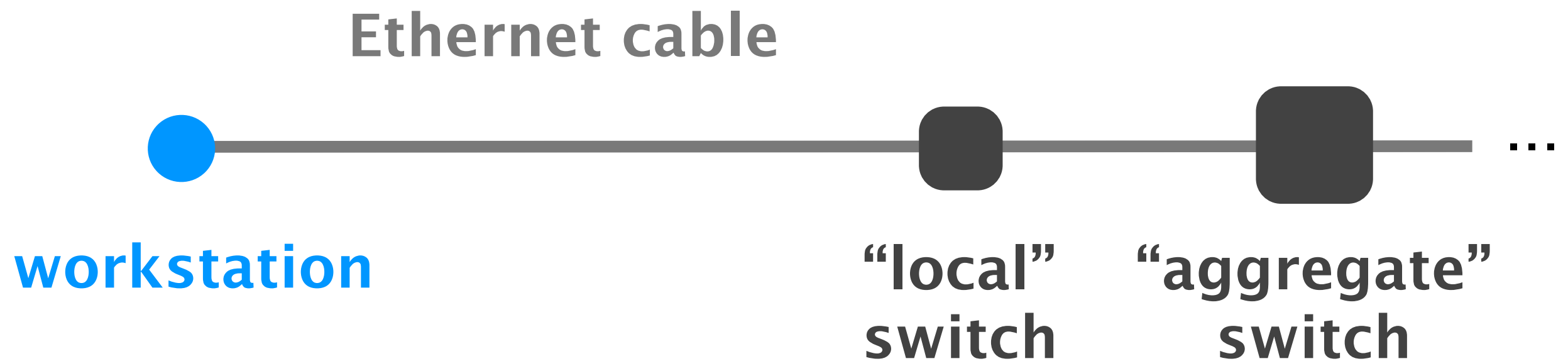


workstation



switch

With respect to DSL and cable providers,
enterprise access networks is *much* simpler



Ethernet is the most widely used Local Area Network technology



Twisted pair copper

1 Gbps, 10 Gbps, 40 Gbps, 100 Gbps, ...

symmetric

ADSL, CATV and Ethernet are only few examples
of access technologies...

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?

Up to now, we've seen
what the last mile of the Internet looks like

What about the rest of the network?

3 requirements for a network topology

Should 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

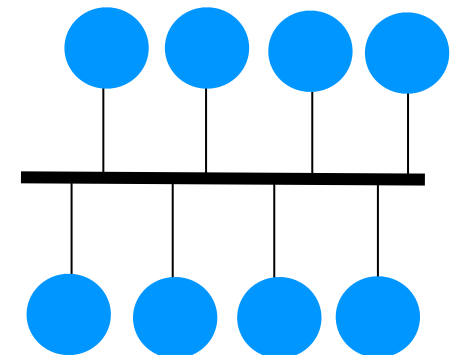
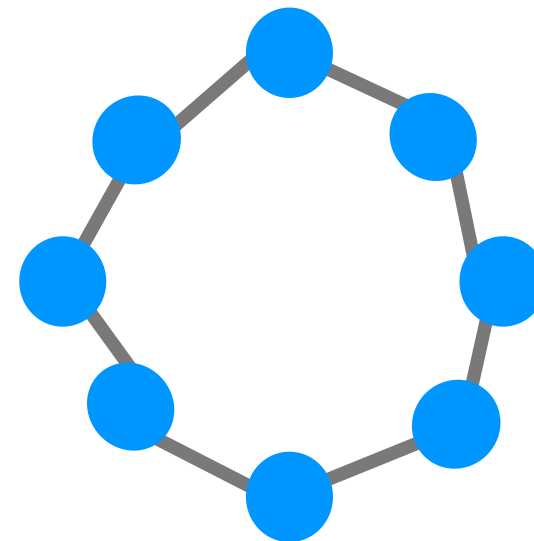
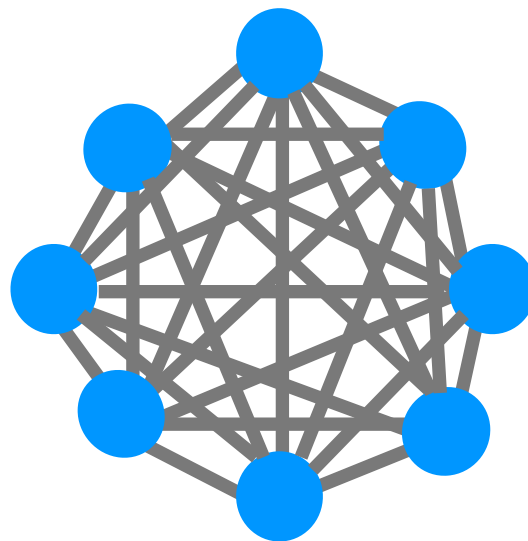
Compare these three designs in terms of
sharing, resiliency, and per-node capacity

design

full-mesh

chain

bus



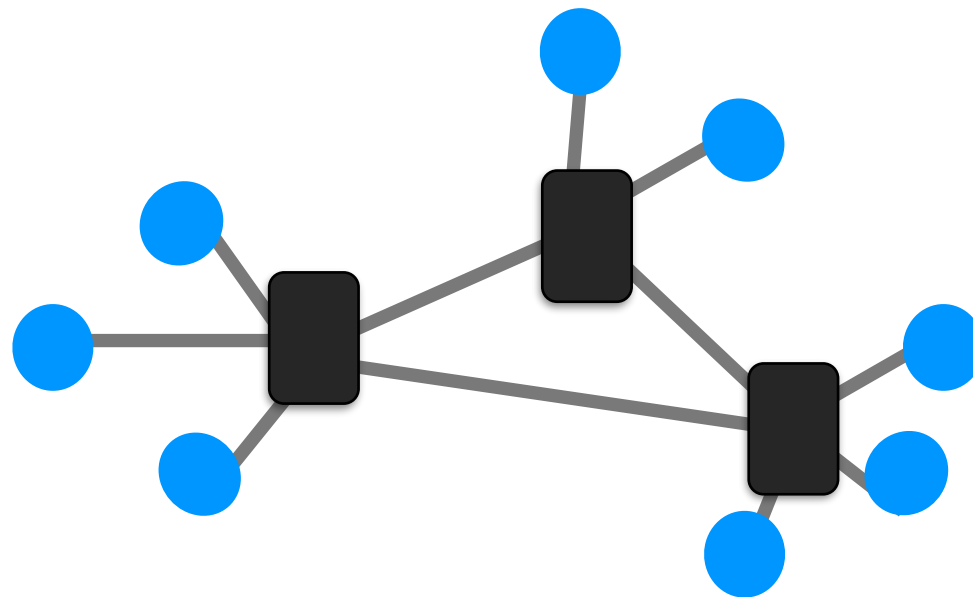
advantages

disadvantages

Switched networks provide
reasonable and **flexible** compromise

design

switched



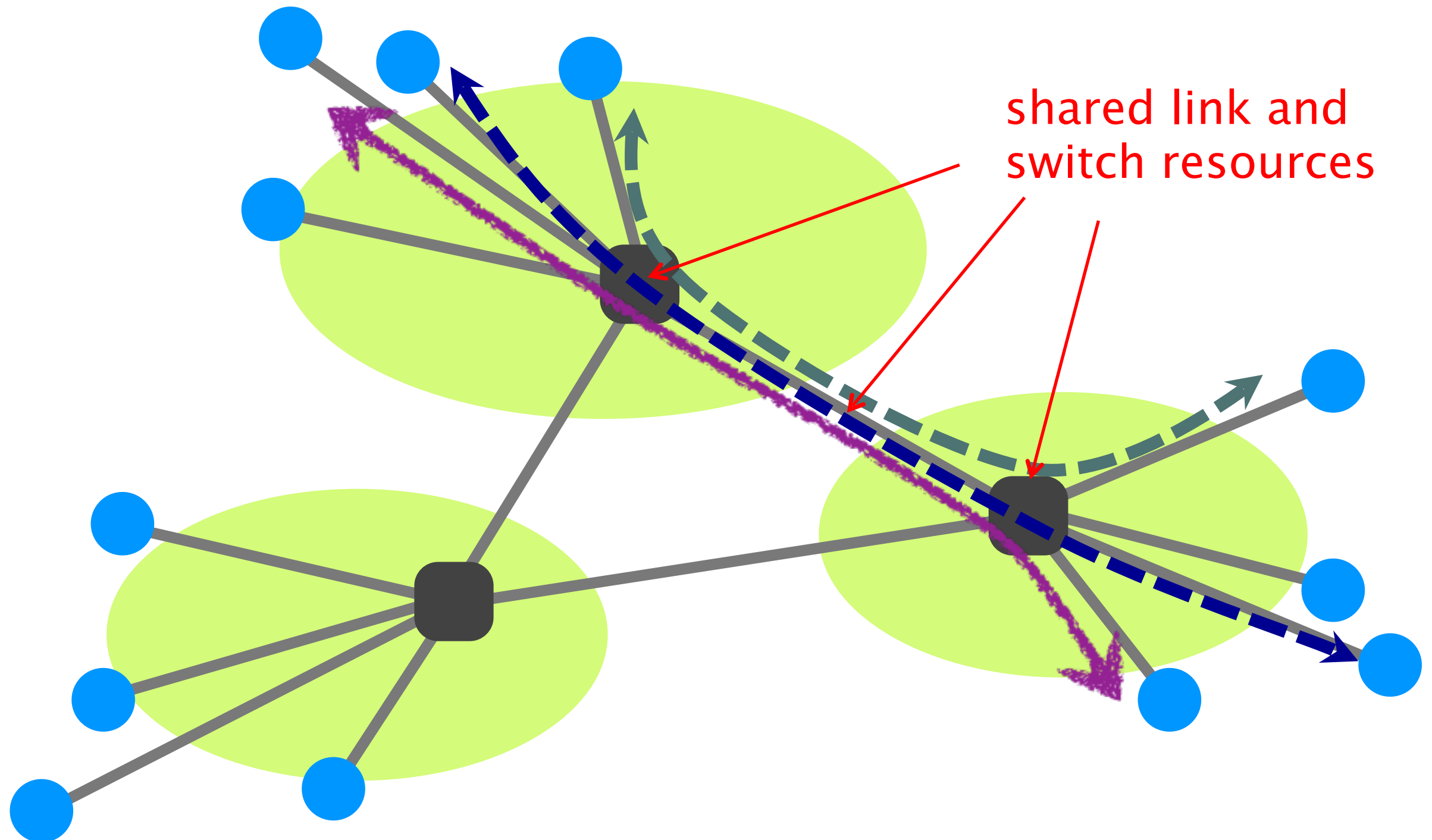
advantages

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

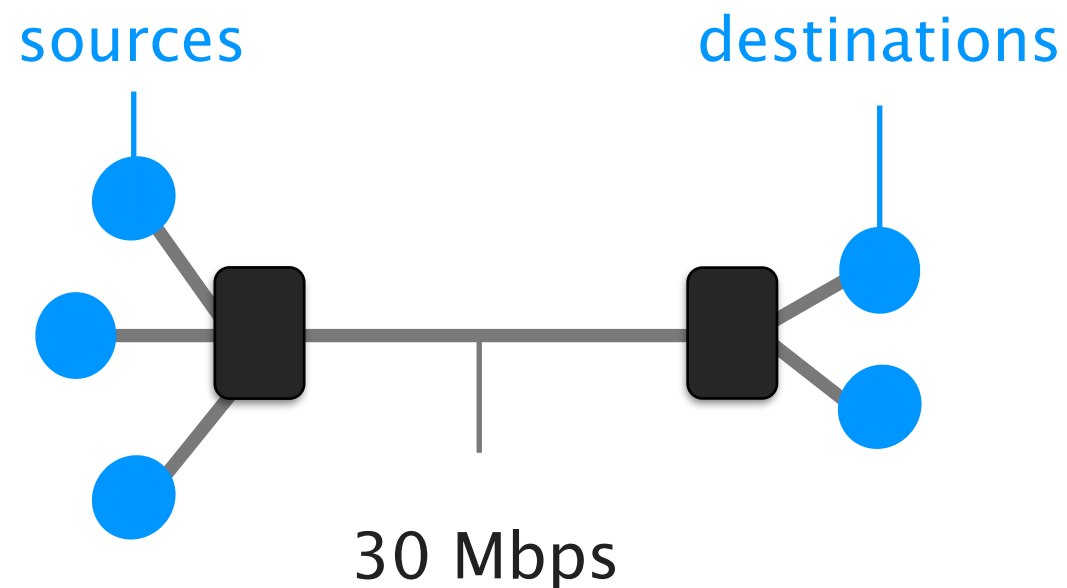
On-demand

multiplexing

at the flow-level

at the packet-level

Between reservation and on-demand:
Which one do you pick?

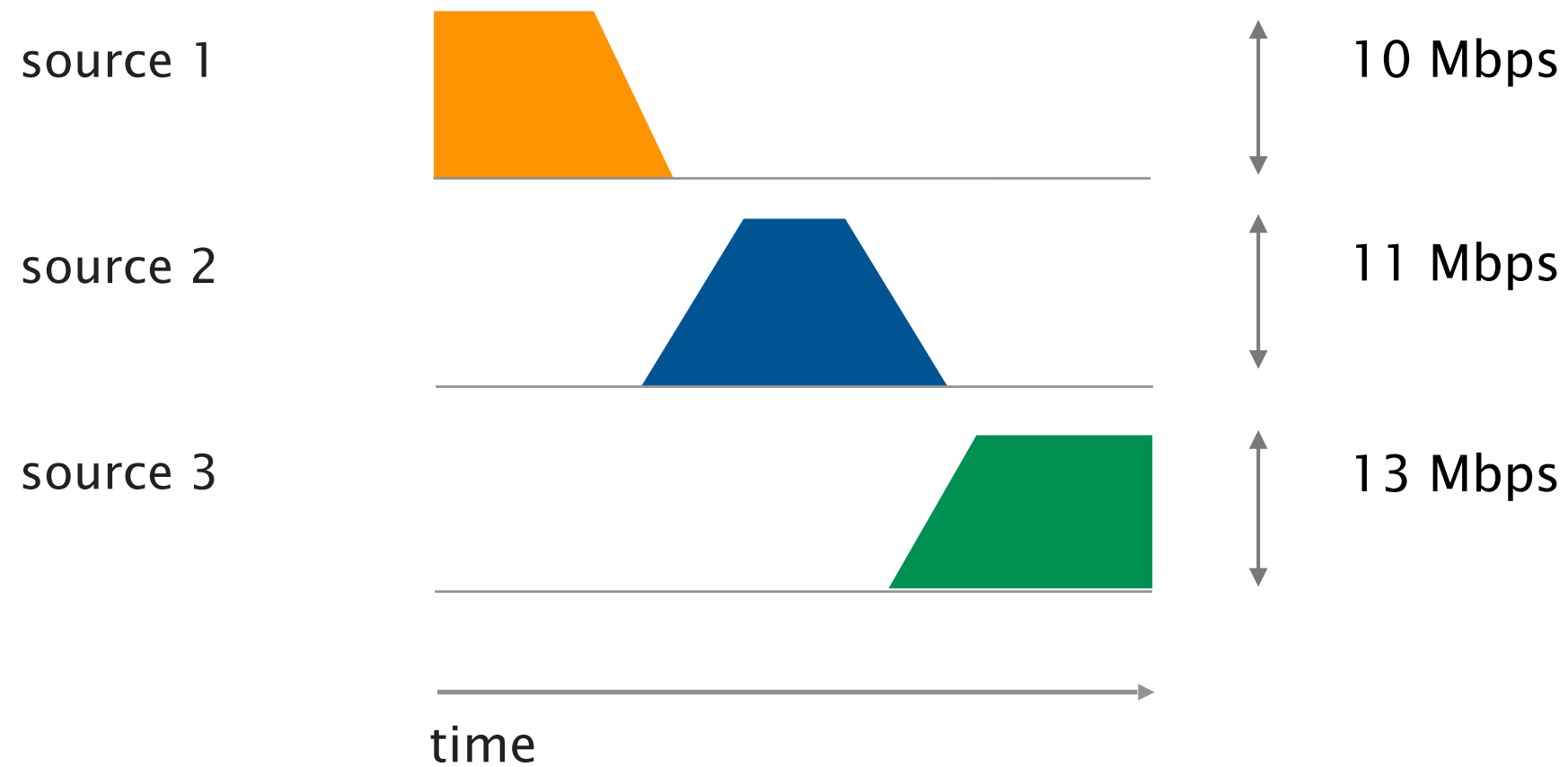


Consider that each source
needs 10 Mbps

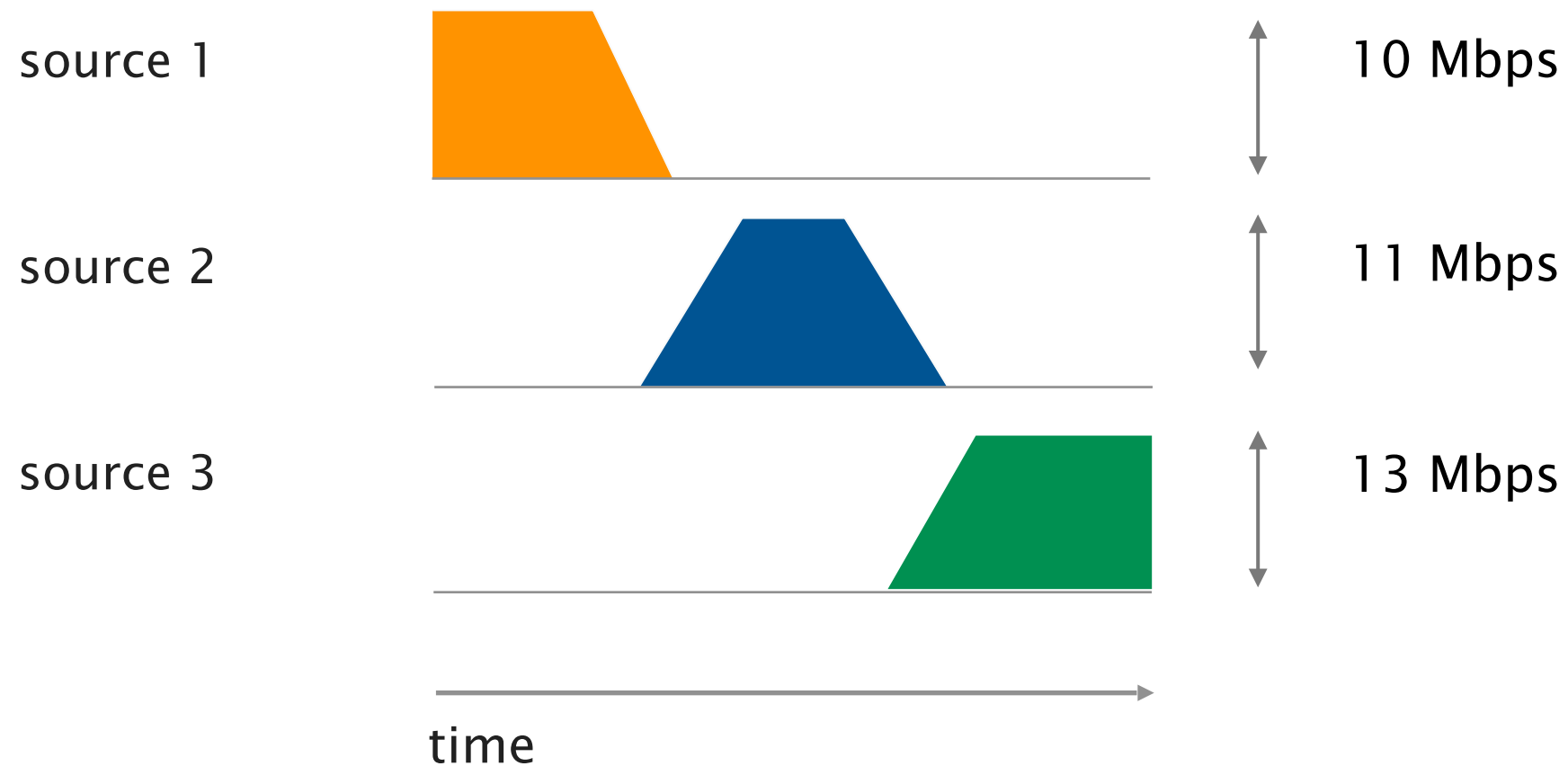
What do they get with:

- reservation
- on-demand

Assume the following peak demand and flow duration



Assume the following peak demand and flow duration



What does each source get with **reservation** and on-demand?

- first-come first-served
- equal (10 Mbps)

Peak vs average rates

Each flow has	Peak rate	P
	Average rate	A

Reservation must reserve P , but level of utilization is A/P

e.g., $P=100$ Mbps, $A=10$ Mbps, level of utilization=10%

On-demand can achieve higher level of utilizations

depends on degree of sharing and burstiness of flows

Ultimately, it depends on the application

Reservation **makes sense** when **P/A is small**

voice traffic has a ratio of 3 or so

Reservation **wastes capacity** when **P/A is big**

data applications are bursty, ratios >100 are common

Ultimately, it depends on the application

Reservation **makes sense** when **P/A is small**

voice traffic has a ratio of 3 or so

Reservation **wastes capacity** when **P/A is big**

data applications are bursty, ratios >100 are common

**That's why the phone network used reservations
... and why the Internet does not!**

In practice, the two approaches are implemented using circuit-switching or packet-switching, respectively



Reservation



On-demand

implem.

circuit-switching

packet-switching

Reservation

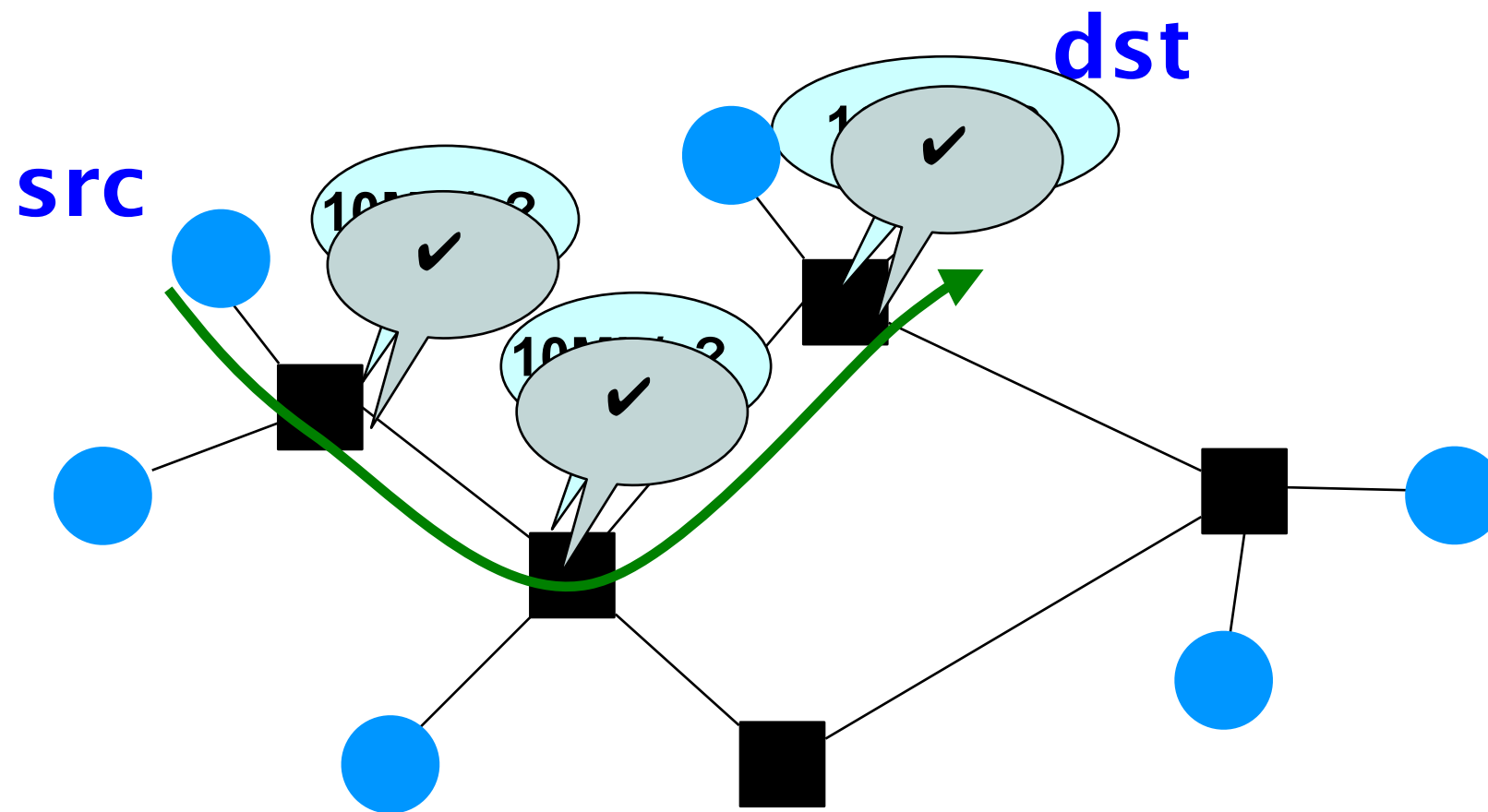
On-demand

implem.

circuit-switching

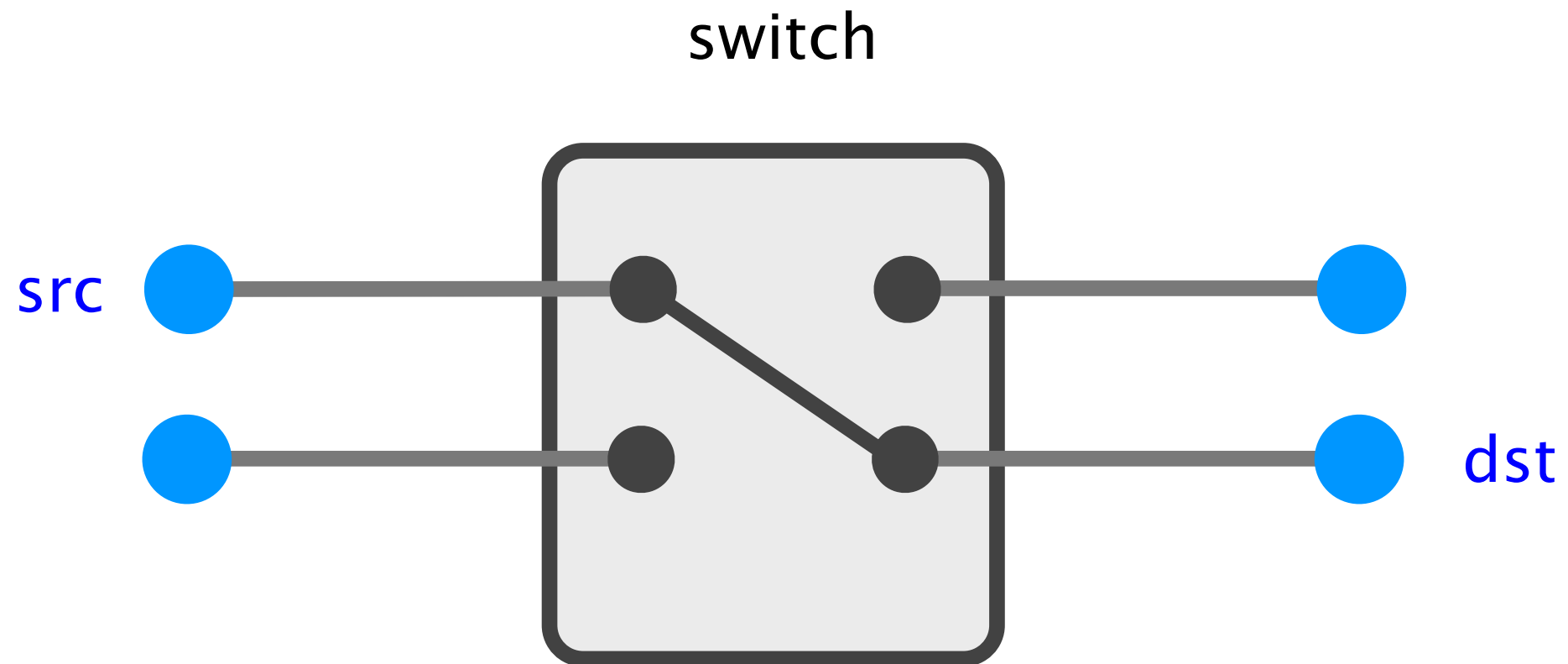
packet-switching

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

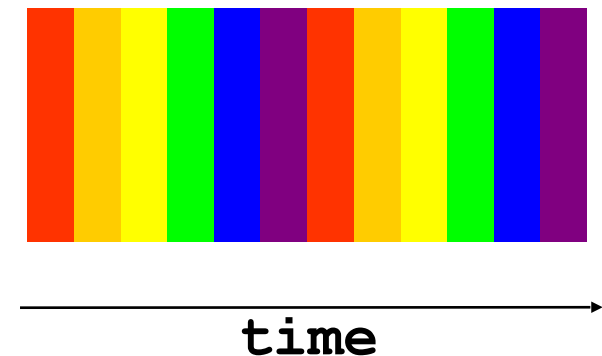
The Resource Reservation Protocol
establishes a circuit within each switch



There exist many kinds of circuits

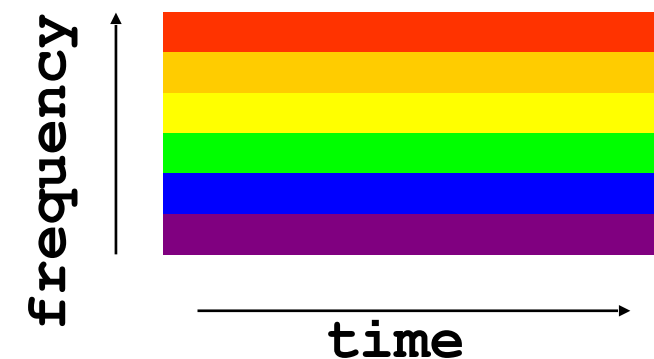
Time-based multiplexing

- divide time in slots
- allocate one slot per circuit

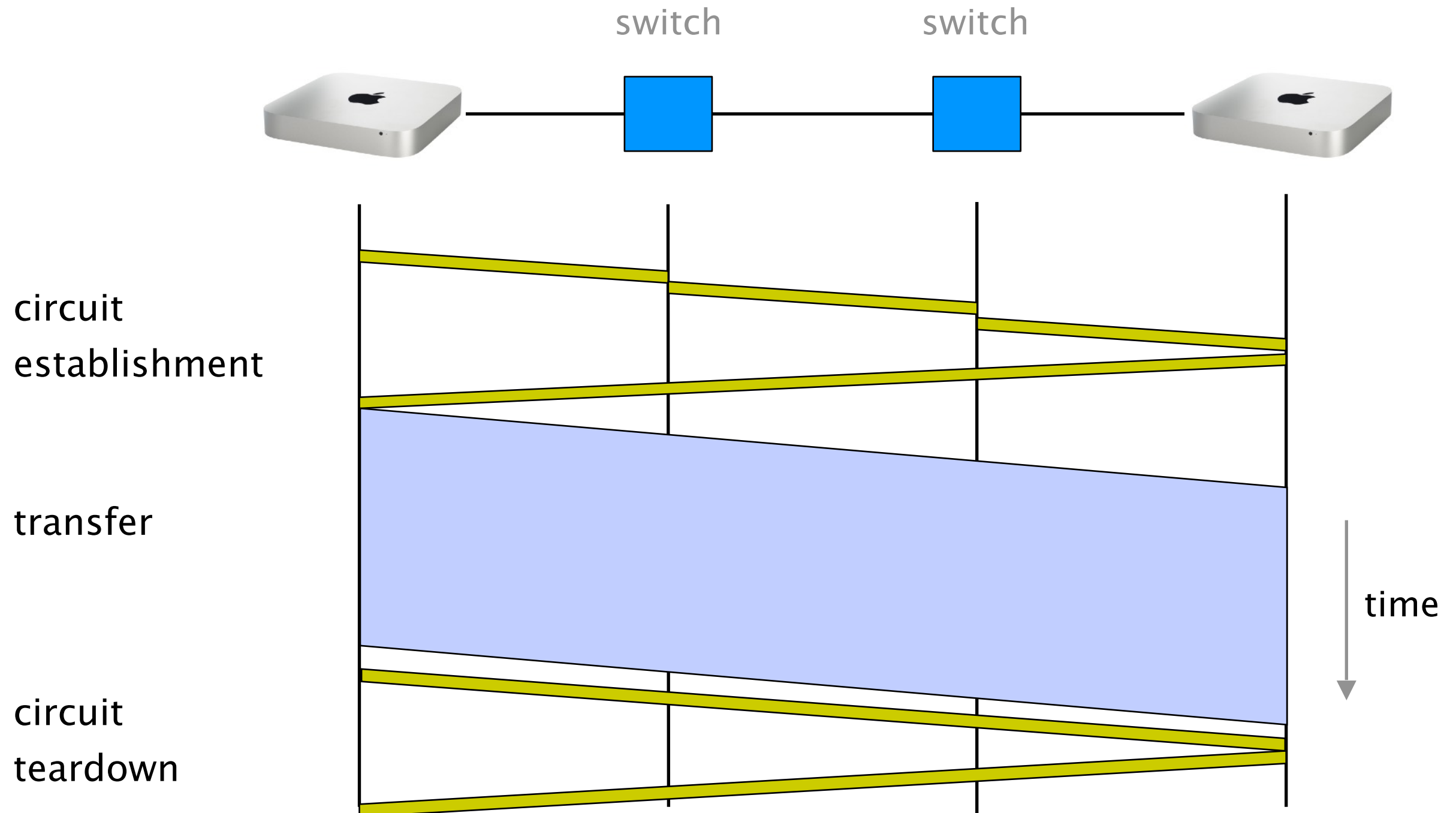


Frequency-based multiplexing

- divide spectrum in frequency bands
- allocate one band per circuit



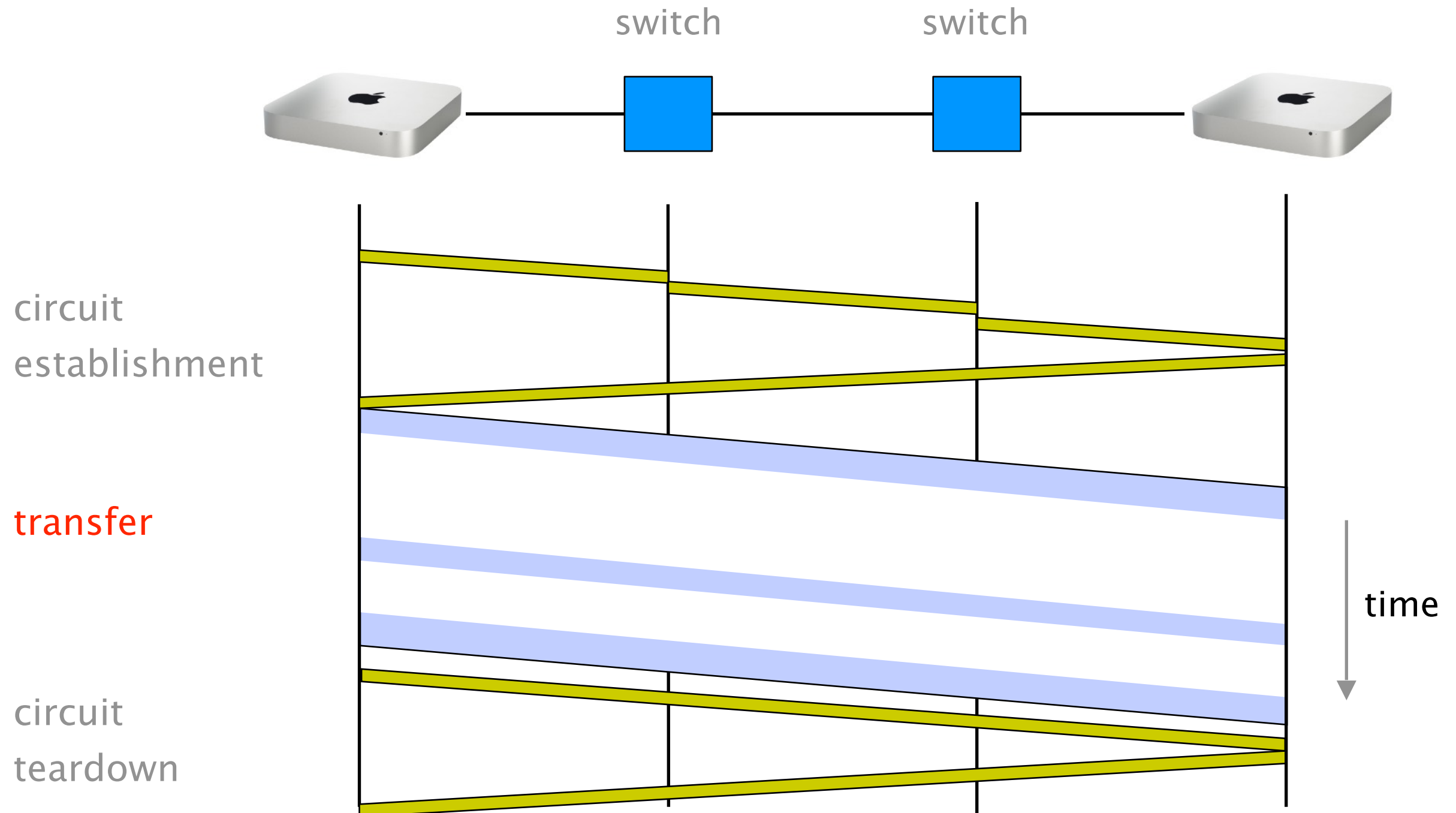
Let's walk through example of data transfer using circuit switching



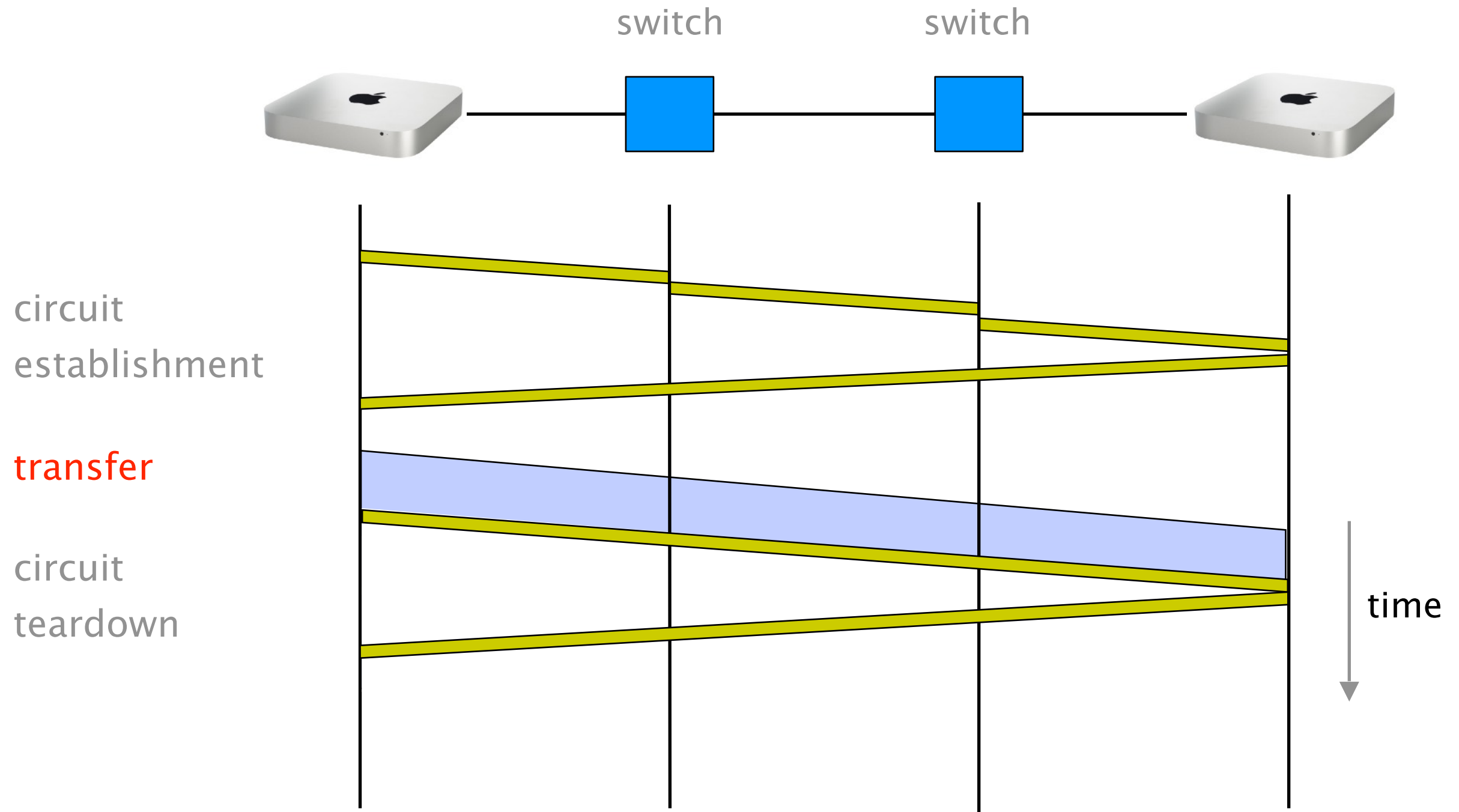
The efficiency of the transfer depends on how utilized the circuit is once established

This is an example of poor efficiency.

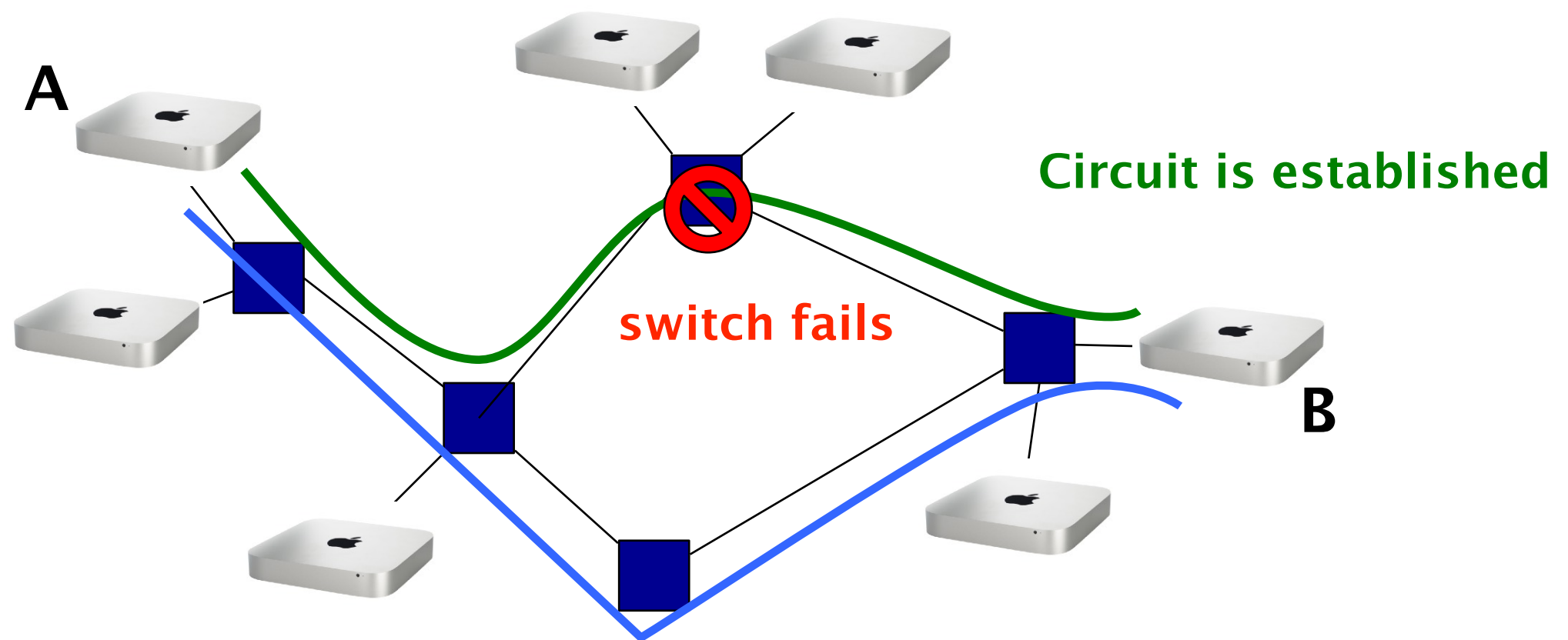
The circuit is mostly idle due to traffic bursts



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

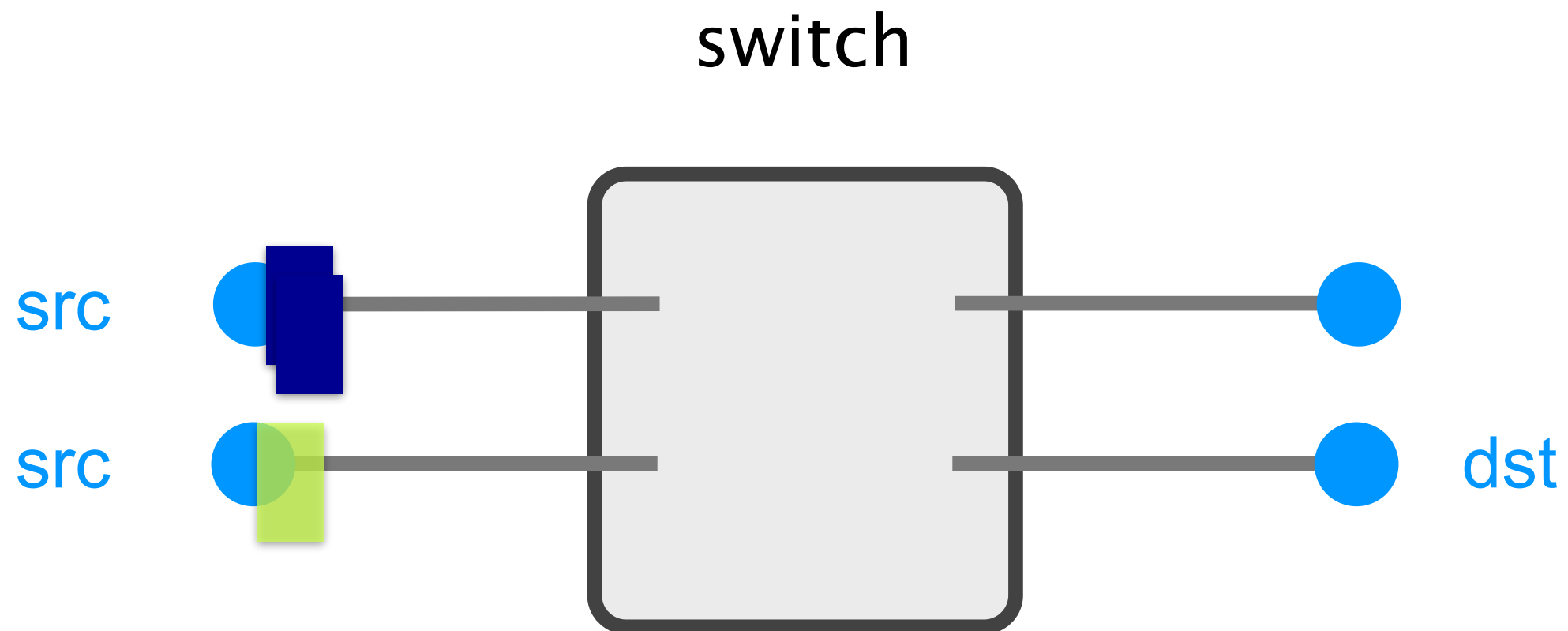
circuit-switching



On-demand

packet-switching

In packet switching,
data transfer is done using independent packets

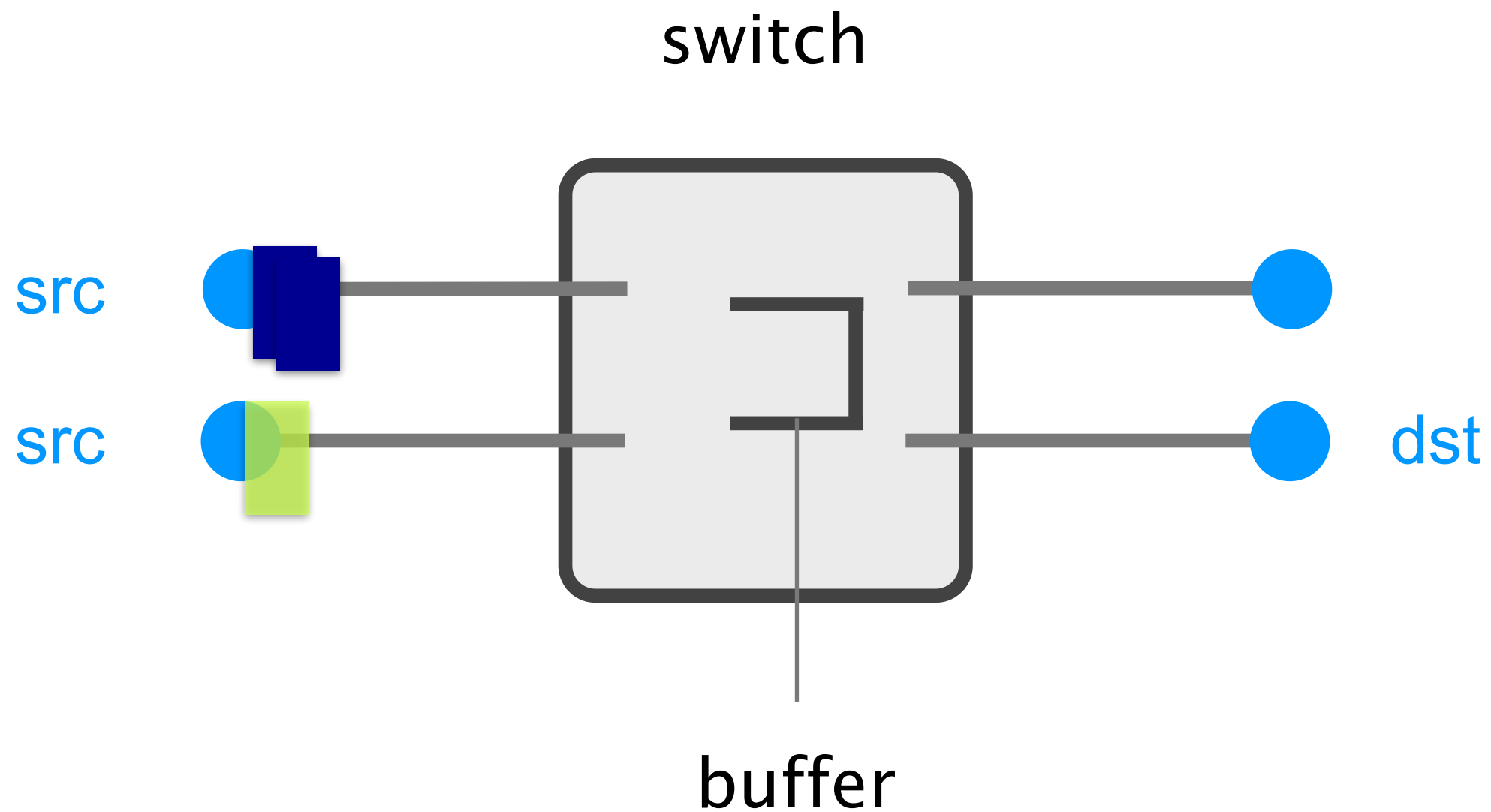


Each packet contains destination (**dst**)

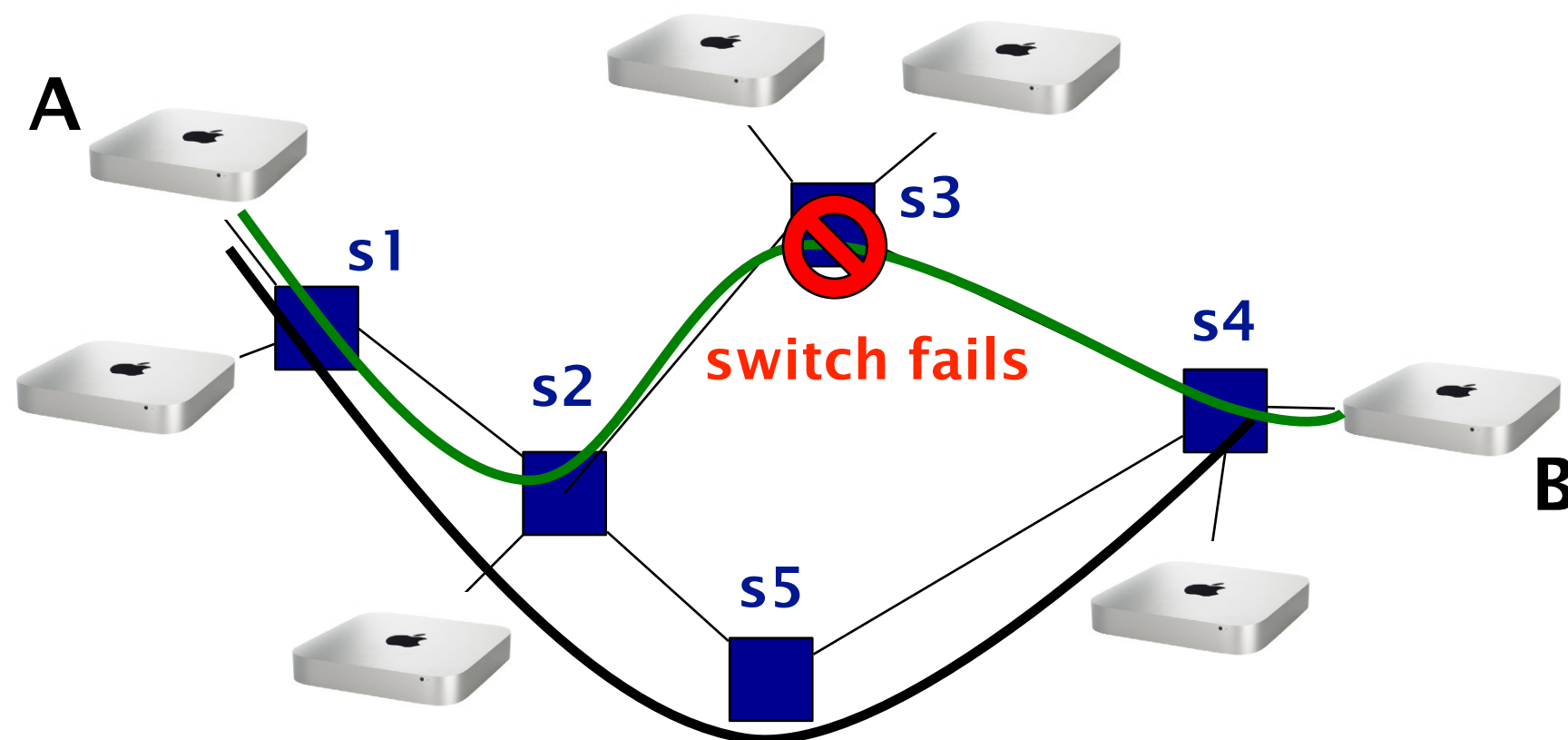
Since packets are sent without global coordination,
they can “clash” with each other

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
than circuit switching


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?

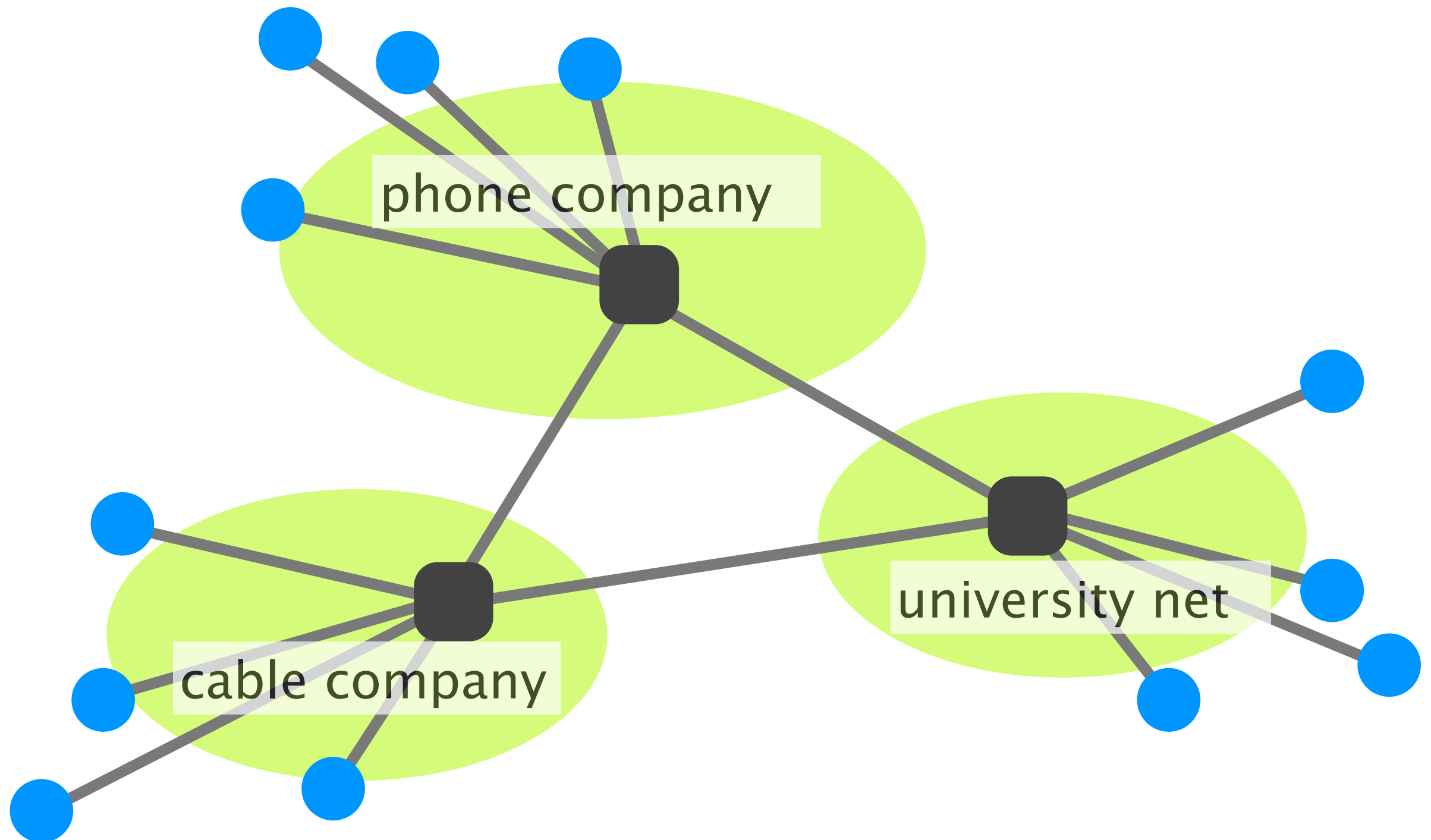
How is it shared?

#3 **How is it organized?**

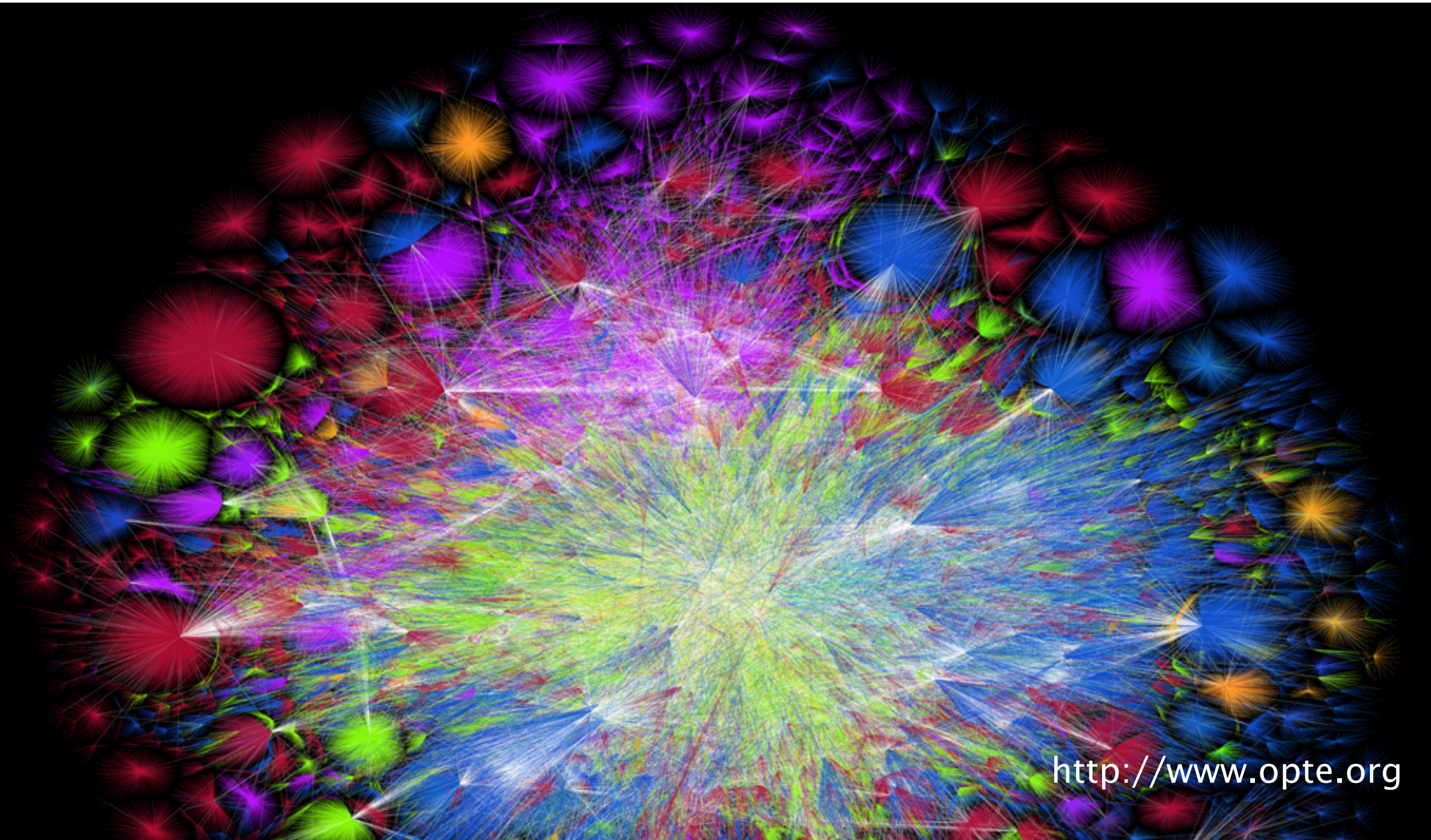
How does communication happen?

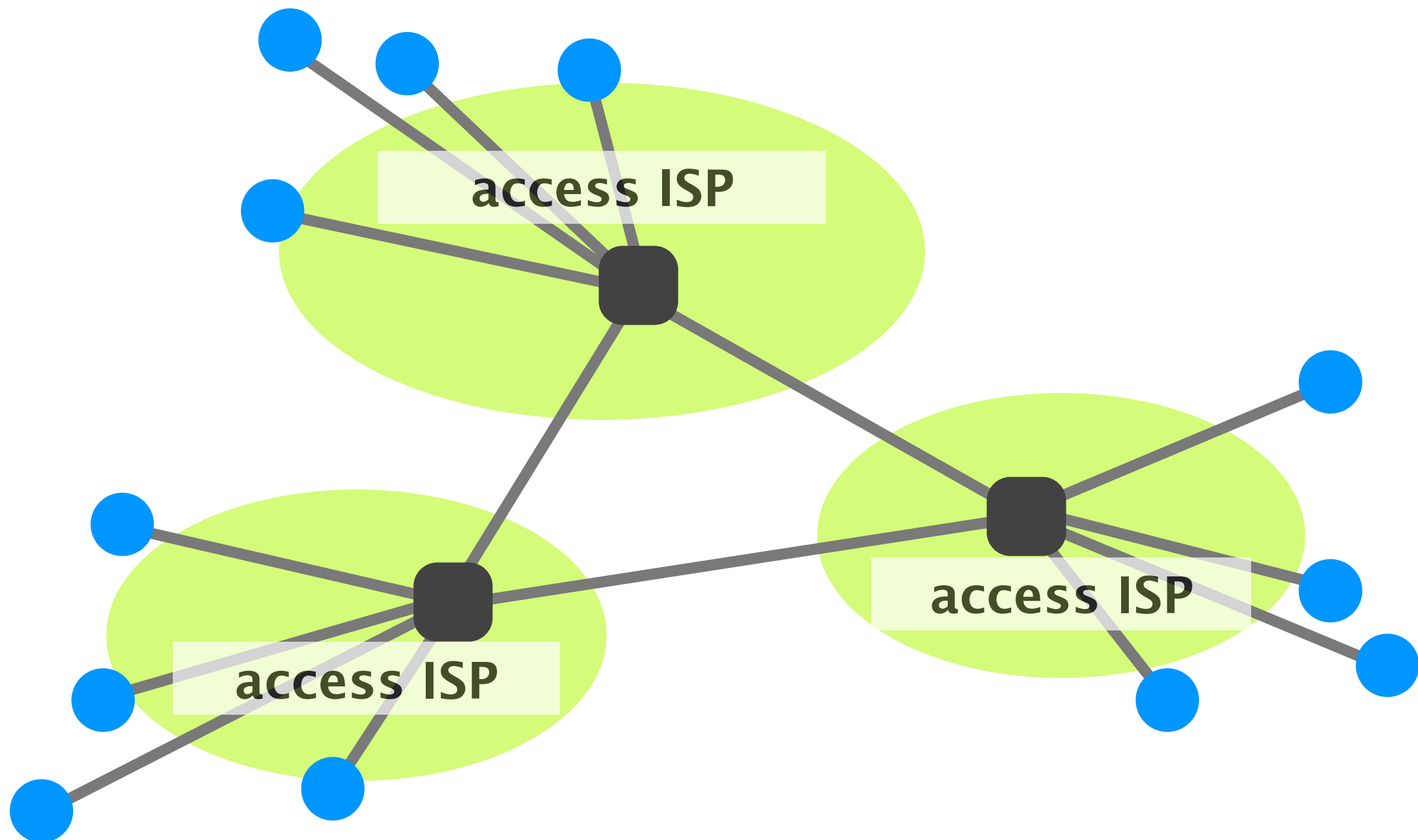
How do we characterize it?

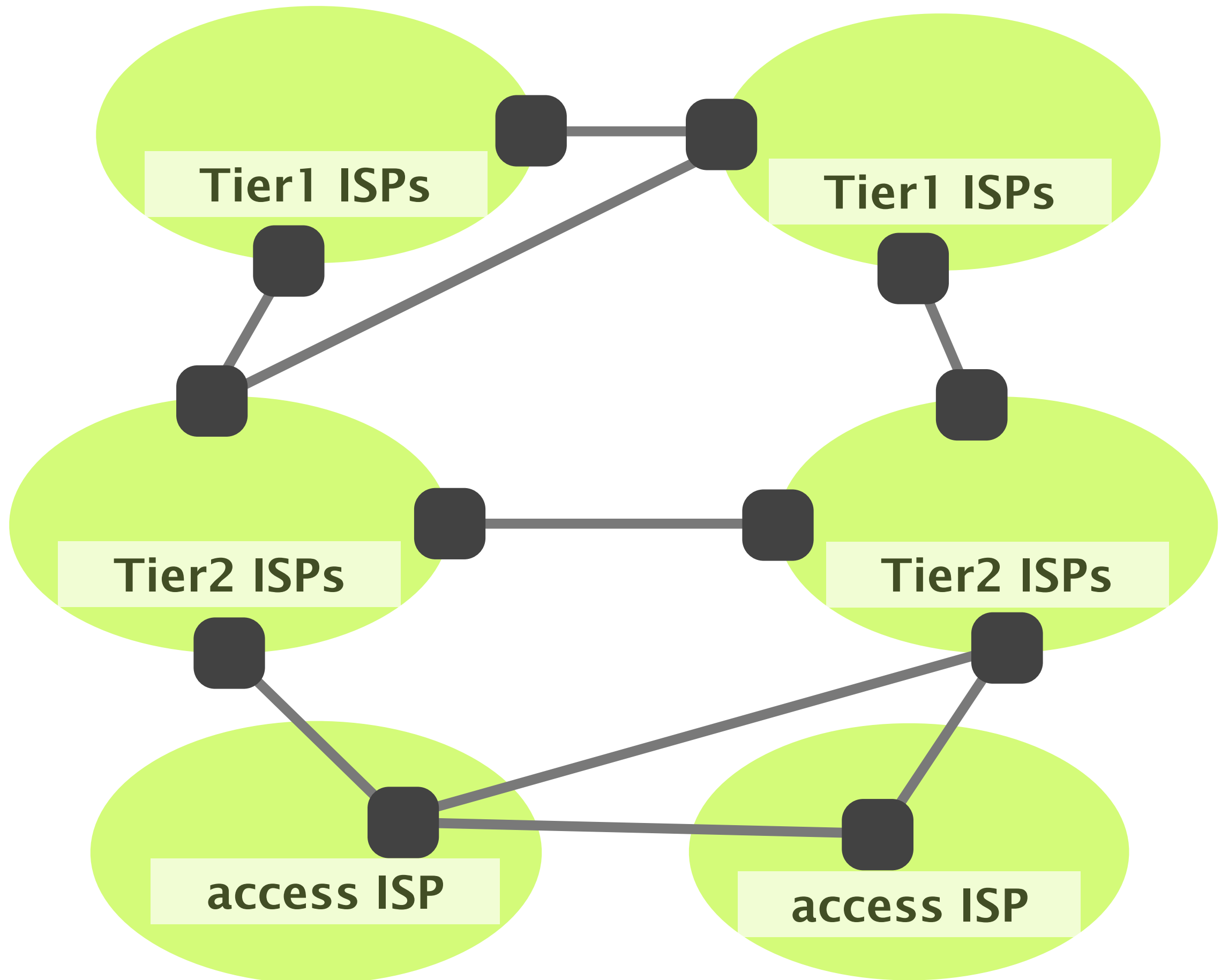
So far, this is our vision of the Internet...



In practice, the Internet is a “bit” more complex







The Internet has a hierarchical structure

Tier-1

international

have no provider

Tier-2

national

provide transit to Tier-3s

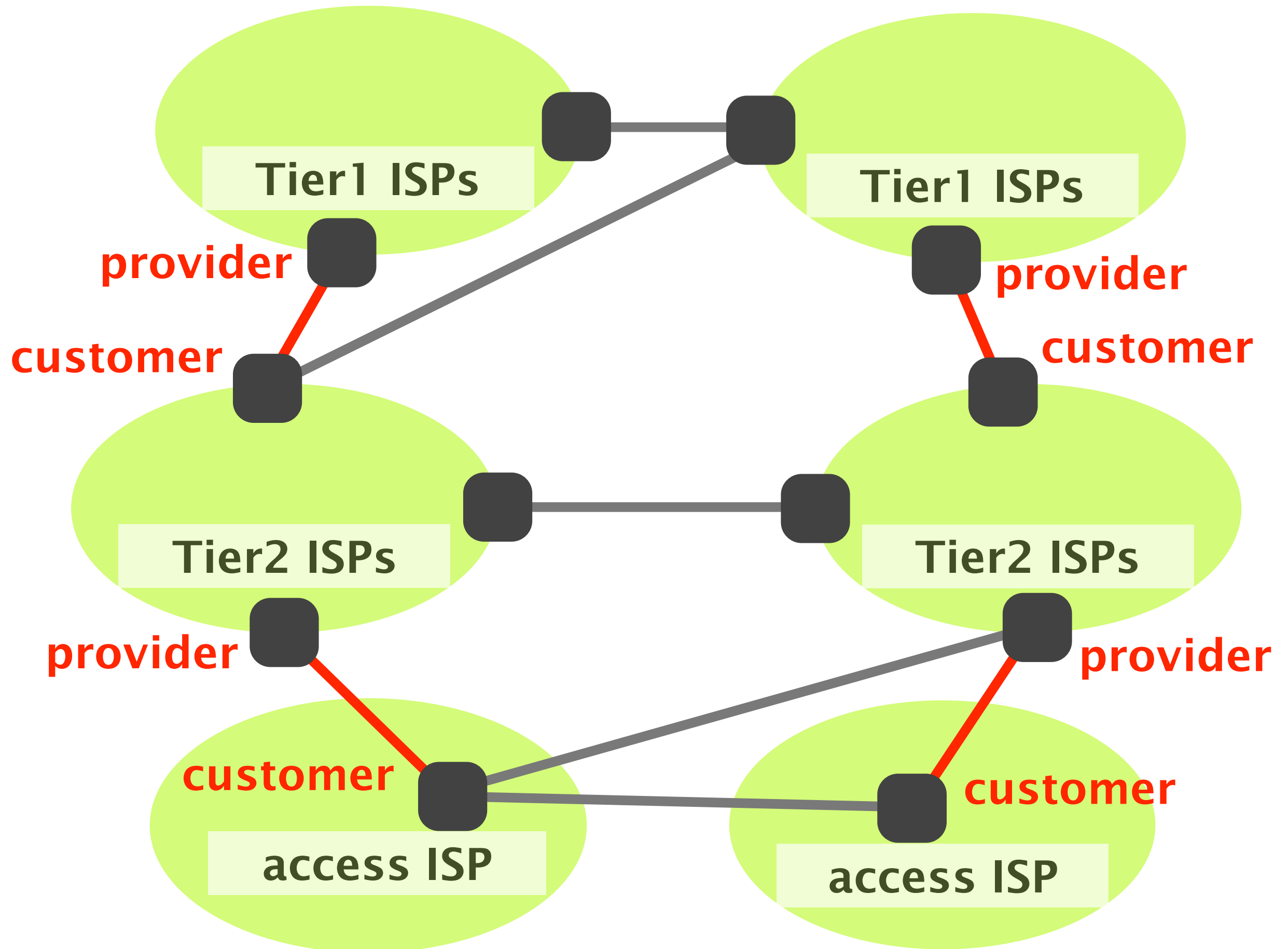
have at least one provider

Tier-3

local

do not provide any transit

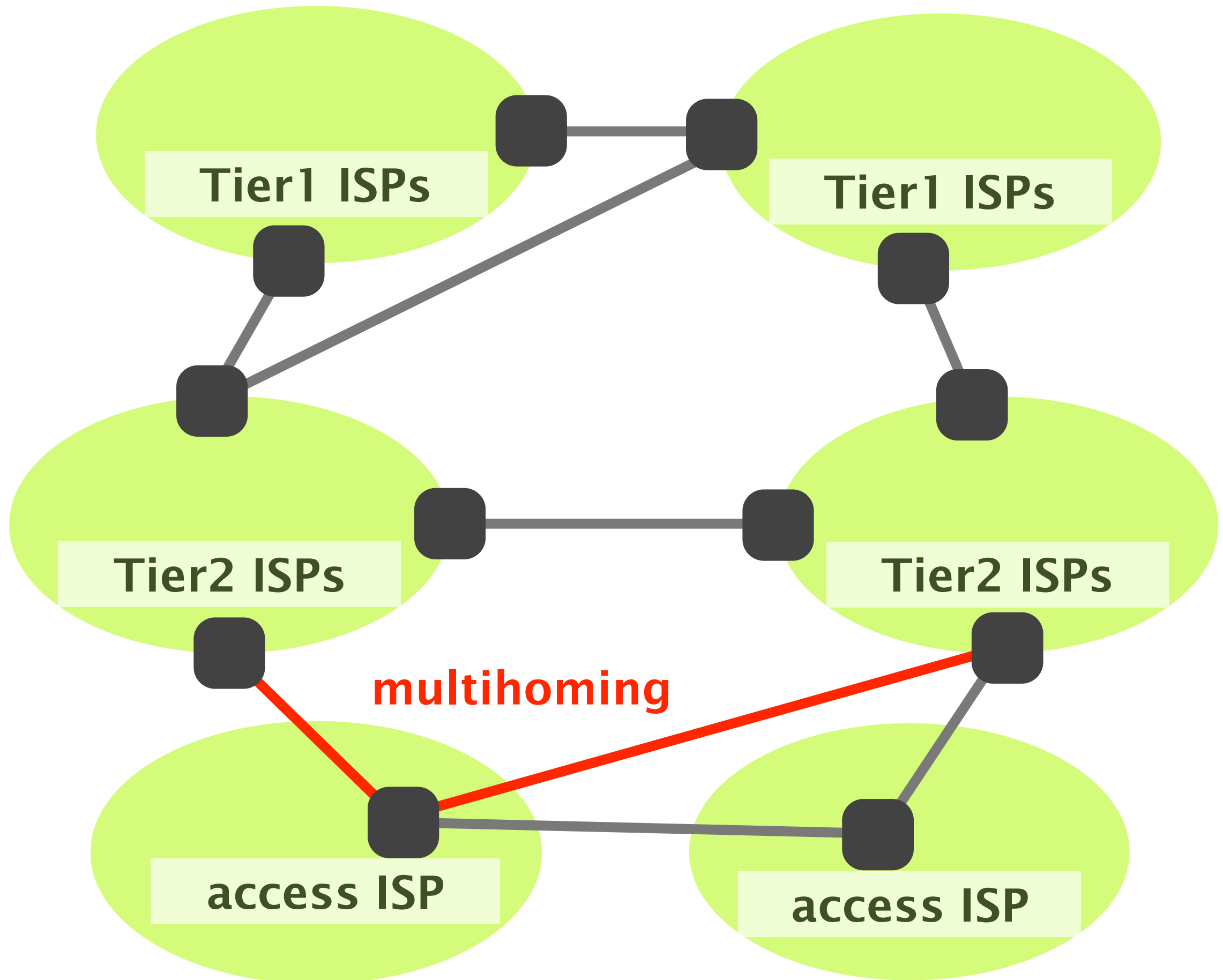
have at least one provider



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

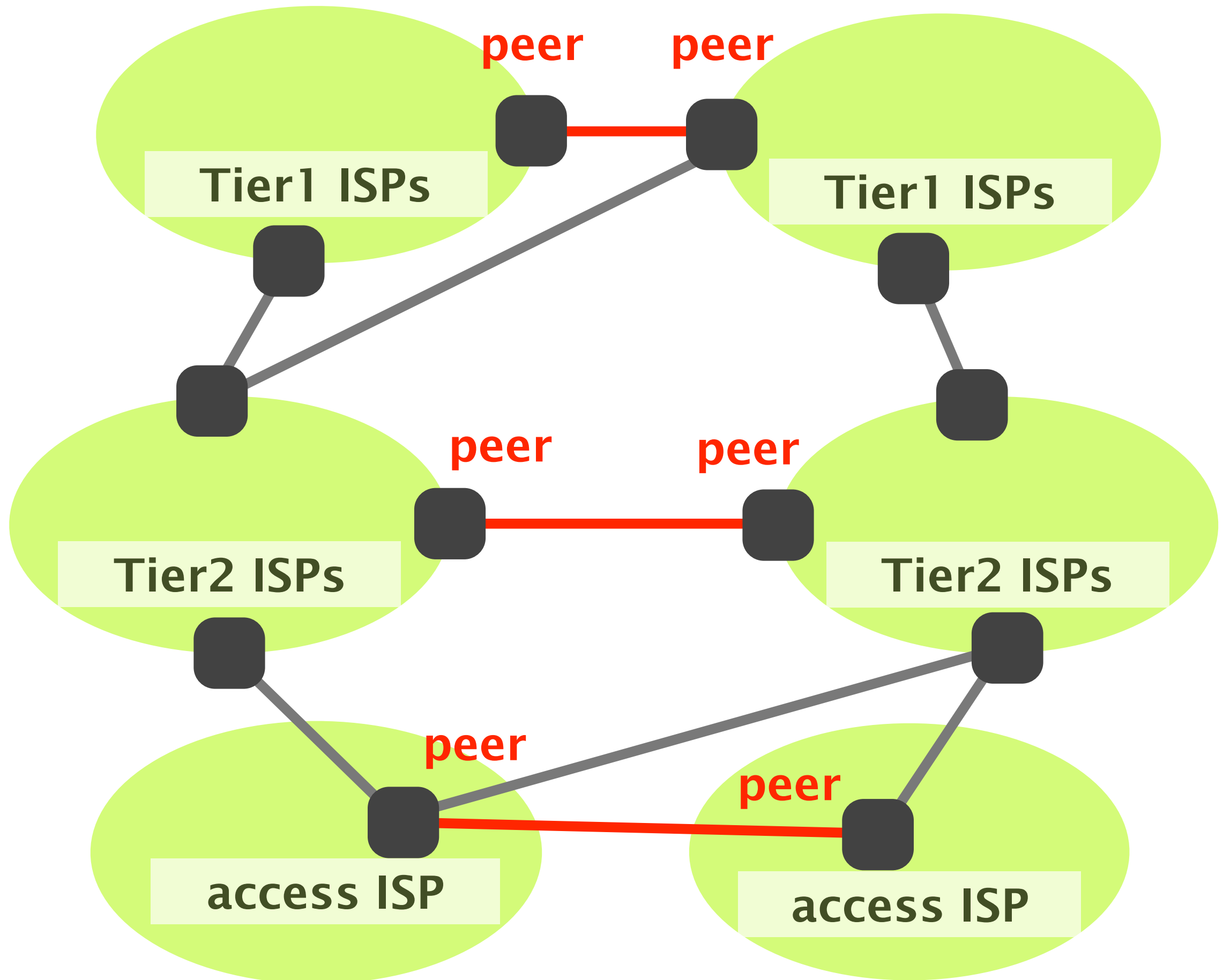
total ~50,000
networks

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 wrt 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

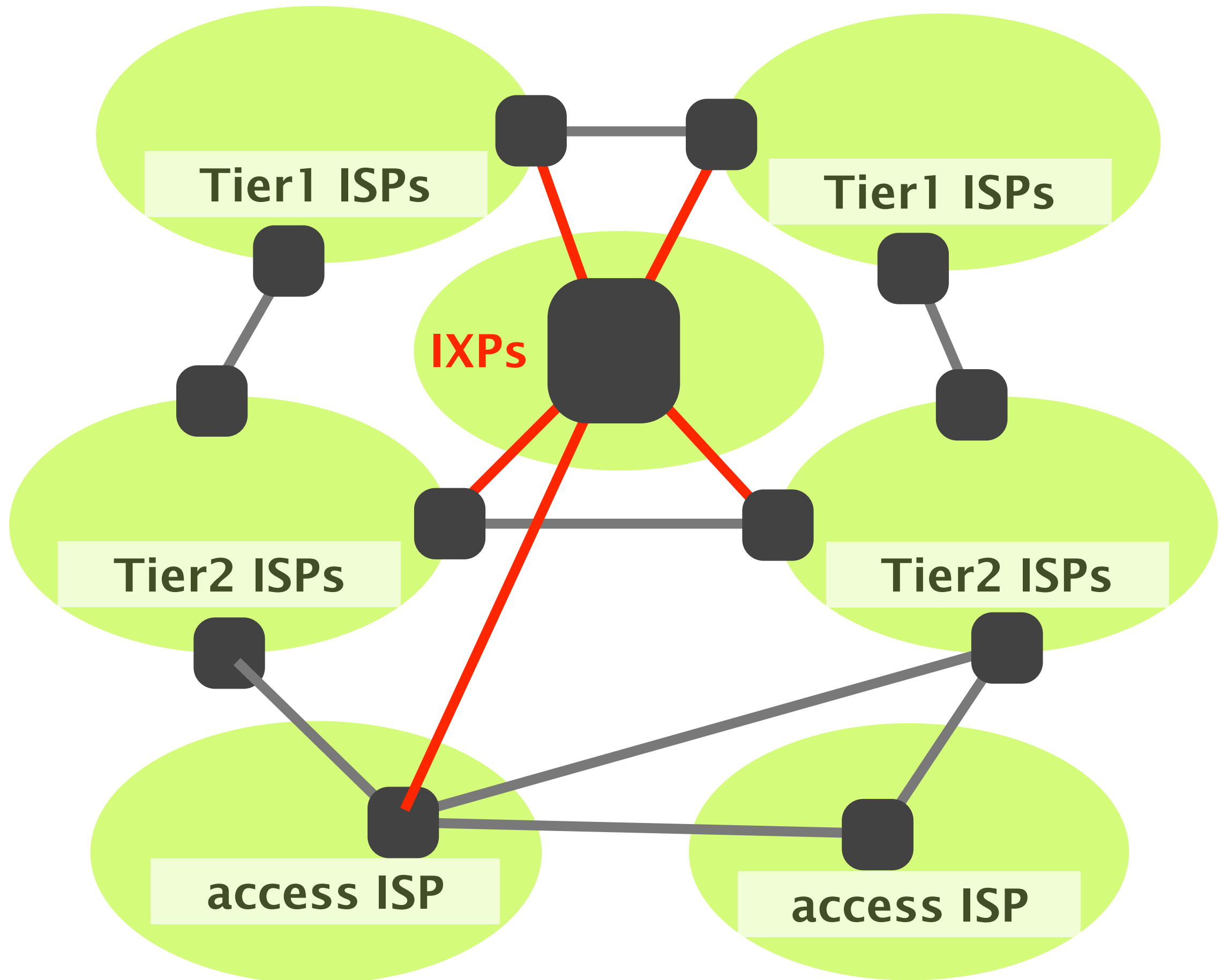
Bandwidth costs

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



Communication Networks

Part 1: Overview



- #1 What is a network made of?
- #2 How is it shared?
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