EECS 489
Computer Networks

Saquib Razak

Material with thanks to Aditya Akella, Sugih Jamin, Philip Levis, Sylvia Ratnasamy, Peter Steenkiste, Mosharaf Chowdhury, Khaled Harras *and many other colleagues.*

Agenda

- Introductions
- Class policies, logistics, and roadmap
- Overview of the basics
  - What is a network and how it is built.

Dr. Saquib Razak

B.S. Electrical Engineering University of Texas, Austin – 1997

M.S. Software Engineering University of Texas, Austin - 2002

Senior Software Engineer, Texas and Michigan 1998 – 2004

Ph.D. Computer Science, State University of New York, 2005-2009

Associate Teaching Professor, Carnegie Mellon University, 2008-2022

Lecturer III, University of Michigan, since 2023

Efe Akinci(GSI)

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Office hour:

Friday. 1:30pm - 3:30pm @ BBB Atrium

Discussion:

Friday 12:30 - 1:30pm

- Hobbies:
  - Cars
  - Music (Any Glass Animals Fans?)

Ruochong Chen (IA)

CSE Junior & 1st year EECS 489 IA

Email: ruochong@umich.edu

Office Hours:

- Tues 3:00pm-5:30pm
- Fri 10:30am-12:00pm

Discussion:

- Every Friday 9:30am - 10:30am @ GFL 107

Hobbies: Digital Art, Piano, CSGO

Some classes I've taken: EECS 489, EECS 471, EECS 484, EECS 445, EECS 442, EECS 270…

Aditya Singhvi (GSI)

SUGS Student & first semester EECS489 GSI

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Office hour:

Thursday. 12:30pm - 4:30pm @ BBB Atrium

Discussion:

Thursday 4:30 - 5:30pm

Hobbies: football, cricket, puzzles, and reading

Jingyi Sun (IA)

Senior CS student & 1st Semester EECS 489 IA

Email: dellsjy@umich.edu

Discussion:

Monday & Wednesday. 4:30pm -6:30pm @ BBB

Discussion:

Friday. 9:30am -10:30am @ GFL 107

Hobbies: Reading, Mobile Games

489 in EECS curriculum

- **EECS 281**
  - High-level logic ⇒ Programs
  - Coding skills learned in 281 are critical for 489 assignments
- *EECS 482*
  - How do machines work?
  - Execute programs, interact with users, etc.
  - Prior 482 experience is not needed

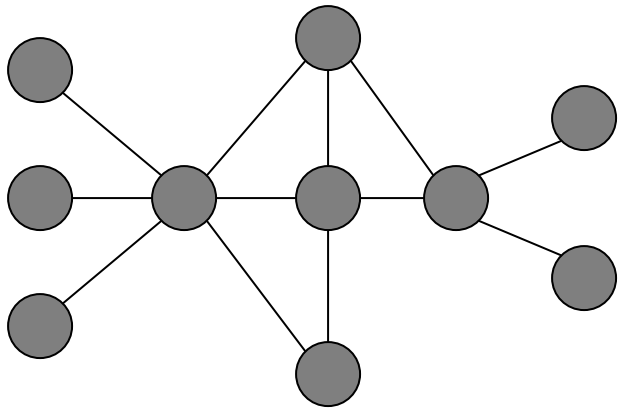
What is missing?

- How do we access *most* services?
  - Examples include search engines, social networks, video streaming, etc.
- How do two machines communicate?
  - When they are directly connected
  - When they are not directly connected

- Using a network

What is a network?

- A system of “links” that interconnect “nodes” in order to move “information” between nodes



- We will focus primarily on the Internet

What is EECS 489 about?

- To learn about (at a high level)
  - How the Internet works
  - Why it works the way it does
  - How to reason about complicated design problems

- What it's not about
  - How to write web services
  - How to design web pages
  - …

Class workload

- Four assignments
  - First one is an individual assignment
  - The rest are in groups of 2-3
- Exams (In person):
  - Midterm: October 16
  - Final: TBD

Grading

	Allocation
Assignment 1	5%
Assignment 2	15%
Assignment 3	15%
Assignment 4	15%
Midterm	25%
Final	25%
Bonus Quizzes	2%

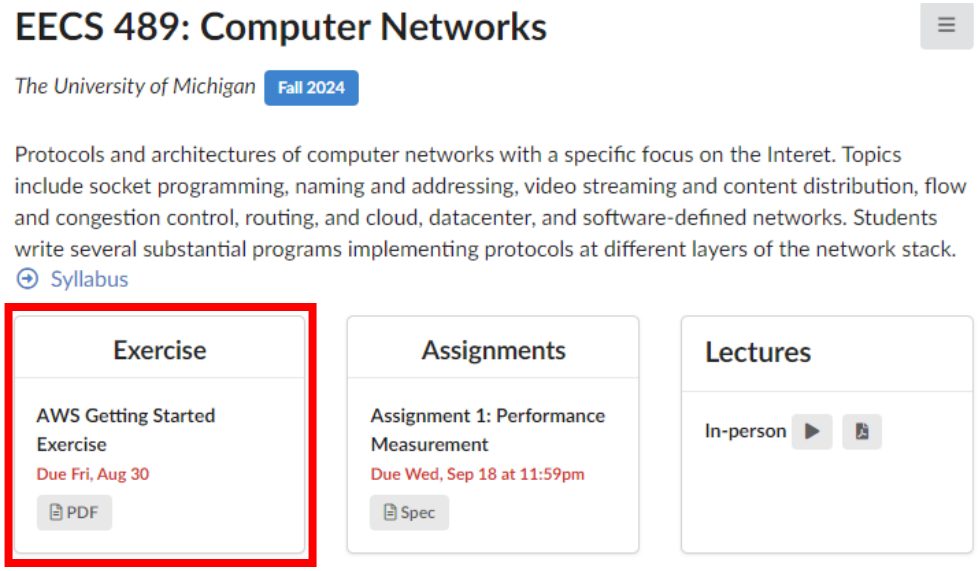
The assignments

- Assignment 1: measure end-to-end throughput and delay of networks (i.e., simple speed test)
- Assignment 2:video streaming from CDNs (i.e., simple youTube)
- Assignment 3: reliable transport (i.e., how to transfer data over an unreliable network)
- Assignment 4: router design (i.e., how do internal elements of the network work)

All on (emulated) realistic networks using *mininet*

Assignments

- Done on ubuntu instances on AWS
- Please complete the exercise to get you started on AWS by Fri Aug 30 – linked from the course website.



Bonus Quizzes

- N-quizzes in the semester.
- Announced during lecture – deadline is 10pm day of lecture.
- Capped at 2 points

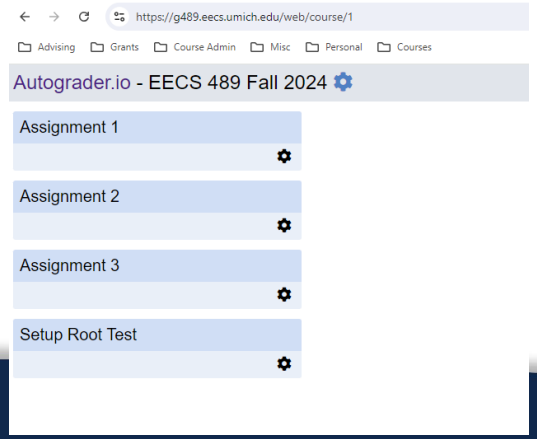
Enrollment and wait list

- Wait-listed students will be admitted in the order of wait list

- If you're planning to drop, please do so soon!

Communication protocol

- Course website: http://www.eecs489.org/
  - Assignments, lecture slides
- Confidential content on Canvas and Gradescope
- Ed for all communication
  - Sign up if you haven't already
  - https://edstem.org/us/courses/61627
- Assignment submission via g489.eecs.umich.edu



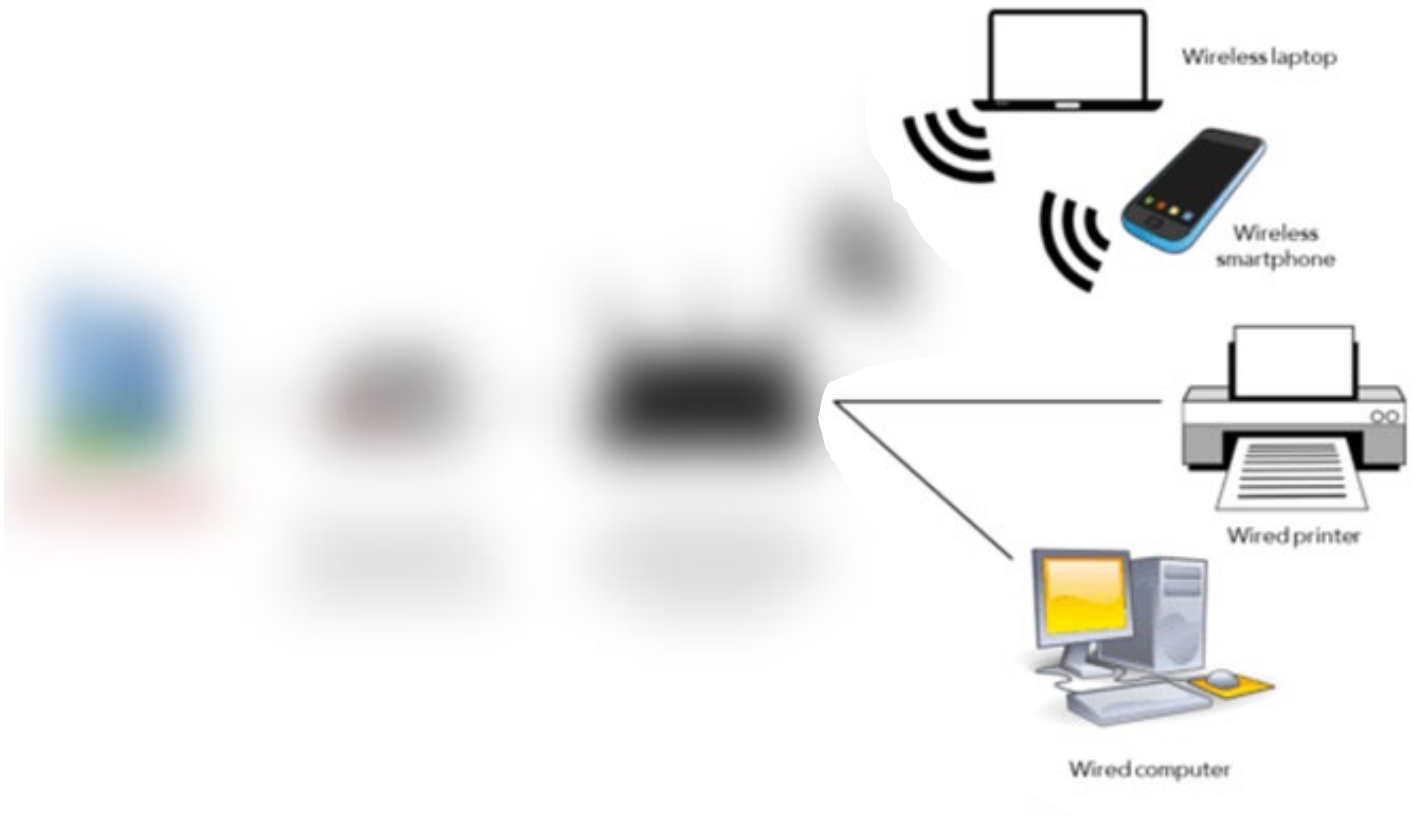
Policies on late submission, re-grade request, cheating …

- Detailed description on the course webpage
- Don’t cheat!

Let’s Talk Internet

How do you connect to the internet

How do you connect to the internet



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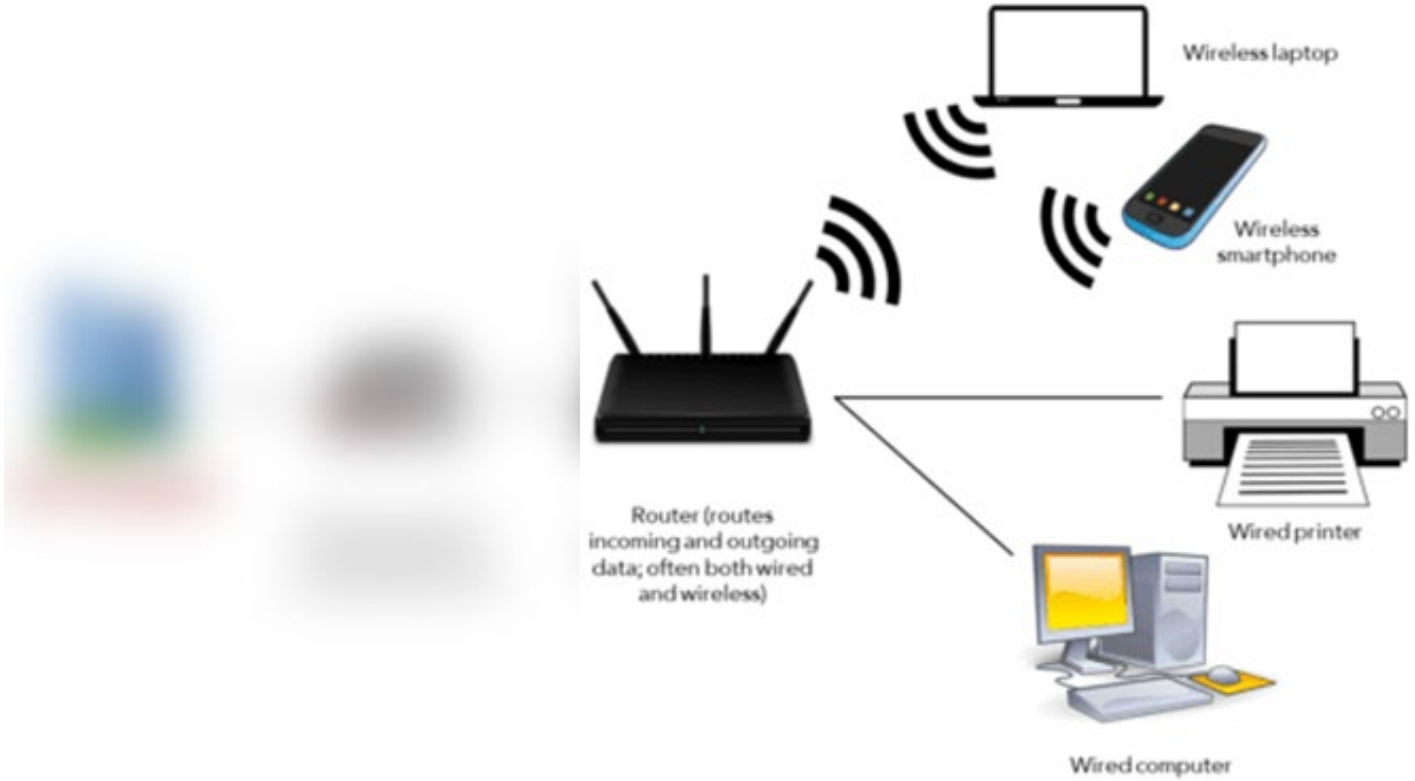

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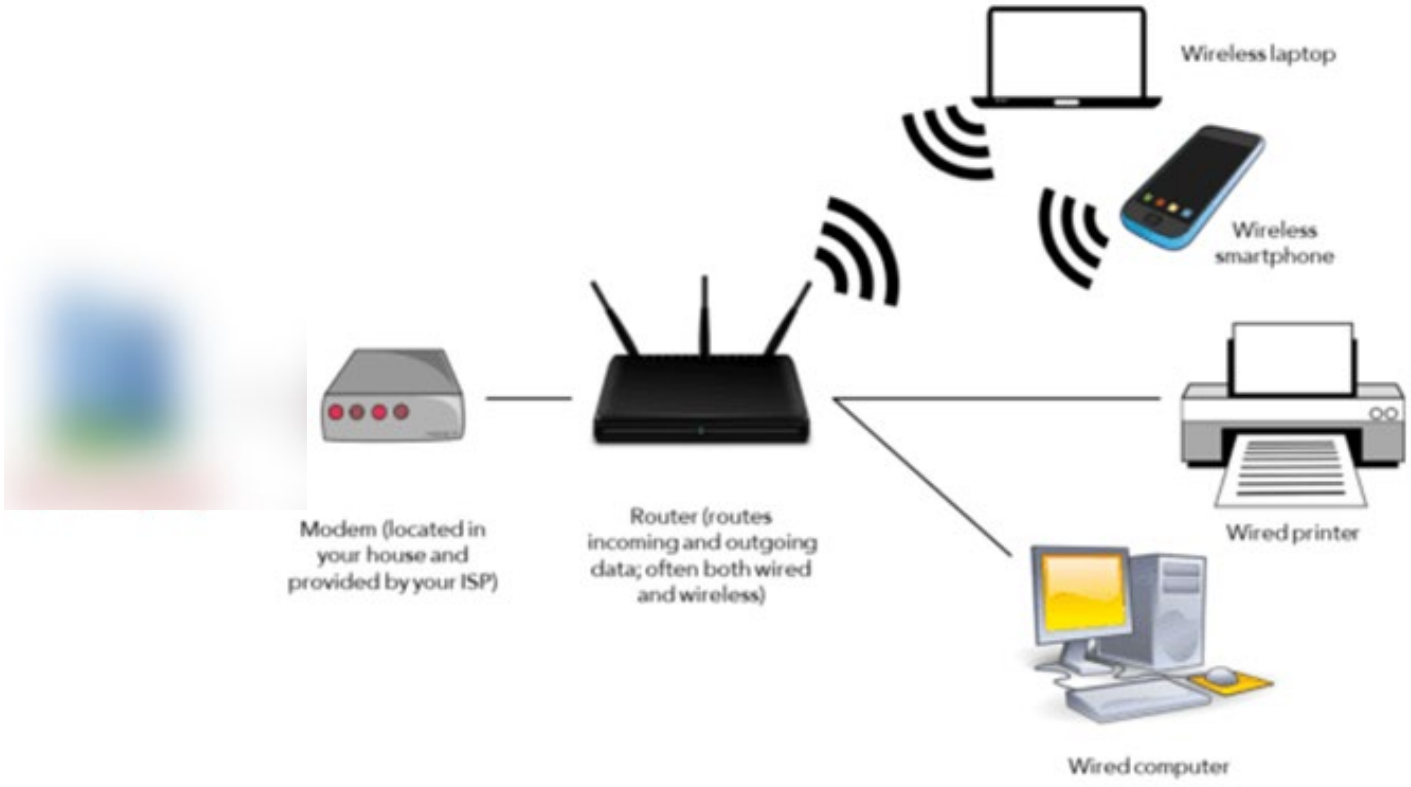

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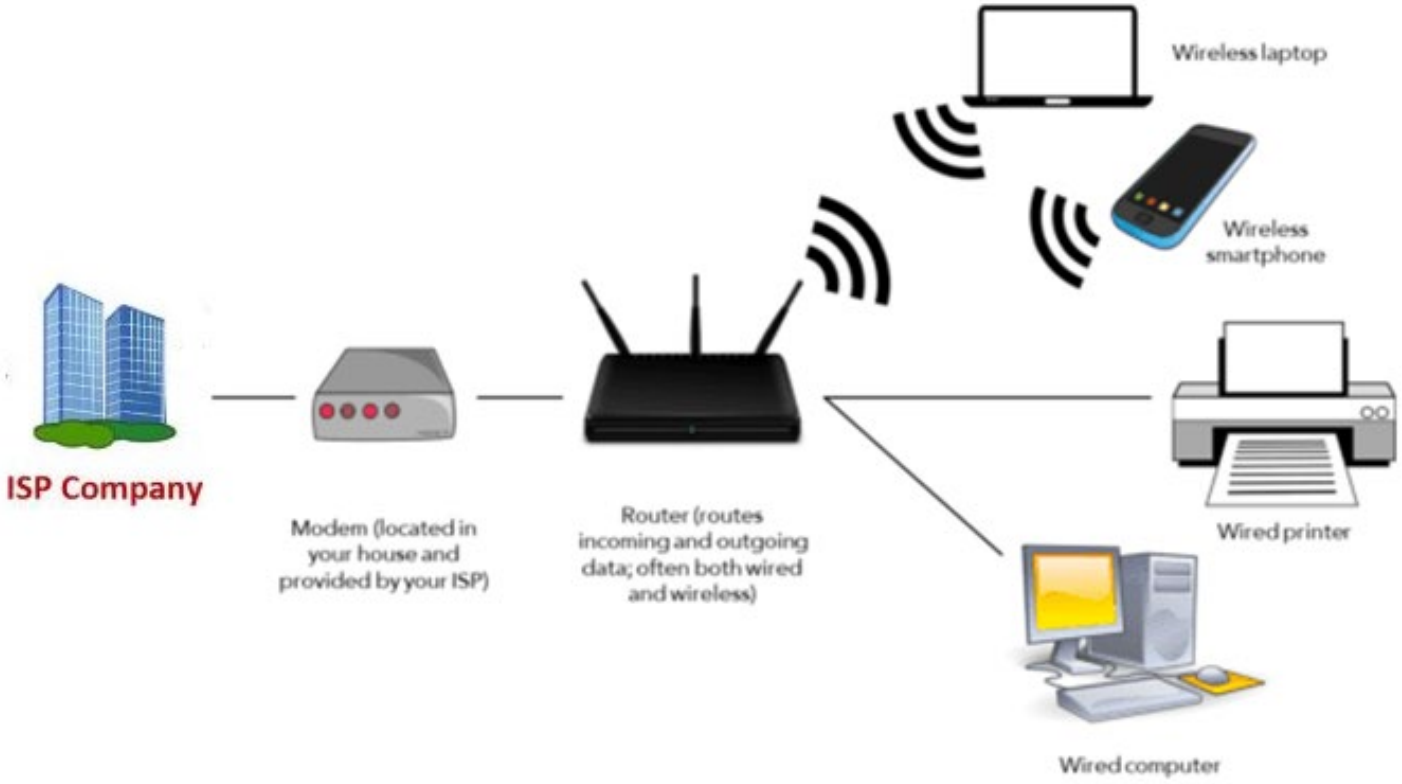
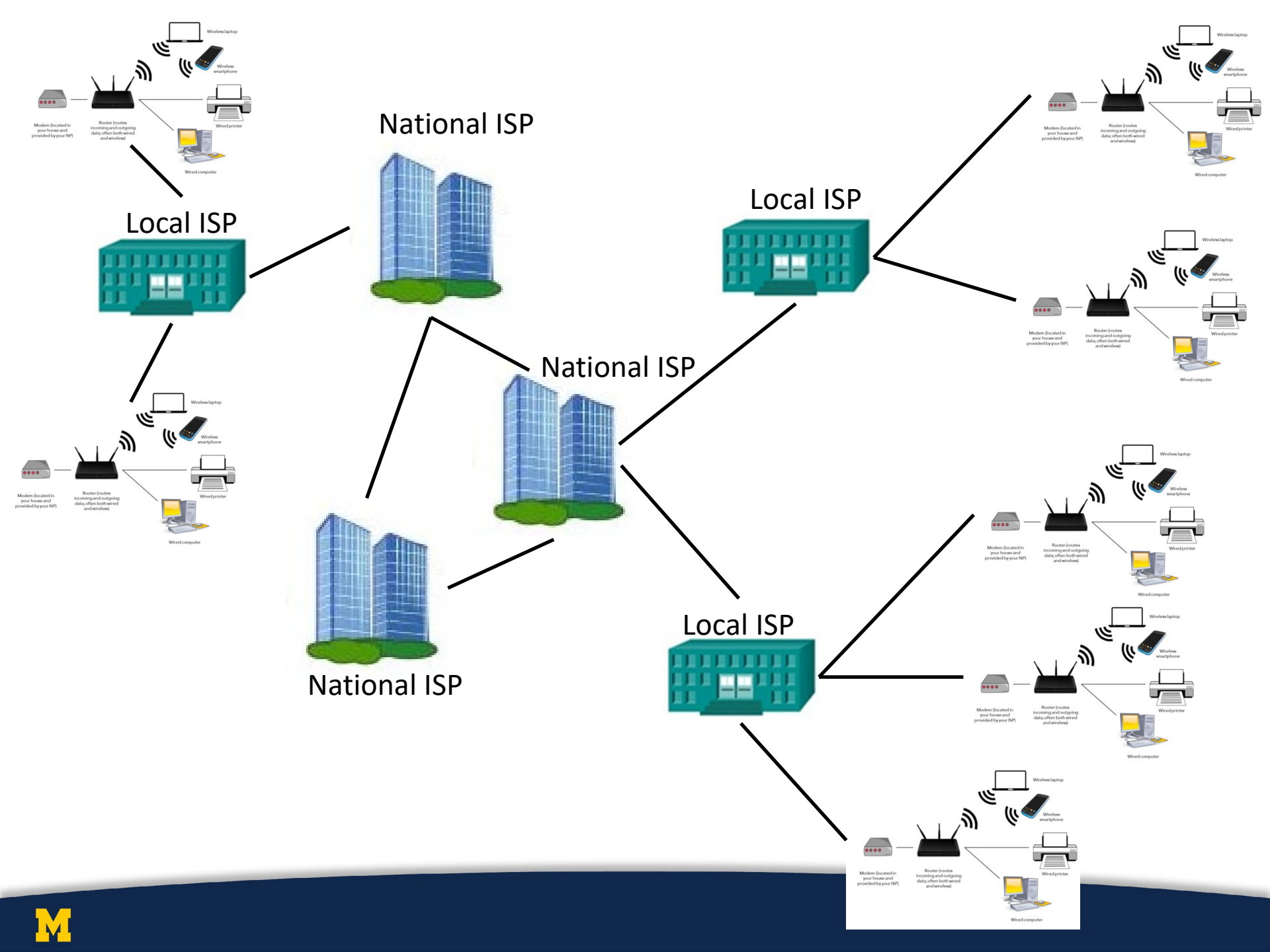
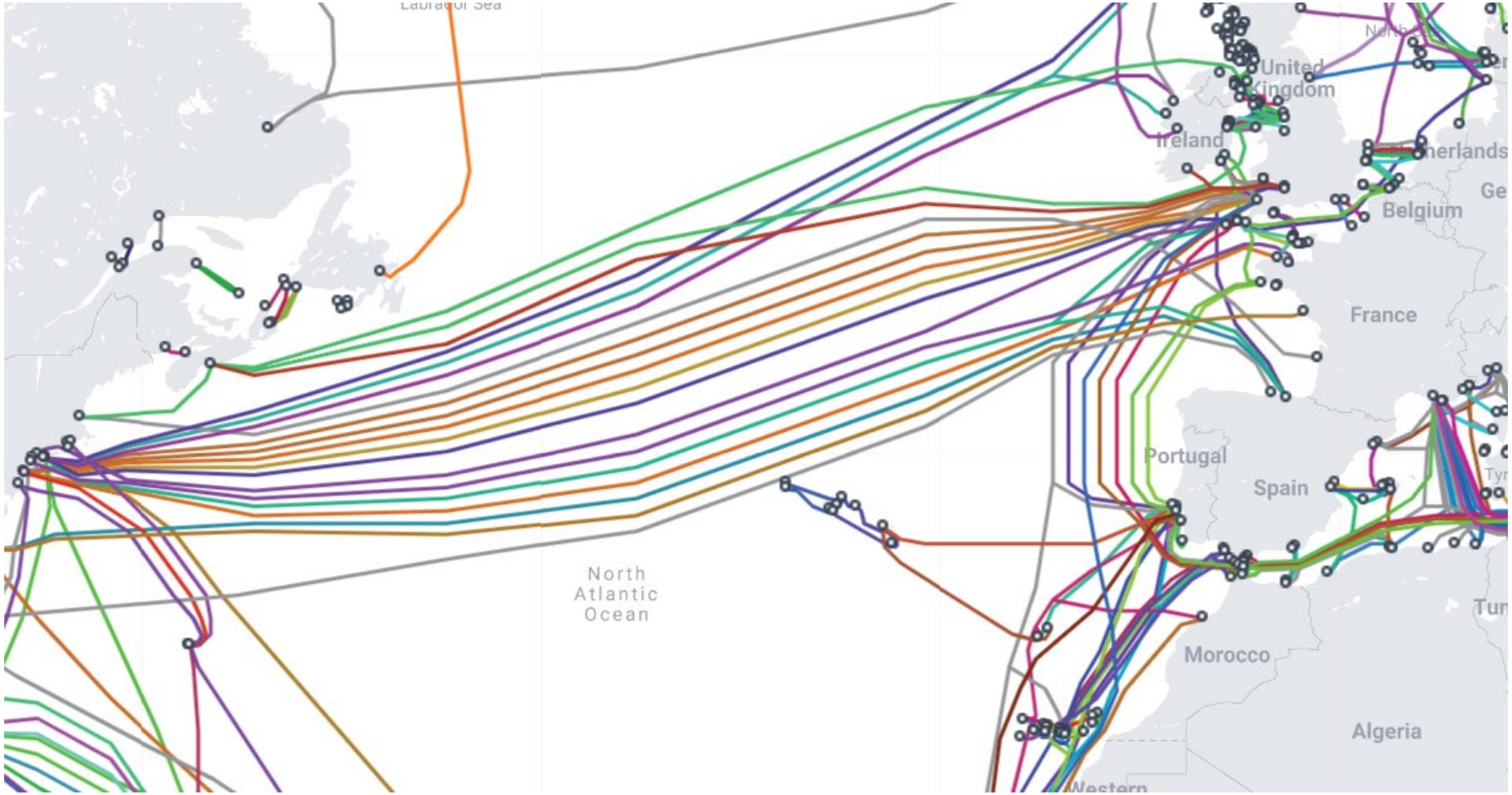


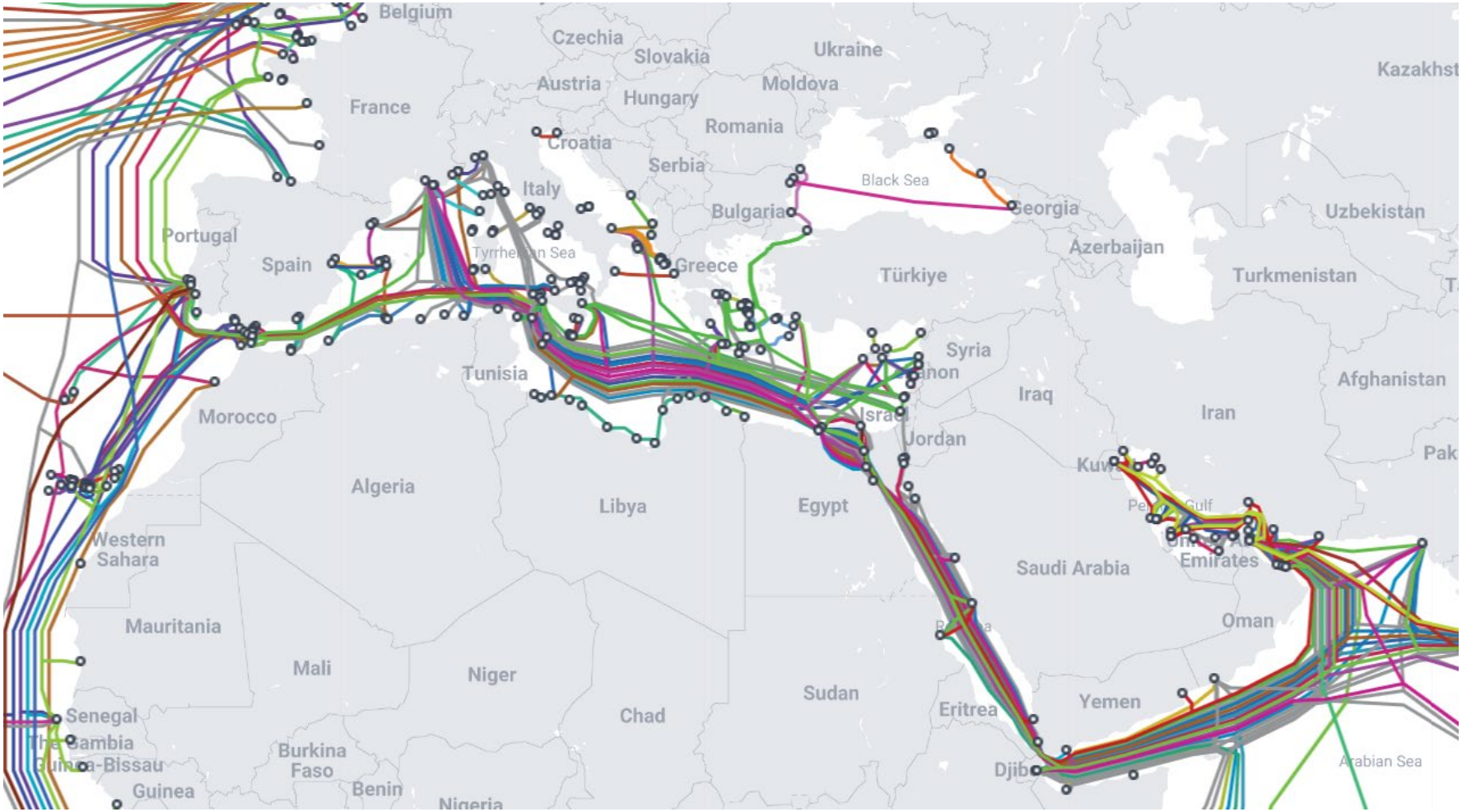

National ISP
Local ISP
Local ISP
National ISP
National ISP
Local ISP
Wireless laptop
Wireless smartphone
Wired printer
Wired computer
Modem (located in your house and provided by your ISP)
Router (routes incoming and outgoing data; often both wired and wireless)

How continents are connected

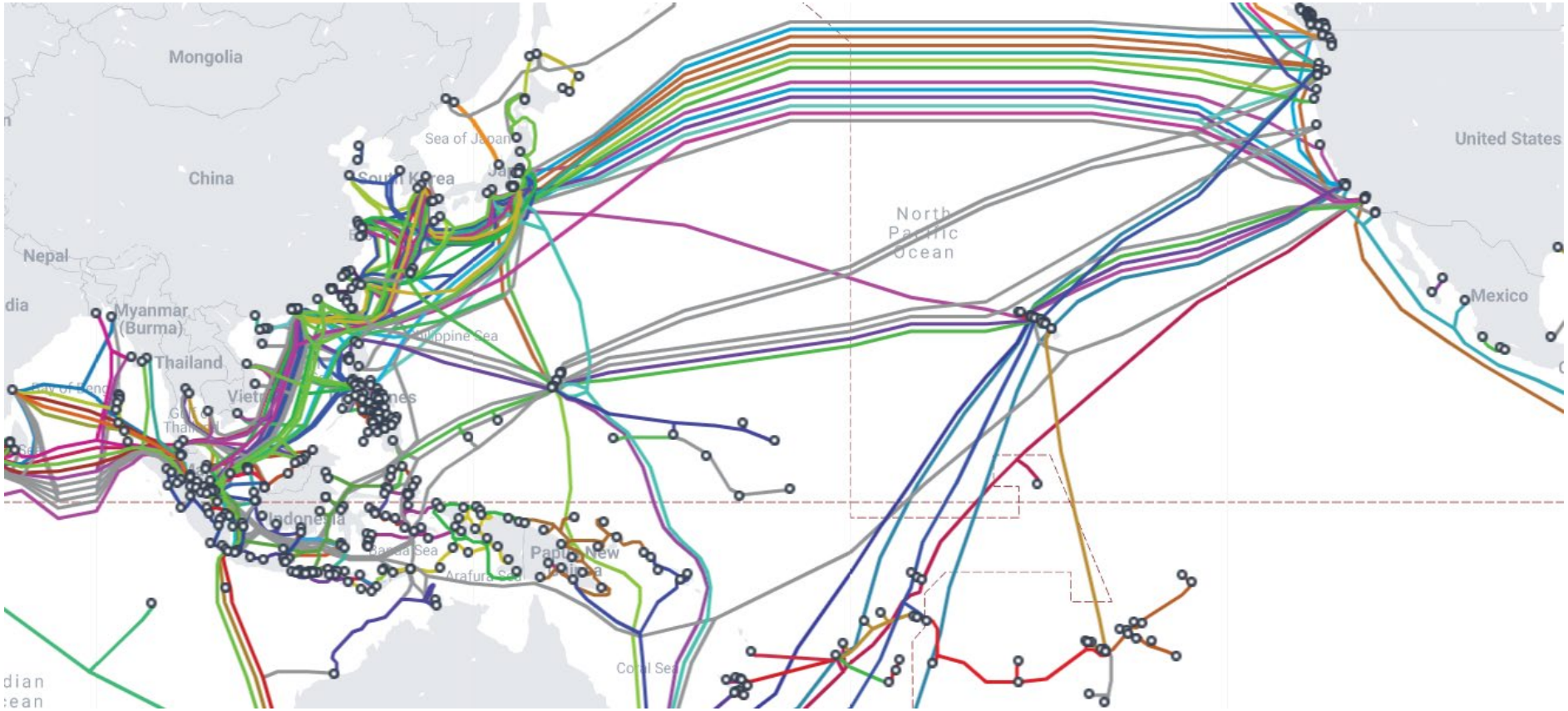


https://www.submarinecablemap.com/

How continents are connected



How continents are connected



*www.theguardian.com

Georgian woman cuts off web access to whole of Armenia

Entire country loses internet for five hours after woman, 75, slices through cable

*npr.org

Damaged Ocean Cable Cripples Internet In East Africa

MARCH 1, 2012 · 3:00 PM ET

HEARD ON ALL THINGS CONSIDERED

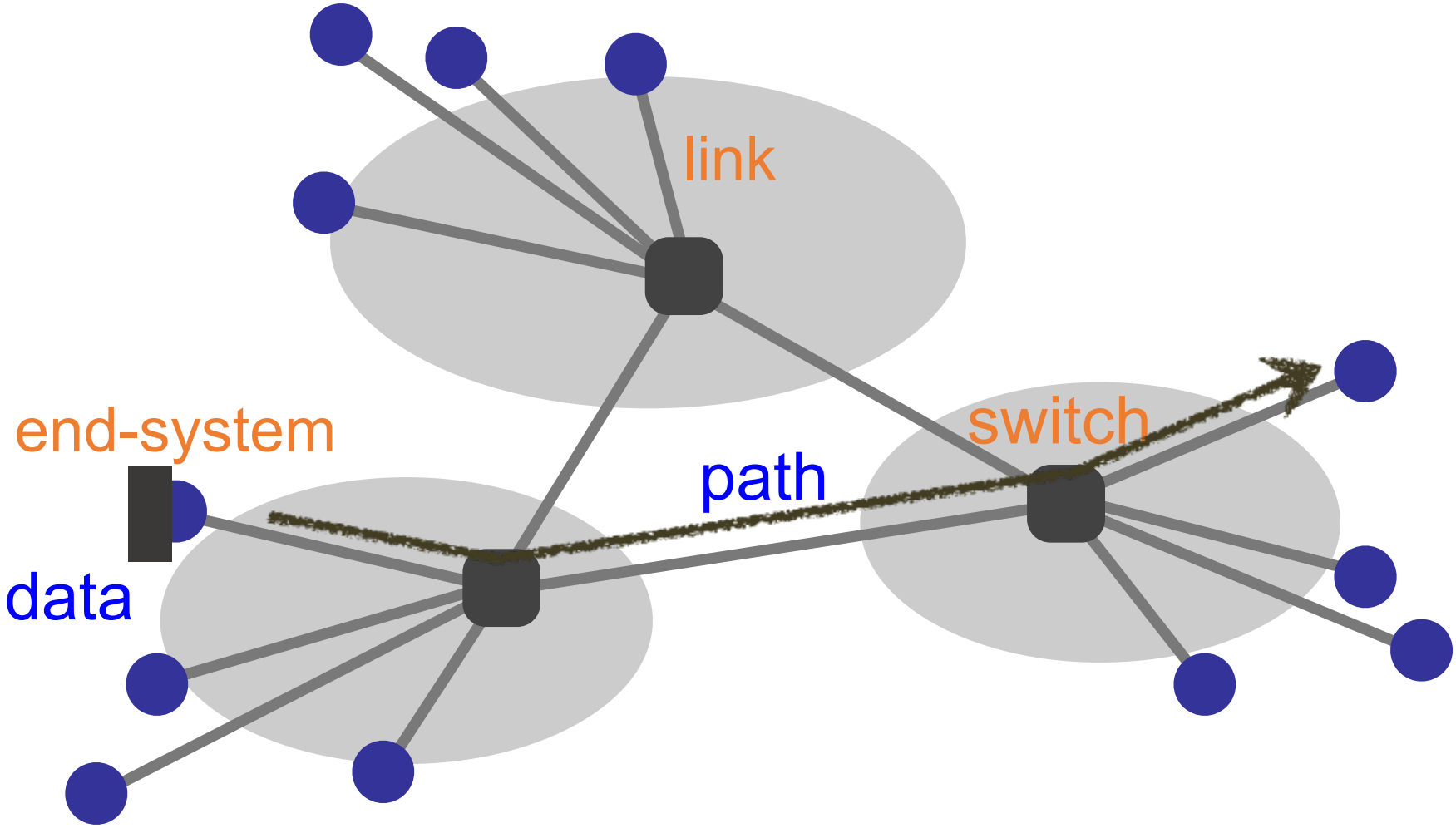
Over the weekend, a ship dragging an anchor severed one of the three undersea data cables linking countries that include Kenya, Rwanda and Ethiopia to the Middle East and Europe. It may take about three weeks to fix.

*www.theguardian.com

Undersea internet cables off Egypt disrupted as navy arrests three

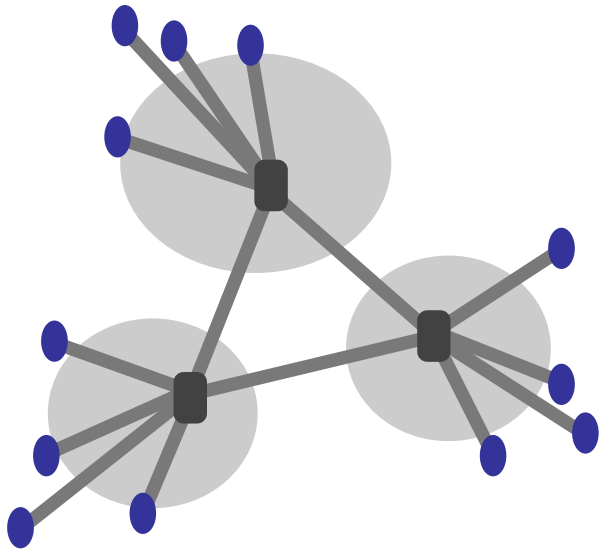
Coastguard arrests three men off Alexandria, claiming they were cutting cable known as SE-WE-ME-4, amid disruptions to internet connectivity in Egypt and beyond

Data Transfer

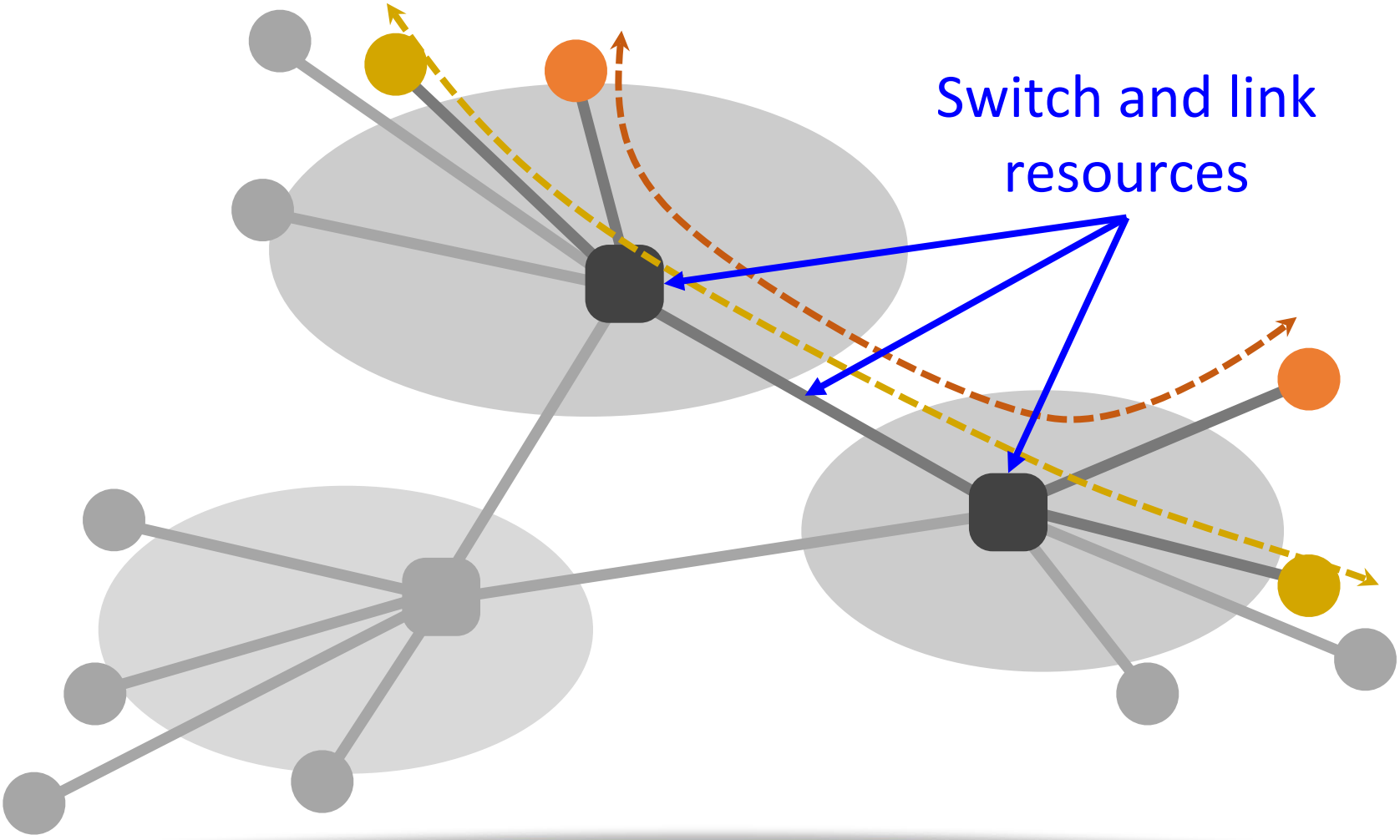


Switched networks

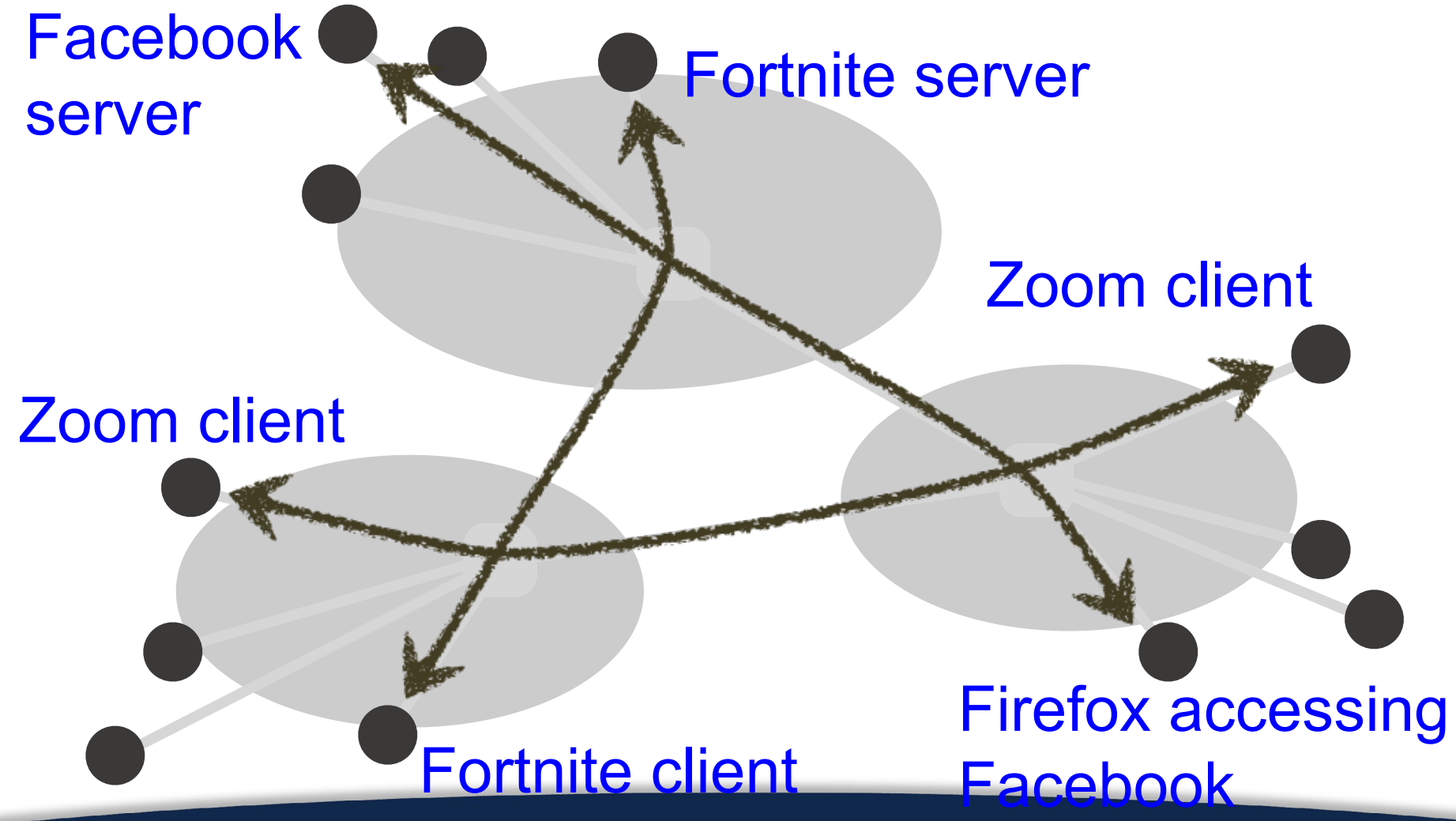
- End-systems and networks connected by switches instead of directly connecting them
  - Why?
- Allows us to scale
  - For example, directly connecting N nodes to each other would require N^2 links!



When do we need to share the network?



Shared among many services

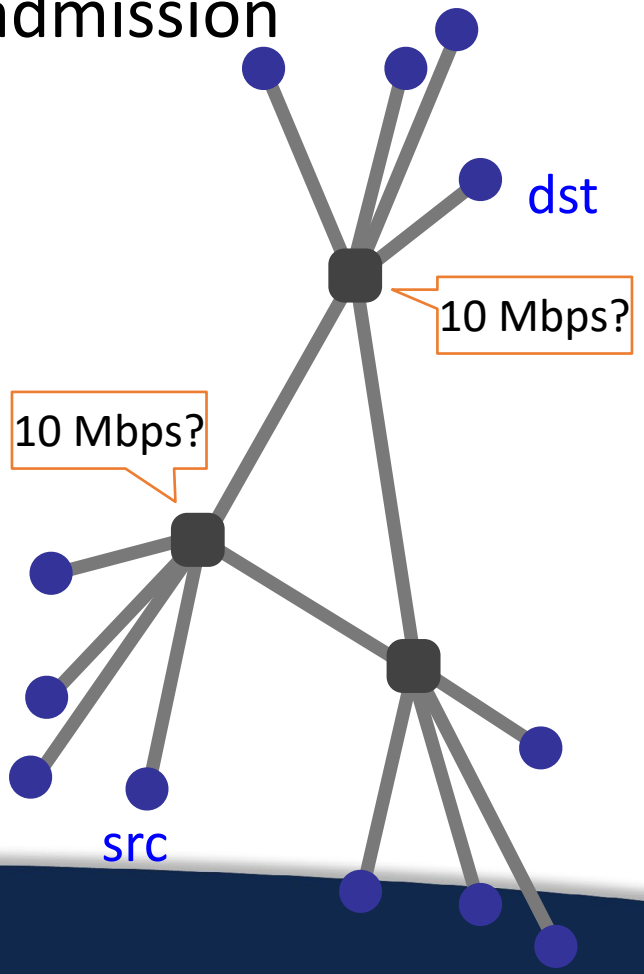


Two ways to share switched networks

- Circuit switching
  - Resource reserved per connection
  - Admission control: per connection
- Packet switching via statistical multiplexing
  - Packets treated independently, on-demand
  - Admission control: per packet

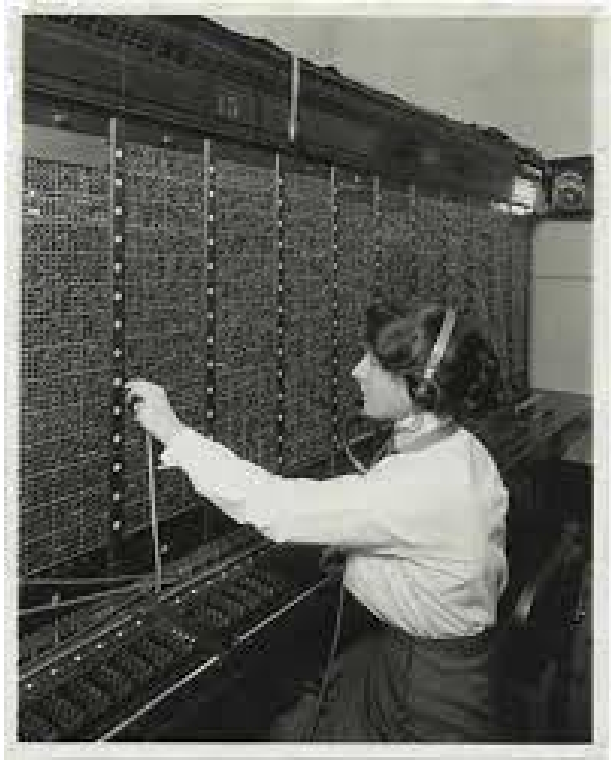
Circuit switching

1. src sends reservation request to dst
2. Switches create circuit *after* admission control
3. src sends data
4. src sends teardown request

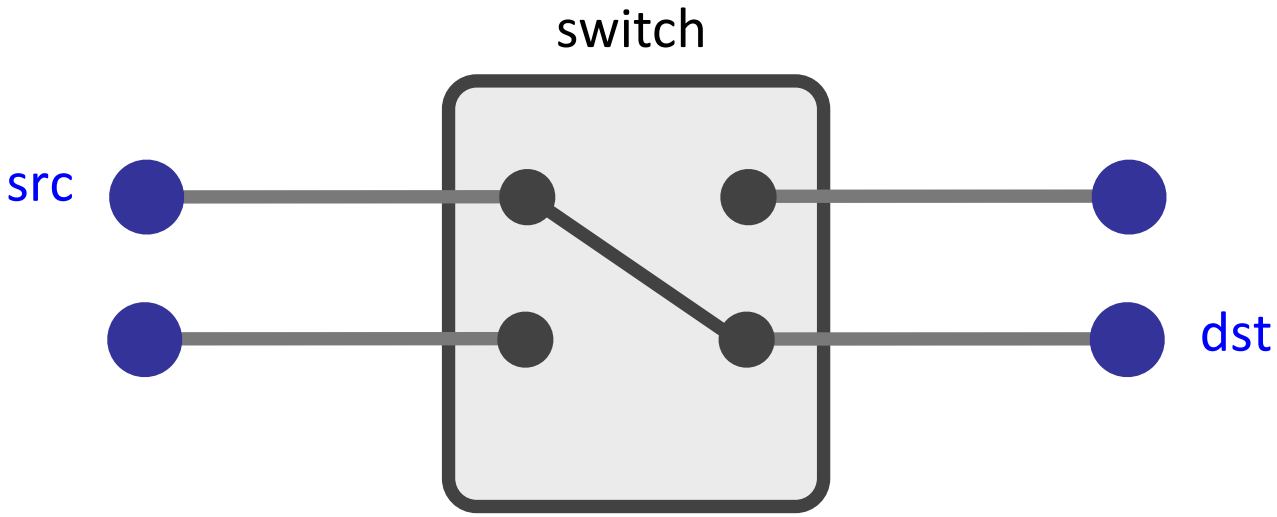


Telephone Exchanges

- Switch Operators create switched circuits



Circuit switching

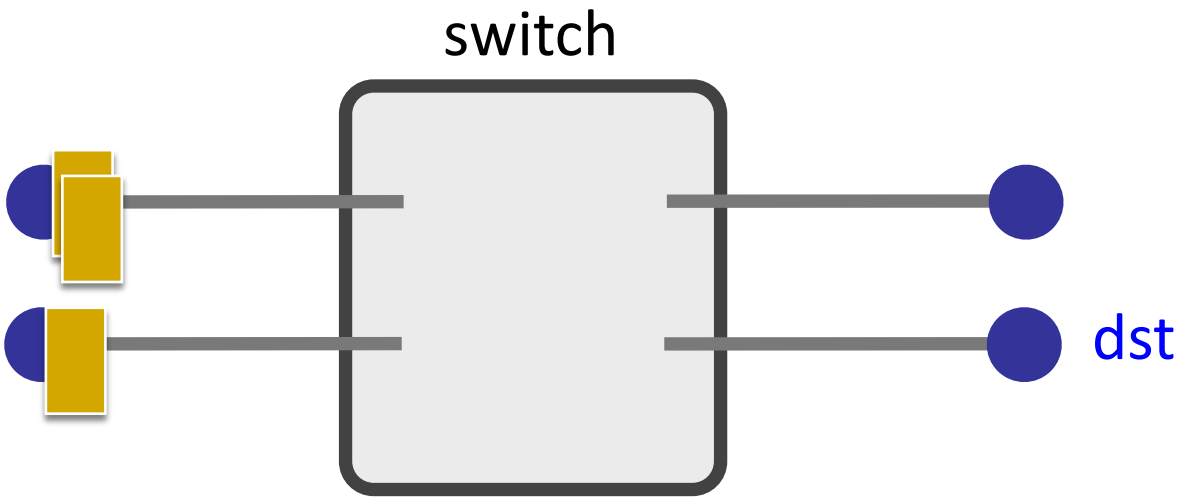


- Reservation establishes a “circuit” within a switch

Circuit switching

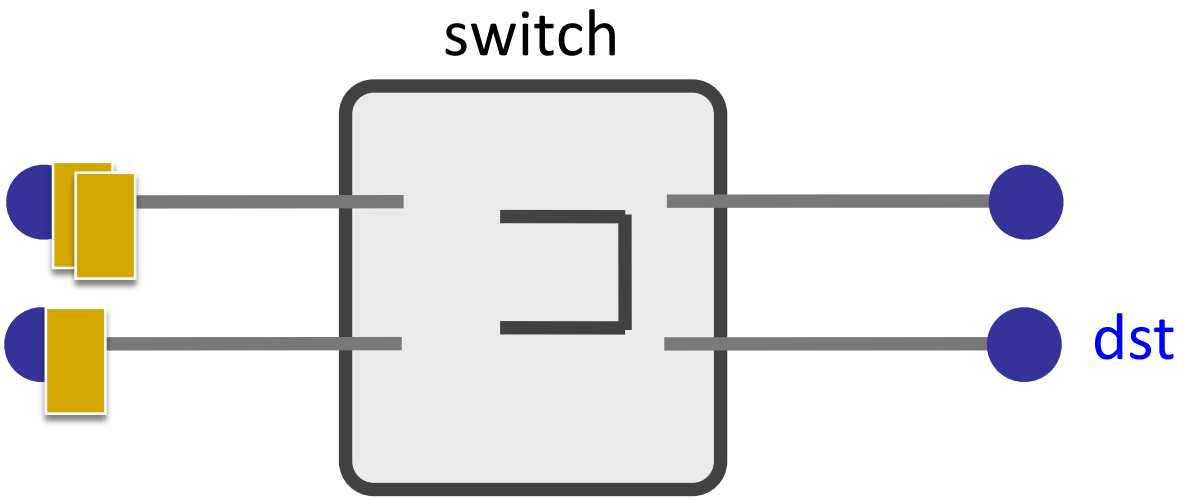
- Pros
  - Predictable performance
  - Simple/fast switching (once circuit established)
- Cons
  - Complexity of circuit setup/teardown
  - Inefficient when traffic is bursty
  - Circuit setup adds delay
  - Switch fails → its circuit(s) fails

Packet switching



- Each packet contains destination (dst)
- Each packet treated independently

Packet switching



- Each packet contains destination (dst)
- Each packet treated independently
- With buffers to absolve transient overloads

Packet switching

- Pros
  - Efficient use of network resources
  - Simpler to implement
  - Robust: can “route around trouble”
- Cons
  - Unpredictable performance
  - Requires buffer management and congestion control

Statistical multiplexing

- Allowing more demands than the network can handle
  - Hoping that not all demands are required at the same time
  - Results in unpredictability
  - Works well except for the extreme cases

MASSIVE Scale

- 5.18 Billion users
- >1.11 Billion websites
- >300 Billion emails sent per day
- >6.5 Billion smartphones
- >2.7 Billion Facebook users
- >1 Billion hours of YouTube watched per day
- Routers that switch 10 Terabits/second
- Links that carry 100 Gigabits/second

Have we found the right solution?

- We don't really know
- What we do know
  - The early Internet pioneers came up with a solution that was successful beyond all imaginations
  - Several enduring architectural principles and practices emerged from their work
- Still, it is just one design with many questions

The Internet is a lesson

- In how to reason through the design of a very complex system
  - What are our goals and constraints?
  - What's the right prioritization of goals?
  - How do we decompose a problem?
  - Who does what? How?
  - What are the interfaces between components?
  - What are the tradeoffs between design options?

Design Questions

- How do we build a network
- How will this network be used
- How will this network be managed
- How will network applications be developed

Network Applications

- Application domains
  - World Wide Web
  - Electronic Mail
  - Social Media
  - Video Streaming
  - Video Conferencing
  - Messaging
  - File Sharing
  - Gaming

Network Management

- Networks need to be operated
  - ISP – Comcast, At&T, etc.
  - Home Networks – you
  - Enterprise networks
  - Campus Networks
- Requirements
  - Fault detection
  - Fault isolation
  - Flexibility in adding new devices
  - Usage (bookkeeping, payment models, etc.)

Application Developers

- People who write networked applications
  - YouTube
  - Facebook
  - Instagram
  - Zoom
- Requirements
  - Guaranteed delivery of messages
  - Mobility
  - Timely delivery
  - Etc.

Network designers

- People who build the devices and protocols that makeup the Internet
  - This will be the focus of this course with context coming from the other three stakeholders
- Requirements
  - Maximize Resource utilization
  - Fair allocations of resources
  - Performance
  - Scalable Connectivity
  - Cost effective resource sharing
  - Support for common services
  - Reliable Message Delivery
  - Manageability