EN.601.419/EN.601.619 Spring 2020

Cloud Computing

Introduction

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JOHNS HOPKINS UNIVERSITY

Today

Overview of EN.601.419/EN.601.619, Cloud Computing

1

Topic 1: Networking overview. How does the Internet work?

2

Next Steps

3


Computer Networks: A Systems Approach, Release Version 6.1

Perspective: The Cloud is Eating the Internet

The Cloud and the Internet are symbiotic systems. They were historically distinct, but today the line between them is increasingly fuzzy. If you start with the textbook definition, the Internet provides end-to-end connectivity between any two hosts (e.g., a client laptop and a remote server machine), and the cloud supports several warehouse-sized datacenters, each of which provides a cost-effective way to power, cool, and operate a large number of server machines. End-users connect to the nearest datacenter over the Internet in exactly the same way they connect to a server in a remote machine room.

That's an accurate description of the relationship between the Internet and the Cloud in the early days of commercial cloud providers like Amazon, Microsoft, and Google. For example, Amazon's cloud circa 2009 had two datacenters, one on the east coast of the US and one on the west coast. Today, however, each of the major cloud providers operates several dozen datacenters spread across the globe, and it should be no surprise that they are strategically located in close proximity to Internet Exchange Points (IXP), each of which provides rich connectivity to the rest of the Internet. There are over 150 IXPs worldwide, and while not every cloud provider replicates a full datacenter near each one (many of these sites are co-location

About EN.601.419/619 Cloud Computing

- Instructor: S Ghorbani
  - PhD in CS from UIUC, December 2016
  - Research areas: datacenters and cloud computing, network verification, network virtualization
  - Office hours: Fridays 4-5pm, Malone 223
  - Email: soudeh@cs.jhu.edu
  - she/her/hers
- Meets Mondays/Wednesdays 12-1:15pm in Hodson 213
- Website: https://www.cs.jhu.edu/~soudeh/teaching/cloud/spring_2020
- Anonymous feedback: https://www.surveymonkey.com/r/9SSJM5D
- We will use Piazza for most of announcements and discussions: https://piazza.com/jhu/spring2020/en601419en601619

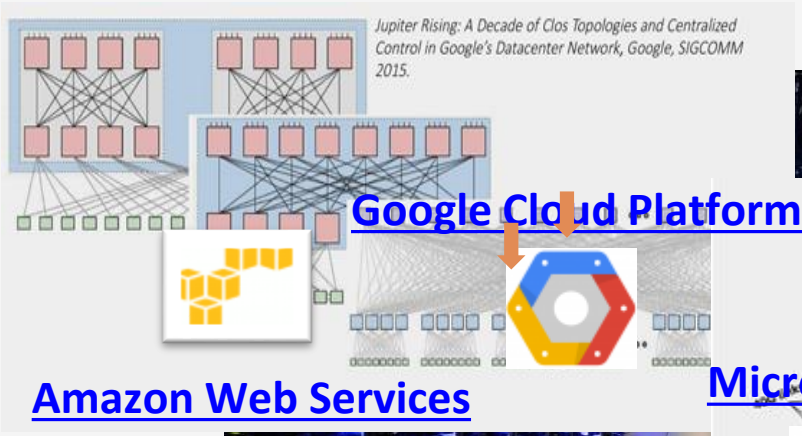
Course Goals

- To become familiar with cloud computing research:
  - Datacenters
  - Network virtualization
  - Software-defined networks (SDN)
  - Verification
  - Big data systems
  - Cloud storage

Cloud Computing: An Exciting Time

Explosive Growth

- Datacenters
- Architectural principles
- Big data systems



Gartner

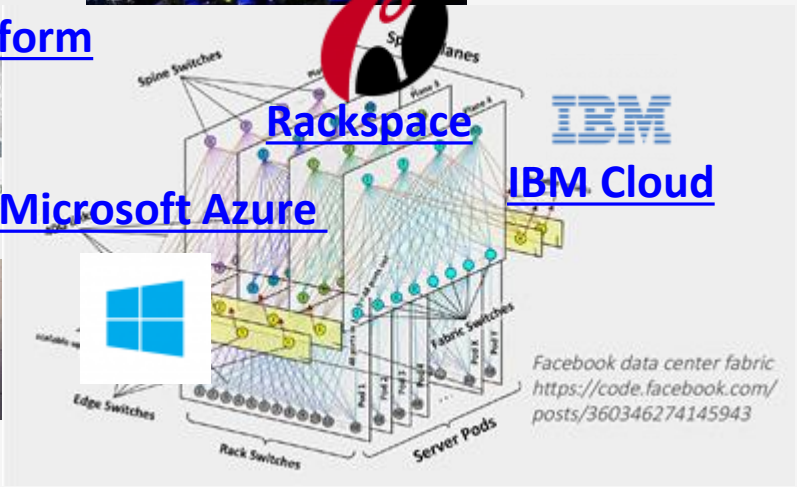
Google Cloud Platform

Amazon Web Services

Rackspace

IBM Cloud

Microsoft Azure

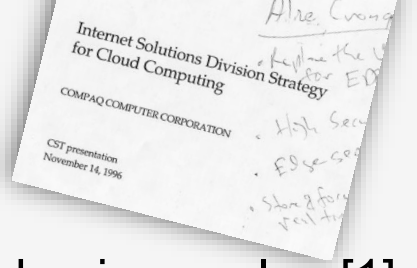


- Cloud storage
- Network virtualization
- Software defined networking
- Verification

But What Is Cloud Computing?

Discuss:

1. How do you define cloud computing?
2. What are its advantages?



- The earliest known use of the term "cloud computing", a 1996 Compaq business plan [1].
- Amazon: The on-demand delivery of compute power, database storage, applications, and other IT resources through a cloud services platform via the Internet with pay-as-you-go pricing [2].
- Microsoft: The delivery of computing services—servers, storage, databases, networking, software, analytics, intelligence and more—over the Internet ("the cloud") to offer faster innovation, flexible resources, and economies of scale. You typically pay only for cloud services you use [3].
- IBM: the delivery of on-demand computing resources — everything from applications to data centers — over the Internet on a pay-for-use basis [4].

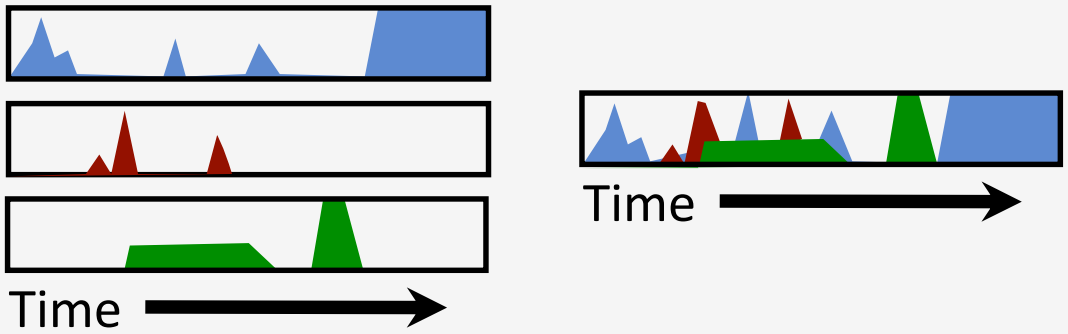
[1] https://www.technologyreview.com/s/425970/who-coined-cloud-computing/
[2] https://aws.amazon.com/what-is-cloud-computing/
[3] https://azure.microsoft.com/en-us/overview/what-is-cloud-computing/
[4] https://www.ibm.com/cloud/learn/cloud-computing

Cloud Computing

- Computing as a utility
  - Purchase however much you need, whenever you need it
  - Service ranges from access to raw (virtual) machines, to higher level: distributed storage, web services
  - Access provided via the Internet
  - Pay-for-use pricing
- Advantages?

Key Advantage: Economy of Scale

- One technician for each 15,000 servers [Facebook]
- Statistical multiplexing
  - Must provision for peak load
  - Many users sharing a resource are unlikely to have their peaks all at the same time



- Reduces barrier to entry to building large service
  - No need for up-front capital investment
  - No need to plan ahead
- Compute, network, and storage become more centralized
  - Ability to custom-design equipment: servers, switches, NICs…
  - New systems and architectures

Course Goals

- To become familiar with **cloud computing research**
  - Datacenters
  - Software-defined networks (SDN)
  - Programmable forwarding
  - Verification
  - Big data systems (MapReduce, Spark, Hadoop)
  - Cloud storage
  - Virtualization
- To get practice in reading and criticizing **research papers**
- To practice performing high-quality **systems research**

What This Course Is NOT about…

- It is **NOT a survey of tools/applications** and software deployed in cloud computing facilities.
  - You will get hands-on experience with a selected few (mininet, network controllers, etc.) via the assignments and the project.
  - There are many, many tools that we will not cover.
- It is **NOT a comprehensive overview of all aspects of cloud**.
  - There are many topics we will not cover: security, privacy, economics, energy efficiency…

Grade

- Research project [45%]
  - Proposal [5%]
  - Checkpoints [10%]
  - Midterm presentation [10%]
  - Final presentation [10%]
  - Final report [10%]
- Paper reviews [15%]
- Assignments [20%]
- Final exam [10%]
- Participation [10%]

Project

- Goal: practice conducting high-quality research in this area. Options:
  1. Tackle a challenge in cloud computing
  2. Build a cloud system
  3. Reproduce cloud research
- Topic: Explore your own idea or talk to me
- Work in groups of 2 or 3
- Steps
  - Project proposal (1 month from now)
  - Checkpoints every two weeks after that
  - Midterm presentation
  - Final presentation and report

Paper Reviews

- Each class we will discuss one or more papers
- The list of papers will be **posted on Piazza**
- Read one paper before class in depth
- Submit in the paper's review thread on Piazza by **5pm the day before we discuss the paper**
- For each paper review:
  - At least **2 comments** (critique, idea for extension, insight that may apply in other domains, etc.)
  - We don't need you to summarize the paper (but make sure to read all of it)
  - Don't just repeat what we already read in the paper!
- Start early.
- Feel free to ask for help.

Assignments

Experimental cloud computing tools and questions about course content

Final Exam

- Topics covered in the class and in papers
- The exam will be open notes and open papers, but closed laptop

Participation

Comment, question, and interact!

Brief Overview of Networks: How Does the Internet Work?

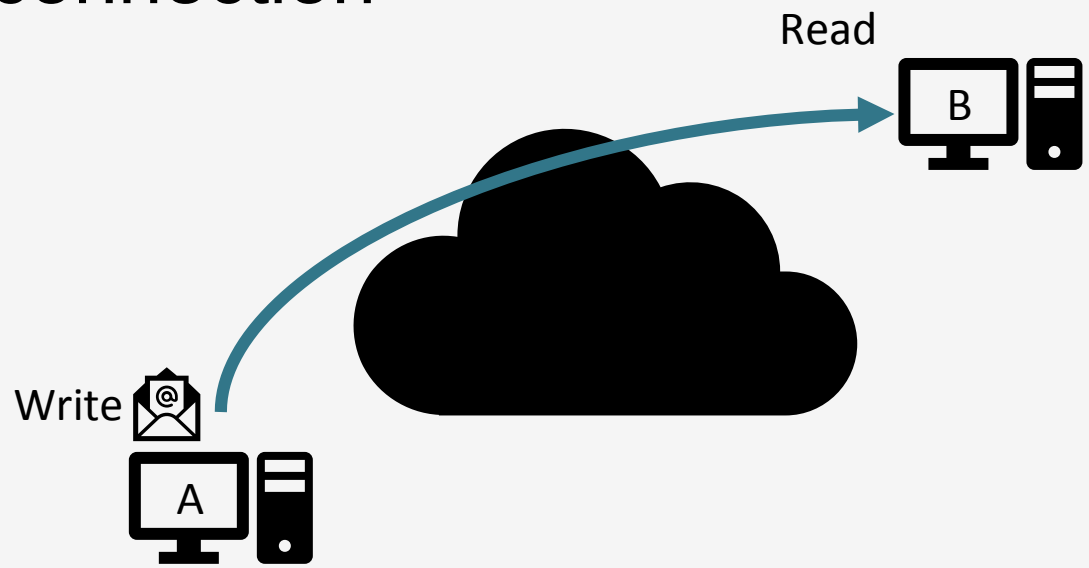
How Does the Internet Work?

- How does an application use the Internet?
- What is a **layered** structure?
- Why is the Internet designed this way?
- What is the Internet Protocol (**IP**)?

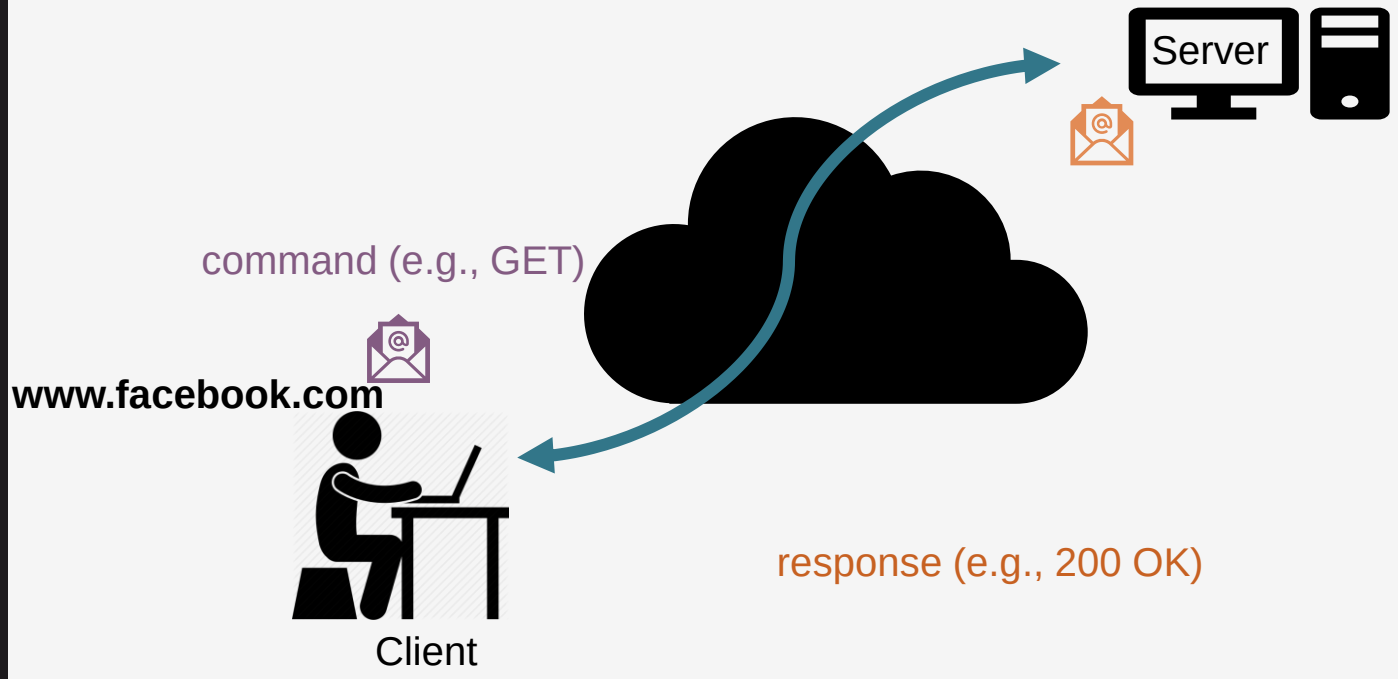
A Day in the Life of an Application

Network Applications

- Read and write data over network
- Dominant abstraction: *bidirectional, reliable* byte stream connection

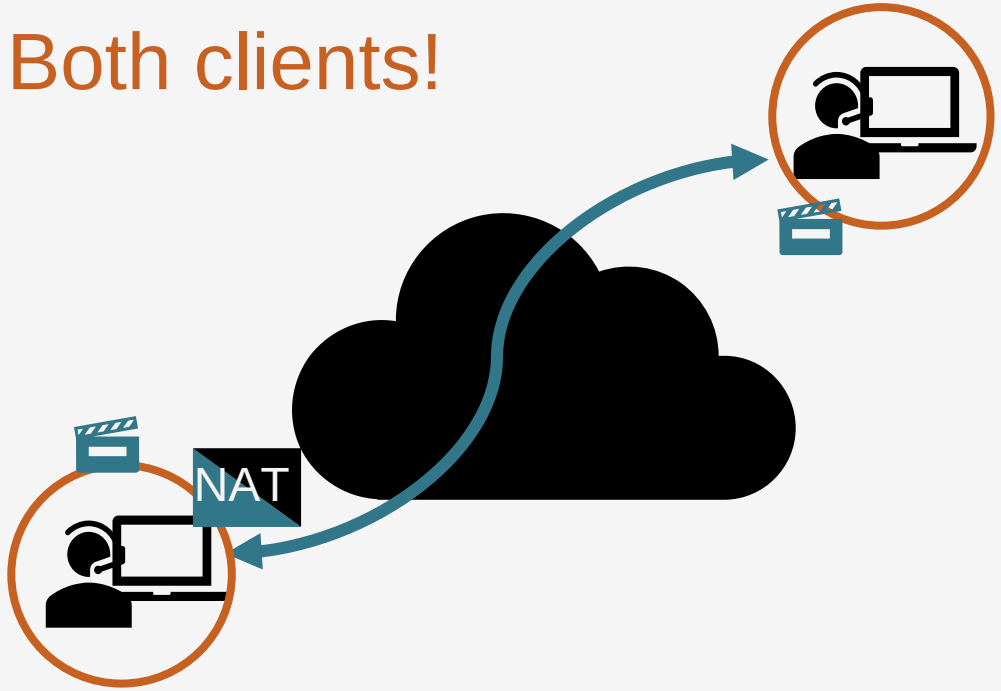


World Wide Web (HTTP)



Skype

Both clients!



Network Address Translators (NAT)

What are they and why are they everywhere?

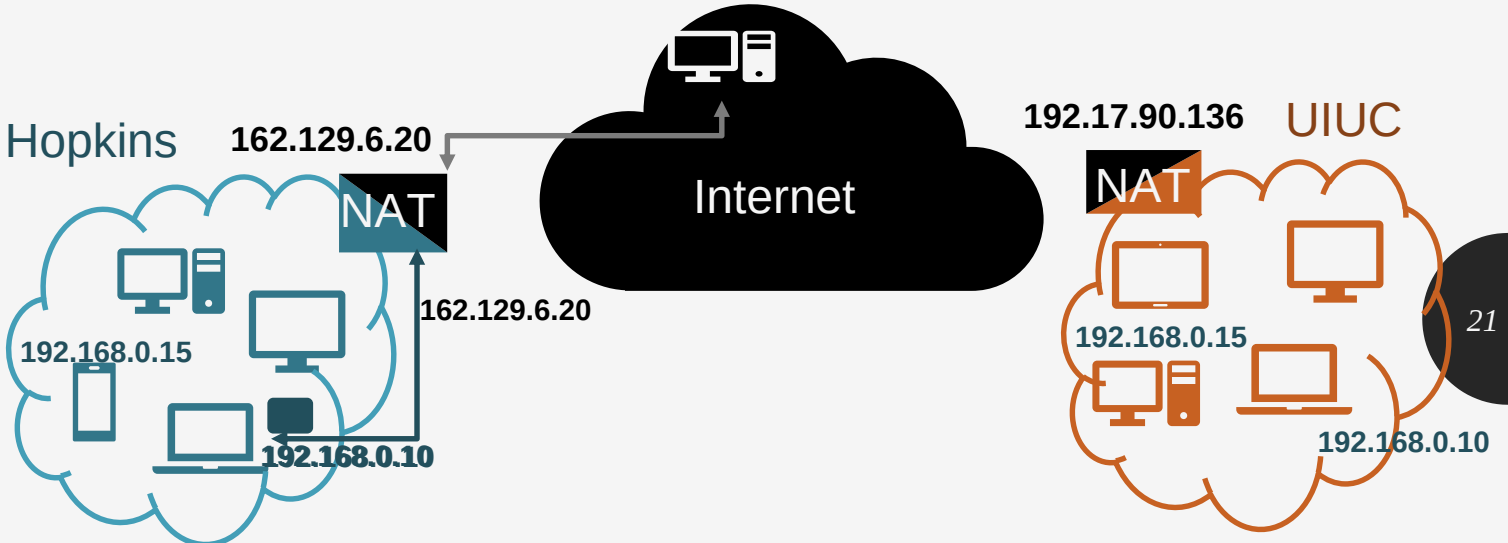
- We ran out of the Internet !(addresses)

- Everyone needs a *globally unique IP address* coordinated by five regional Internet registries (RIR).
- RIR ran out of IP addresses everywhere except Africa:
  - Asia-Pacific RIR exhausted its IPs in 2011
  - Europe, Middle East and Central Asia RIR in 2012
  - Latin America and the Caribbean RIR in 2014
  - North America RIR in 2015

Network Address Translators (NAT)

What are they and why are they everywhere?

- Everyone needs a *globally unique IP address* coordinated by five regional Internet registries (RIR).
- RIR ran out of IP addresses everywhere except Africa
- … then how is the Internet still working and growing?
  - Black-market ☹
  - IPv6
    - Enough for each atom on earth to be given one. ☺
    - Moving is expensive and time-consuming. ☹
  - Network Address Translators (NATs)



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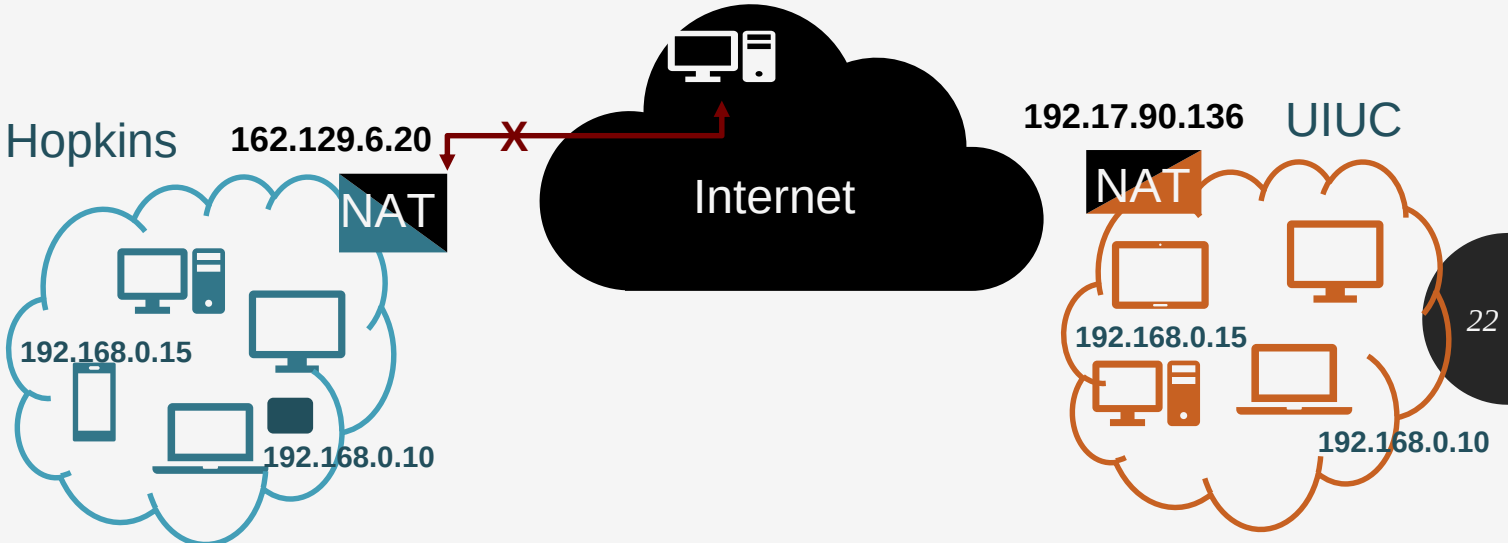
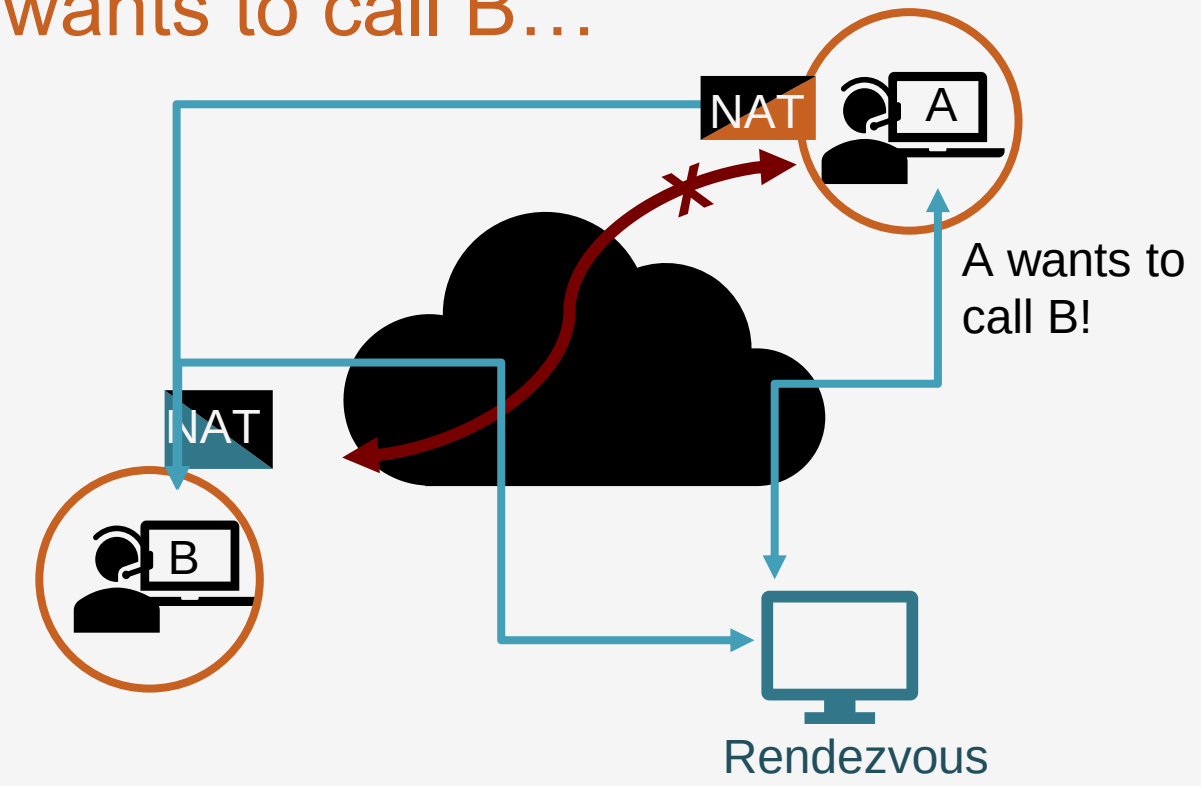


Skype

A wants to call B…



Reverse connection

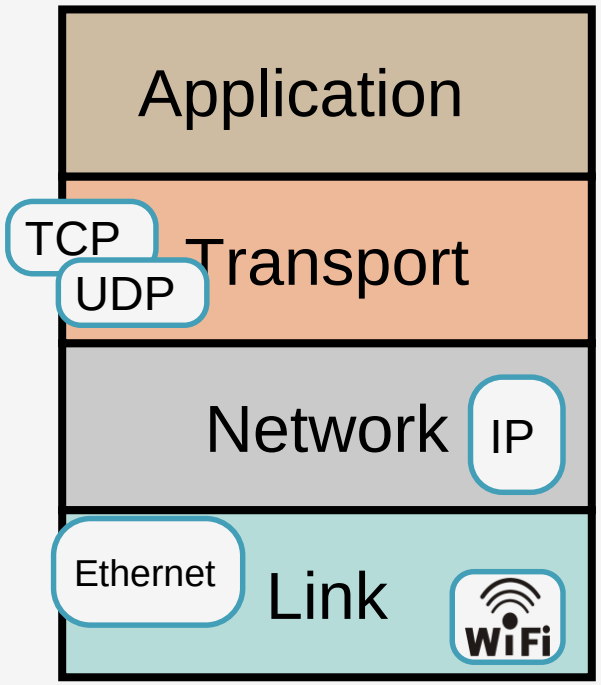
What if both A and B are behind NATs?

A Day in the Life of an Application

Network Applications

- Read and write data over network
- Dominant abstraction: *bidirectional, reliable* byte stream connection

4 Layer Model



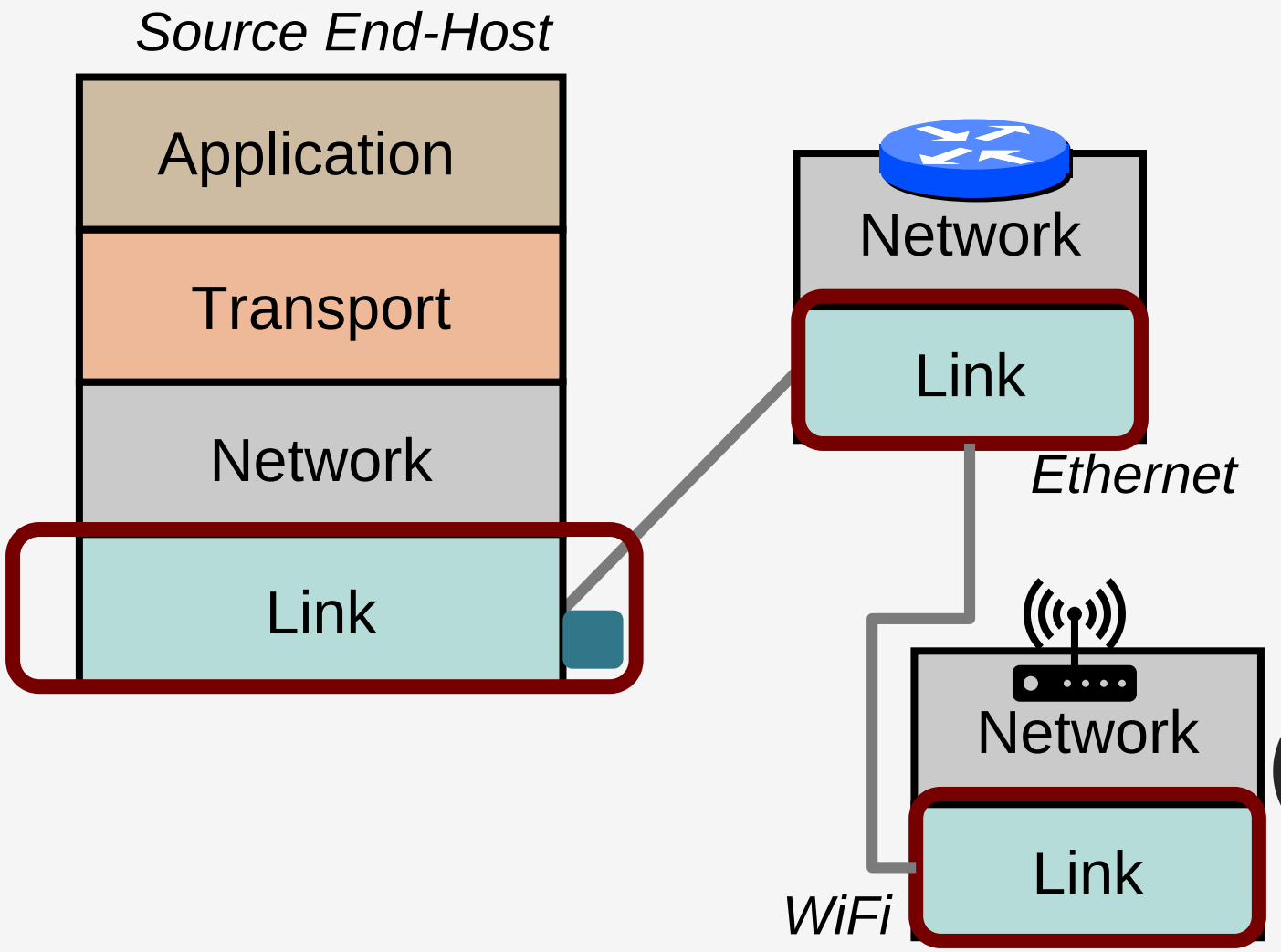
Bi-directional reliable byte stream

Reliable in-order delivery of data
Flow control and controls congestions

Delivers packets end-to-end
Best-effort delivery

Delivers data over a single link

The 4 Layer Internet Model



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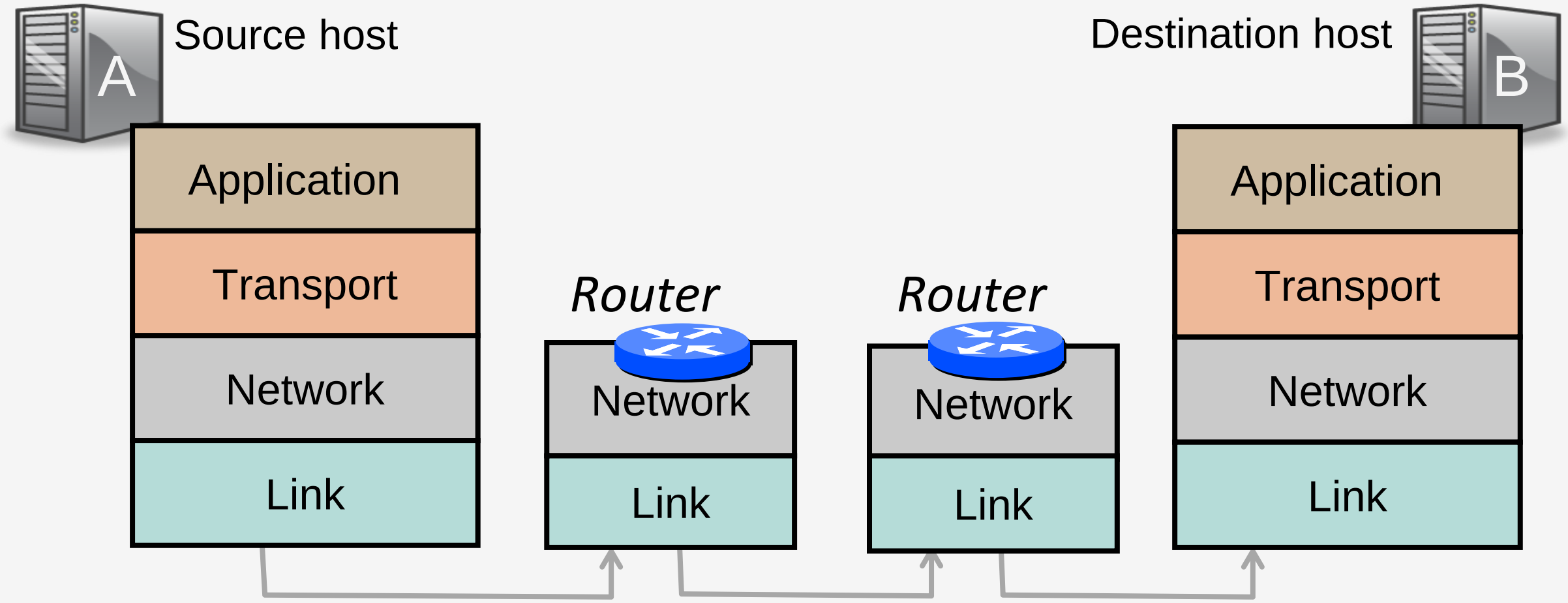

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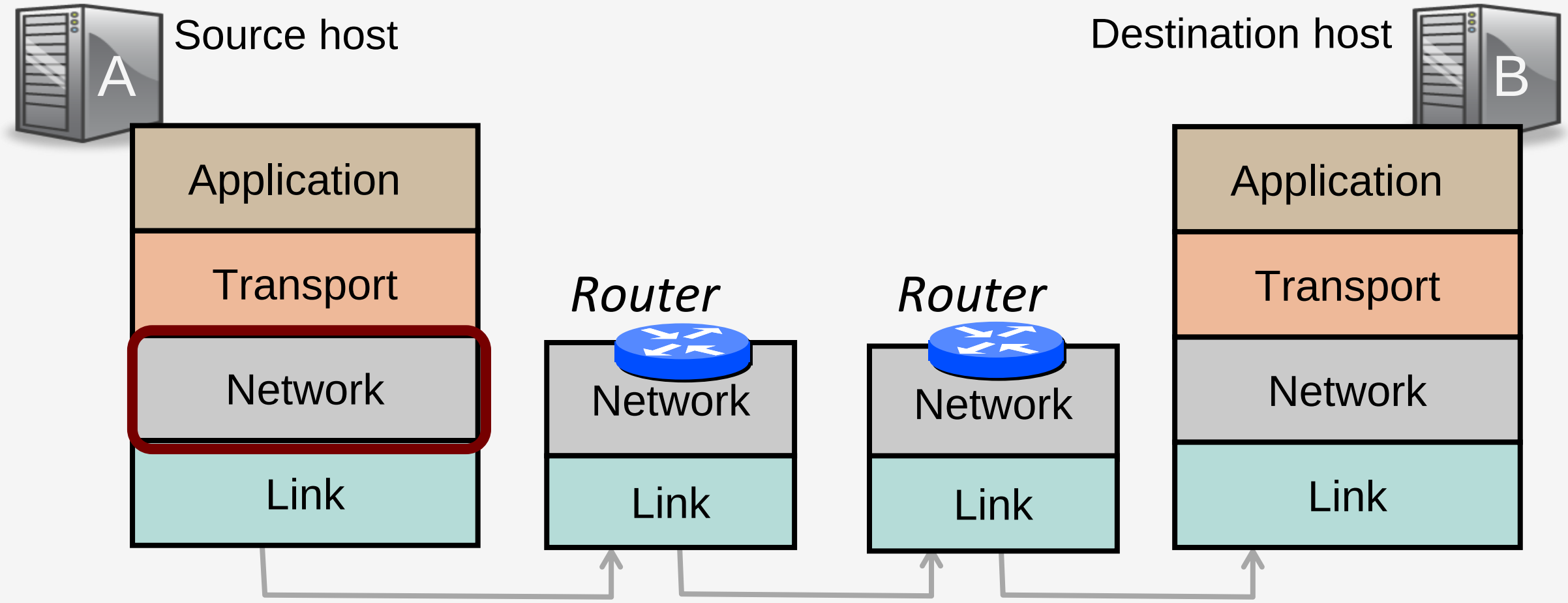
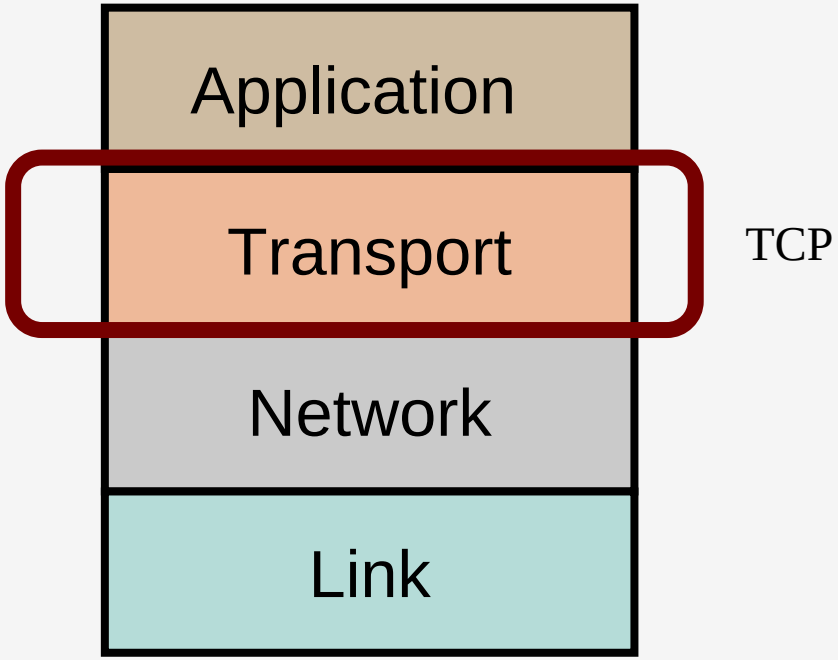


The Network Layer Is "Special"

We must use the Internet Protocol (IP)

- IP makes a best-effort attempt to deliver our datagrams to the other end. But it makes no promises.
- IP datagrams can get lost, can be delivered out of order, and can be corrupted. There are no guarantees.

The 4 Layer Internet Model



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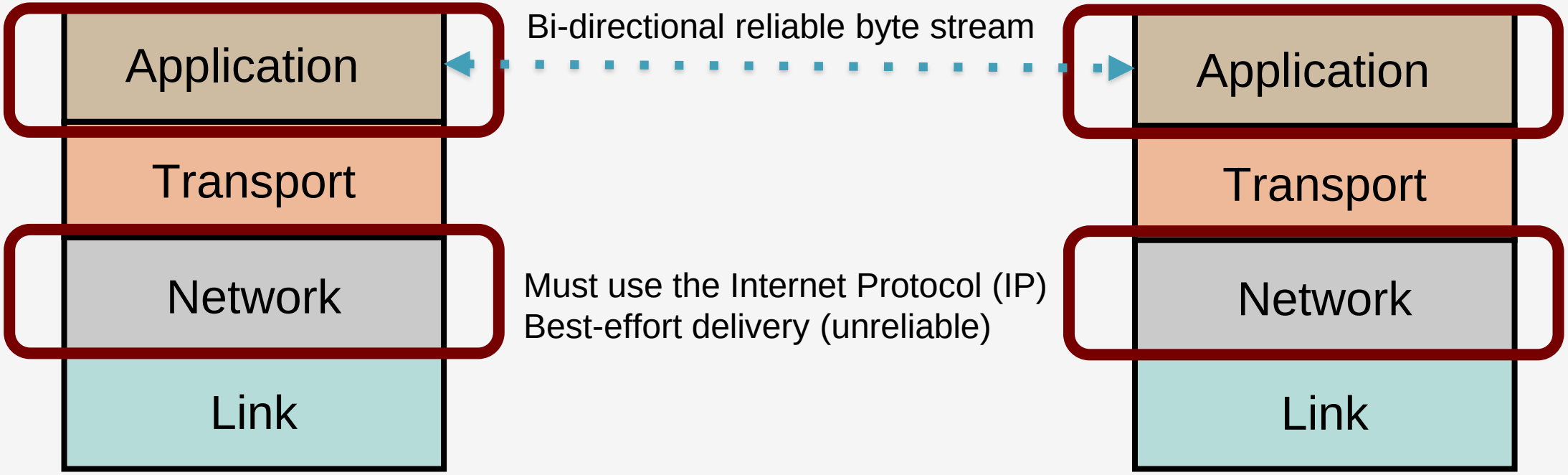
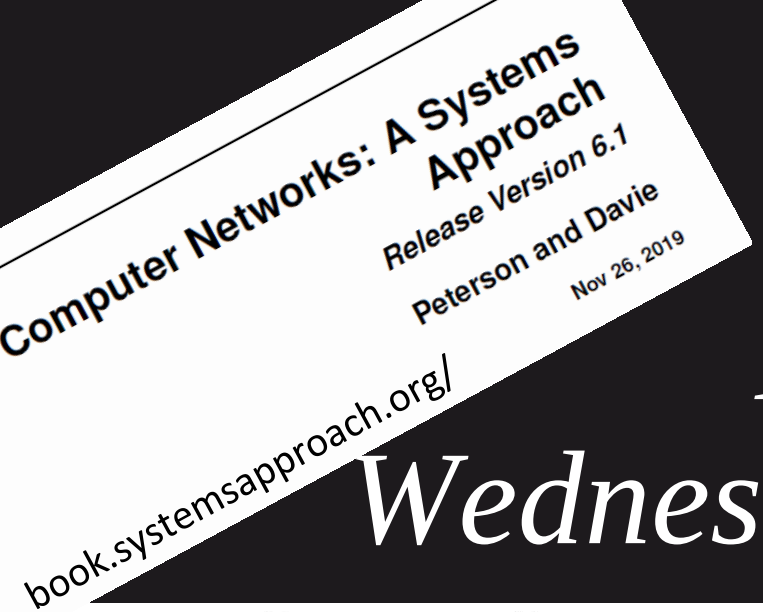


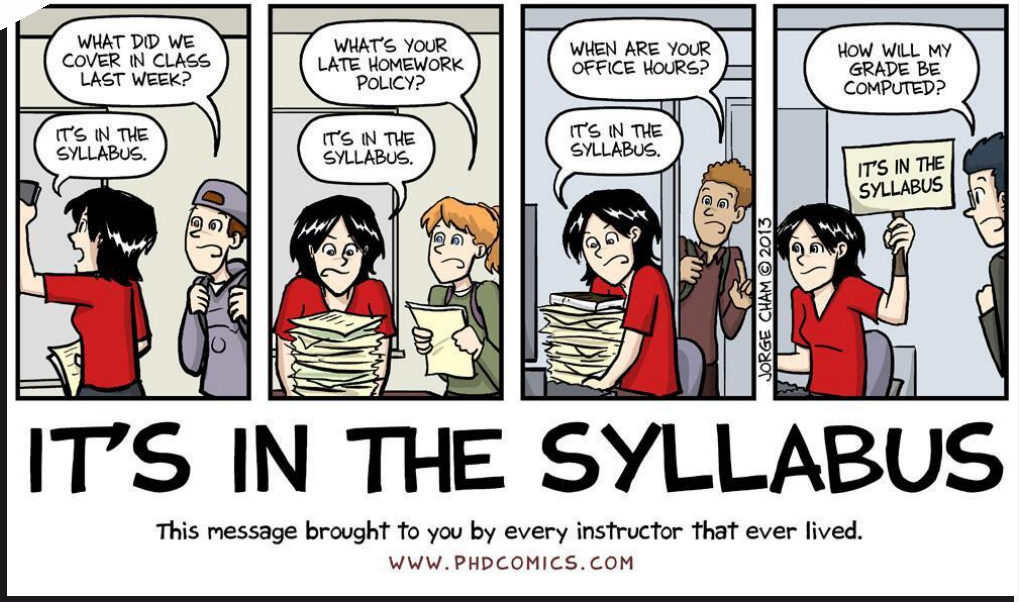
Discussion

1. Your web browser uses HTTP transported over TCP. The webservers at Facebook has one network layer IPv4 address and is connected to an Ethernet network. After learning about layering, you decide to change your laptop to use an alternative protocol at each of the layers. Which of the following changes will still allow you to access facebook.com without any changes to the server? Choose all that apply.

a. Unplug your laptop and use WiFi to access the network
b. Update the client to use IPv6 addressing
c. Change the transport to UDP
d. Use FTP instead of HTTP in the web browser



For Wednesday



- Reading: parts on **Ethernet** from Peterson and Davie **v. 6.1**
  - Section 2.6, Multi-Access Networks (until 2.6.1), page 77
  - Section 2.6.3, Longevity of Ethernet, page 83
  - Section 3, Datagrams (until 3.1.1), pages 103-107
  - Section 3.2, Switch Ethernet, page 116
  - Section 3.2.1, Learning Bridges, pages 116-117
  - Optional: Spanning Tree Algorithm (until broadcast), pages 119-123
- Read the syllabus https://www.cs.jhu.edu/~soudeh/teaching/cloud/spring_2020/#syllabus
- Join Piazza and complete Assignment 0 (introduction)